Norwegian Aggregate Model

Documentation of NAM 19.2

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Contents

1 INTRODUCTION

> "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.

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 analyze the current situation of the Norwegian macro economy, as an aid for medium term macroeconomic forecasting, and to quantify the dynamic responses to shocks from the world economy, or from policy changes and structural changes in the domestic economy. All of these usages have practical sides to them (data input, model estimation and simulation, reporting) that need to be handled. IN the case of NAM, these tasks are solved by running (executing) a single file in the computer program package Eviews.[1]. The NAM Eviews file creates the database, estimates all the equations of the model, simulates (i.e., solves) the model, and graphs and tabulates output from model simulations. The NAM-Eviews file is updated four times a year, usually after each release quarterly national accounts. Chapter 4 in this documentation contains more about the practical aspects the NAM-Eviews file.

For more than a decade, the properties and performance of NAM model have been reviewed through work with forecasting and econometric assessment of model equations (cf Frame 1). As the model became more transferable, i.e. between model-producer and model-user, the feedback from model users have gained in importance for the development of NAM . This process has been particularly important for the adaptive capability of the model.

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. Since the consequences of structural changes pile up quickly, a model left "unattended" will lose relevance and become defunct , usually sooner than later.

Hence, Lawrence Klein, one of the founding fathers of macroeconometric modelling, hit the nail on the head when he wrote:

> 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, for-

[1] For information about Eviews, see http://www.eviews.com/home.html

> merly submerged in aggregation, is now important. ... Every two or three years the model must be revised to keep it up to date. Klein (1962, p.269)

However, although the detailed specification of a viable empirical model may have to be changed frequently, there are also important features of the model that are relatively constant over time. The framework used to model the supply side is one such feature. In this part of the model, the assumption of monopolistically competitive firms is combined with a model of wage formation that captures important aspects of the national system of wage formation in Norway.

Another defining trait of NAM is that it is a genuinely empirical model where the macroeconomic variables are modelled as they have been measured, without making use of smoothing filters or any sort of "data massaging" before model specification and estimation.[2]. This approach is different from the macroeconomic modelling tradition that brings the data as close to the theoretical counterparts (e.g., as a deviation form an a priory defined steady-state path) before any attempt is made to quantity the relationships.

The organization of the documentation reflects the twin purpose of giving not only the necessary information about the model current specification, chapter 2-6), but also a presentation of the general macroeconomic theoretical framework, and the econometric methodology that has been used important in the development and maintenance of NAM (chapter 7 and 8).

Chapter 2 gives with an overview of the model's modular structure. We commence with the main accounting relationships of the Norwegian national accounts, i.e., how they are represented in terms of NAM variables. Thereafter the endogenous components of the aggregate supply (and imports) and aggregated demand are presented.

Underlying the modelling av supply is the assumption of monopolistic competitions. Hence, an increase in demand will as a rule lead to both higher GDP and to higher imports, and prices will be relatively unresponsive in the short-run. Conversely, a drop in demand will be in the main, and as a rule, be equilibriated by quantity changes rather than by price changes. Price adjustments are determined by mark-up relationships, which are briefly mentioned in chapter 2.4, together with the module for nominal wage formation.

There are two main measurements of unemployment in Norway, the registered unemployment percentage and the labour force survey rate. NAM has both of them as endogenous variables. The number of wage earners employed by the monopolistically competitive firm and the government sector (and the smaller number of self employed) are of course important for the development of the two unemployment rates. NAM endogenizes the number of registered unemployed as well as the labour force (see chapter 2.5).

NAM includes modules for several asset and credit markets (e.g. the market for foreign exchange and the housing market) and their main price and yield indicators. These are surveyed in Chapter 2.6 - 2.9.

In Chapter 3, some of the important relationships between the modules are illustrated with the aid of flow-charts. In the same way as in Chapter 2, the exposition is non-technical and with the

[2] It goes without mentioning that correctable measurement errors are not counted as data massaging

emphasis on the main lines of economic interpretation. In Chapter 4, the aim is to explain briefly how the operational version of NAM is implemented as a program file in Eviews. The chapter contains examples of how NAM can be used, in forecasting the Norwegian macro economy and for policy and scenario analysis.

In Chapter 5 the endogenous and exogenous variables of NAM are listed and defined, while the detailed estimation results of the modular structure are given in Chapter 6.

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 principles followed in the model development process, and not just the end-product of the process. With that in mind, Chapter 7 addresses several methodological aspects of empirical macroeconomic model building.

Chapter 8 goes in more detail about the underlying theoretical view about the supply-side of the Norwegian economy, and why the specifications of wage and price formation in particular are important for several of the total model properties of NAM.

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). Has been an transferable and operational model since 2006, when regular model updates began.

2 THE MODULAR STRUCTURE

In this chapter the different sectors and sub-models of NAM are discussed. We start with the main national accounts relationships in NAM, cf. Chapter 2.1. The two first sub-chapters 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).

The modelling of domestic GDP in particular needs to be consistent with the the assumption made about the labour market and of wage formation. The key to reconciliation is to assume imperfect competition in both product and labour markets. GDP produced by domestic (Mainland-Norway) firms will then in general be a function of aggregate demand and of relative relative product prices (which we represent in a simple way, by the real exchange rate). Nominal prices are set by the domestic firms, and average nominal wage compensation we assume is regulated by collective agreements between the firm and worker side of the bargain.

Nominal wage and price formation (including import prices) are discussed in Chapter 2.4 and hours worked, employment and unemployment i Chapter 2.5,

Since Norway is a small open economy, the market for foreign exchange is of great importance for macroeconomic stability and dynamics, cf Chapter 2.6. In the final sub-chapters we discuss how housing prices, interest rates and credit are modelled in NAM.

2.1 NATIONAL ACCOUNTS RELATIONSHIPS

A main use of an empirical macro model for the Norwegian economy is to analyse and forecast variables in the National Accounts. Figure 2.1 shows an excerpt from the *Main Table* in the National accounts, which contains the components of final expenditure as well as GDP (as the sum of value added by sectors) from the supply side and imports (only the "demand side" is shown in the picture).

NAM can be used to forecast the variables in the *Main Table* in an consistent way because the national accounting identities are included in the model.

For example, the general budget of the Norwegian economy is represented in the model. Because of the importance of the petroleum sector, oil and natural gas exports and capital formation in that sector are represented by separate variables.On the supply side, there is the distinction between GDP of Mainland-Norway, and the value added in the petroleum sector (production and transportation).

	Constant 2016-prices (NOK million)						
	2017K1	2017K2	2017K3	2017K4	2018K1	2018K2	20
Final consumption expenditure of households and NPISHs	347 491	358 797	356 191	380 965	349 918	372 316	36
¬ Household final consumption expenditure	326 785	339 421	338 331	360 203	329 321	351 202	34
¬ Final consumption expenditure of NPISHs	20 706	19 376	17 860	20 762	20 597	21 113	1
Final consumption expenditure of general governmen	192 216	194 753	194 519	196 979	197 106	199 190	19
Gross fixed capital formation (GFCF)	197 822	206 369	203 267	211 413	187 896	208 827	208
¬ Extraction and transport via pipelines (GFCF)	37 576	41 620	38 240	41 711	34 063	41 826	4
¬ Ocean transport (GFCF)	983	1 021	1 857	41	847	595	
¬ Mainland Norway (GFCF)	159 263	163 728	163 170	169 661	152 986	166 406	16
¬¬ Mainland Norway excluding general government (GFCF)	118 838	119 161	122 263	124 100	110 518	119 507	11
¬¬¬ Dwelling service (households) (GFCF)	48 604	48 830	48 879	47 704	44 912	43 278	4
¬¬¬ General government (GFCF)	40 425	44 567	40 907	45 560	42 469	46 900	4
Acquisitions less disposals of valuables	109	102	88	116	110	117	
Changes in stocks and statistical discrepancies	49 480	7 740	15 825	34 755	47 420	28 606	14
Gross capital formation	247 410	214 210	219 179	246 284	235 426	237 551	22
Final domestic use of goods and services	787 118	767 760	769 889	824 228	782 449	809 057	78
Final demand from Mainland Norway (excl. changes in stocks)	698 971	717 278	713 880	747 605	700 010	737 913	72
Total exports	271 054	273 720	[illegible]	[illegible]	263 420	[illegible]	[illegible]

Figure 2.1: Excerpts from Norwegian National Accounts showing final expenditure and gross domestic product (Table 09190, https://www.ssb.no/en/statbank/table/09190/).

Table 2.1: 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

Table 2.1 shows the main national accounting identities in terms of NAM variable names. For reference, Chapter 5 contains a full listing of variable definitions, but we also give "short" definitions in this chapter, in order to ease the exposition.

According to Table 2.1, total supply of goods and services in fixed prices in NAM (*TOTS*) is defined by:

$$TOTS = B + YFbasis + YOIL1 + YOIL2 + YUSF + AVGSUB \tag{2.1}$$

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 variable 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 (2.1 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 Mainland-Norway.

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

$$TOTD = A + CP + CO + JO + JBOL + JFPN + JOIL + JUSF + JL \tag{2.2}$$

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 (2.2) is *JL* which represents both changes in inventories and statistical errors.

Figure 2.2 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 2.2, the discrepancies are so small that they do not represent a problem in practice.

Returning to (2.1), there is presently no decomposition of total imports (*B)* in NAM. GDP in Mainland-Norway, evaluated at basic prices, is however decomposed as:

$$YFbasis = YFPbasis + YO. \tag{2.3}$$

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

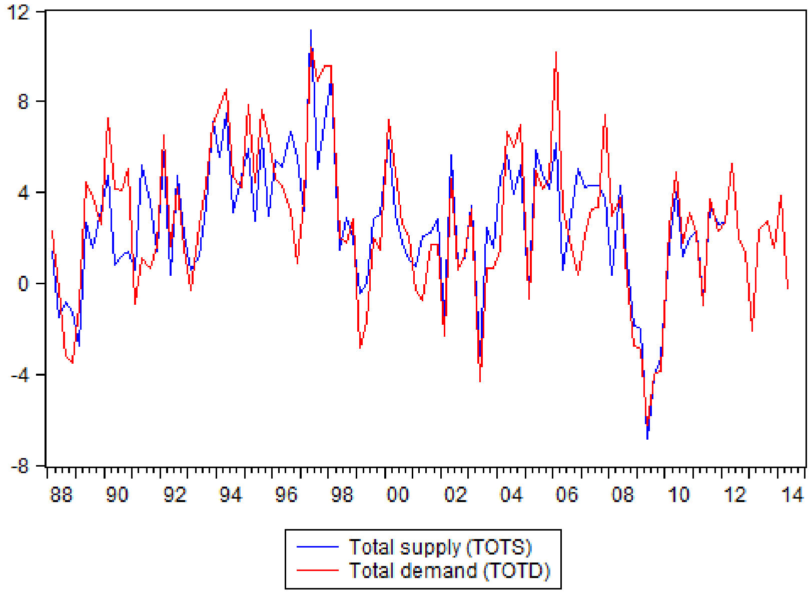


Figure 2.2: Four quarter percentage change in total demand, *TOTD*, and total supply, *TOTS*.

and retail trade, *YFP3*. The three private sector value-added variables are measured in basic values, hence we define *YFPbasis* as:

$$YFPbasis = YFP1 + YFP2 + YFP3 \tag{2.4}$$

On the demand side, (2.2) 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

$$A = ATRAD + ATJEN + AOIL + ASKIP, \tag{2.5}$$

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:

$$LY = PYF \cdot YF + PYOIL1 \cdot YOIL1 + PYOIL2 \cdot YOIL2 + PYUSF \cdot YUSF, \tag{2.6}$$

where PYF is the deflator of YF in (2.3). PYOIL1, PYOIL2 and PYUSF are the deflators of the corresponding fixed price variables in Table 2.1.

Disposable income for Norway is given by:

$$YDNOR = LY + RUBAL - LKDEP, \tag{2.7}$$

where *LY* is GDP in current prices and *LKDEP* is capital depreciation in current prices and *RUBAL* denotes the net incomes from abroad ("rente og stønadsbalansen").

The trade surplus of Norway is in NAM defined by:

$$LX = PATRAD \cdot ATRAD + PATJEN \cdot ATJEN + PAOIL \cdot AOIL + PASKIP \cdot ASKIP - PB \cdot B, \tag{2.8}$$

where *PATRAD*, *PATJEN* , *PAOIL* and *PASKIP* are the deflators (price indices) of the export categories, and *PB* is the price index of total imports. The current account of Norway is given by:

$$LXR = LX + RUBAL. \tag{2.9}$$

2.2 COMPONENTS OF AGGREGATE DEMAND

2.2.1 EXPORTS

As noted above, there are four export categories:.

- 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:

$$A = ATRAD + ATJEN + AOIL + ASKIP \tag{2.10}$$

The graphs in Figure 2.3 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.

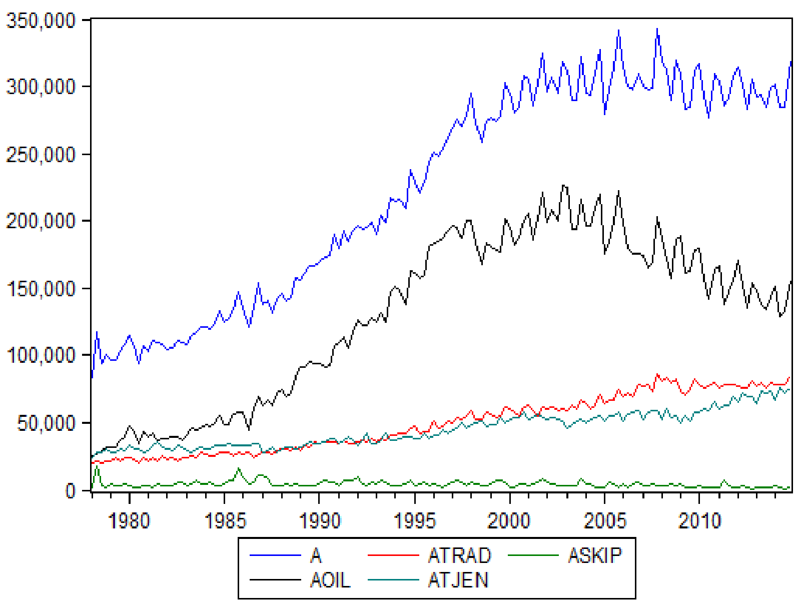


Figure 2.3: Total exports and its components

$AOIL$ is a non-modelled (exogenous) variables in NAM, while the three others are endogenous. As shown in Figure2.3, $ASKIP$ is a small component of total exports. It is modelled by a simple autoregressive process in NAM, cf. section 6.2.3. 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 categorize exports as "demand side"variables, these variables are mainly determined by firms. As already mentioned when we discussed price setting in Chapter 8.3, 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 6.2.1 has the (international) marked indicator (MII) and the real-exchange rate as the long-run determinants. Hence, the estimated long-run relationship is:

$$LOG(ATRAD) = 1.1LOG(REX) + 0.8LOG(MII) + Constant \tag{2.11}$$

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

$$REX =: \frac{PCKONK \cdot CPIVAL}{CPI} \tag{2.12}$$

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 a versions of the model, it may be that that an export price index become included. For the time being, the estimated elasticity of near unity in 2.11 indicates 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 (6.2.1) 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 -0.28.

In 2016, the model projections for $ATRAD$ significantly overshoot the actual exports. The interpretation made was that the markets for Norwegian exports developed less favourably than indicated by MII. This can be realistic, since the Norwegian engineering and supply companies operate on the global market for equipment and services to sub-sea petroleum production and investments. To capture this development, a dummy ($ACOSTCUT$) was introduced in the model equation for $ATRAD$. It has a "peak-shape", with the top located in 2016q4. The interpretation is that during 2017 and 2018, the markets for specialized Norwegian export products gradually became realigned with the growth in MII. A complementary interpretation is that Norwegian firms, after several years with focus on cost-cuts but also after in investments in research and development, have come up with new product and services that are competitive on the export markets.

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.

The estimation results in section (6.2.2), show that the equation for exports of services has the same features as the model for traditional exports. However there, the elasticities are different, and the long-run relationship between MII and $ATJEN$ is:

$$LOG(ATJEN) = 0.5LOG(REX) + 0.55LOG(MII) + Constant. \tag{2.13}$$

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 2.12. The results in section 6.2.2 shows that this is particularly important for improving on the current specification of the model for $ATJEN$.

2.2.2 PRIVATE CONSUMPTION

Consumer expenditure is the largest component of spending in the Norwegian economy, and in most other countries as wel, cf. Figure 2.4 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.

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:

$$\ln(CP) = 0.6\ln(\frac{YDCD}{CPI}) + 0.1\ln(\frac{PH \cdot HK}{CPI}) + \mu_C \tag{2.14}$$

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 (2.14) 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.

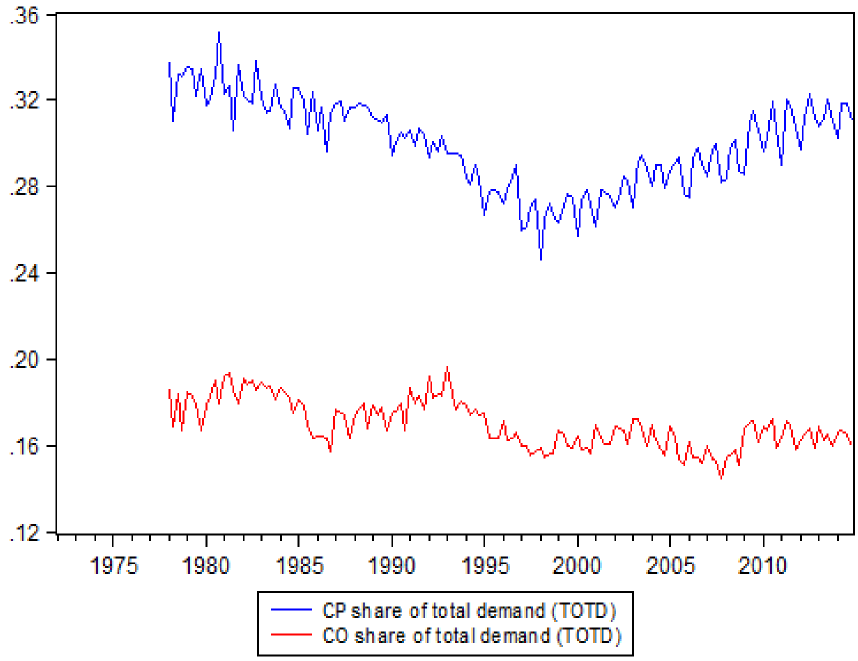


Figure 2.4: Private consumption (*CP*) and government consumption(*CO*) as shares of total demand *TOTD*

FRAME 2: 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 (2.14) 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 (2.14) 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 (2.14) cannot easily be reconciled with the mainstream theoretical presumption (actually an implication of the stochastic permanent income hypothesis) that saving is a stationary variable, Campbell (1987).[1] On the other hand (2.14) has the potential of accounting for periods with stable saving, but also for episodes with sudden movements in the savings rate.

One version of (2.14) that give insight, is to re-write it as

$$s = 0.4\ln(\frac{YDCD}{PH \cdot HK}) + 0.3\ln(\frac{PH \cdot HK}{CPI}) - \mu_C \tag{2.15}$$

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.

Figure 2.5 shows the savings rate of the household sector together with the four quarter growth percentage in real housing prices.[2] 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.

Although there is no real interest rate variable in (2.14) and (2.15), 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 which is documented in section 6.2.4. The economic interpretation is nevertheless that the interest rate strongly affects the level of the savings rate. Hence , using the results in section 6.2.4, we can write a version of (2.15) which is more true to the estimated model equation as:

$$s = 0.4\ln(\frac{YDCD}{PH \cdot HK}) + 0.3\ln(\frac{PH \cdot HK}{CPI}) + 0.006(RL - INF) - \mu_C^{'} \tag{2.16}$$

where RL is the nominal interest rate in percent, and INF is the annual percentage rate of change in CPI ($\mu_C^{'}$ is the intercept after the real interest rate effect has been taken out of μ_C).

Because (2.16) 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

[1] 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.

[2] 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.

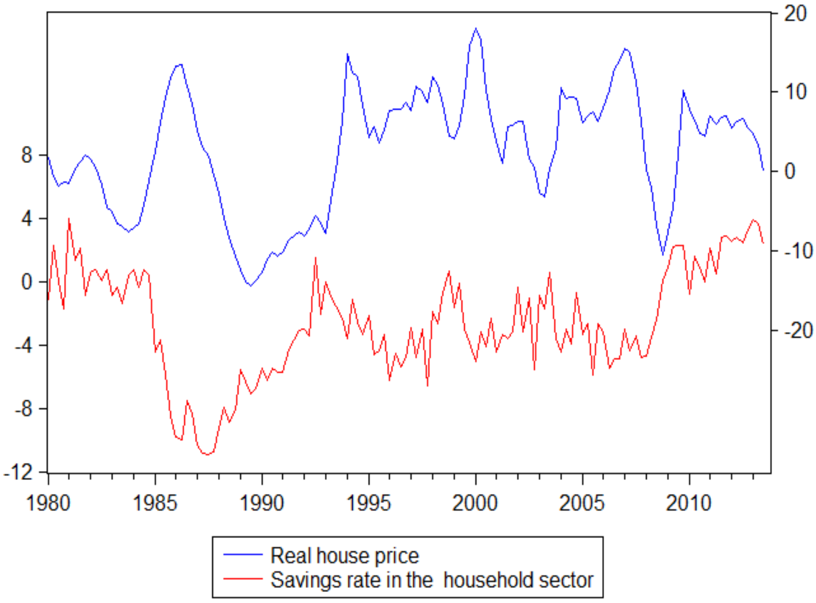


Figure 2.5: Four quarter percentage change in the real house price index and the private savings rate (dividend payments has been subtracted from the disposable income series, see footnote).

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 6.2.4 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 6.2.4. 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 3: 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 disposable income for non-profit institutions serving households (NPISH for short).

$LOENNH$, $RENTEINNH$ 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 6.11.5. The remaining components are exogenous variables in the current model version.

2.2.3 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 2.6 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 6.2.7 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 8.3. In that case, positive sales opportunities will first lead to increased production (towards full capacity), and second to realization of investment plans in order to increase capacity again.

In addition, the estimated equation in section in Chapter 6.2.7 includes he real interest rate, with a negative coefficient. In addition the interest rate affects capital formation via the profit-to-investment ratio $(YDFIRMS/PYF)/JFPN(-1)$, where $YDFIRMS$ is a measure of the dis-

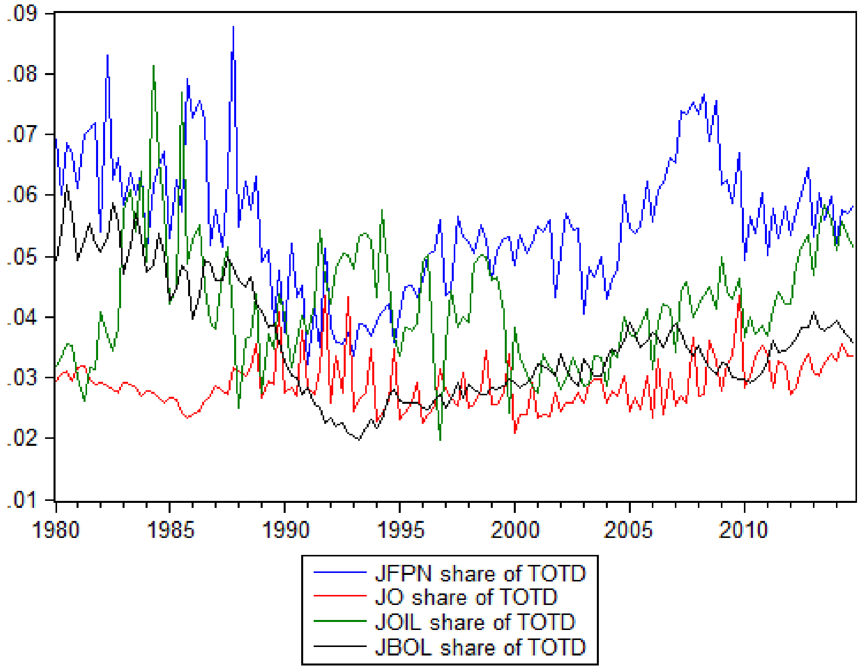


Figure 2.6: Gross capital formation as shares of total demand (*TOTD*). Private Mainland-Norway (*JFPN*), government (*JO*), production of oil and natural (*JOIL*), residential housing (*JBOL*)

posable income of firms, see the definition in section 5.2. 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.

2.2.4 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 6.2.5, while the technical "transition equation" from housing chapter (HS) to investments is reported in Chapter 6.2.6.

A main result in Chapter 6.2.5, 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 2.7.

FRAME 4: 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. section 6.13. 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 6.2.5, 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.

2.3 COMPONENTS OF AGGREGATE SUPPLY

Figure 2.7 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 $TOTS$.

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.

2.3.1 MAINLAND-NORWAY GDP AND TOTAL GDP

All the components shown in Figure 2.7 are endogenous in NAM. For example YF, valued at market prices, is given by:

$$YF = YFP1 + YFP2 + YFP3 + (LAVGSUB/PYF) + YO \tag{2.17}$$

where the three first terms make up *YFP* in Figure 2.7, and YO is value added in government administration.[3] *YFP2* where the three first terms make up YFP in Figure 2.7, and YO is value added in government administration.[4]

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

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

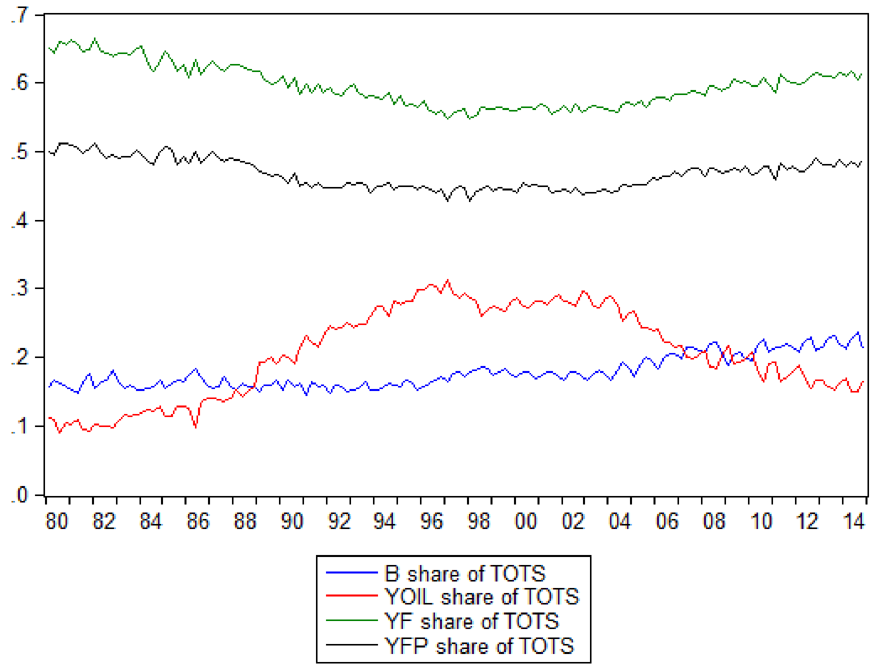


Figure 2.7: Import, oil and Mainland-Norway components of total supply *TOTS*

Total GDP is given by:

$$Y = YFP1 + YFP2 + YFP3 + (LAVGSUB/PYF) + YO + YOIL1 + YOIL2 + YUSF \tag{2.18}$$

As noted, all the different components of aggregate supply are endogenous variables in NAM. The variables YO, and $YOIL$ are modelled as 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.

2.3.2 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 6.3.4. 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 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.

2.3.3 VALUE ADDED IN MANUFACTURING

As mentioned above, the common assumption about producer behaviour is monopolistic competitive. An implication of then that product prices are set as mark-ups on marginal costs, and that firms in general have capacity as meet the demand for their products. Price setting is discussed together with wage formation in section 2.4 below.

Section 6.3.1 contains the detailed estimation results for the model equation for value added in manufacturing, $YFP1$, which is a dynamic equation that relates change in manufacturing value added to changes in variables that determine the evolution in demand for manufacturing products.

The static long-run relationship implied by the estimation results becomes:

$$log(YFP1) = \underset{(0.07)}{0.34}\,(log(0.7(DOMD)) + 0.3log(MII)) - \underset{(0.20)}{0.31}\,log(W1COST), \tag{2.19}$$

where a constant has been omitted for simplicity, and $DOMD$ is domestic demand in Norway and *MII* is the GDP based measure of foreign market potential. Hence the coefficient 0.34 is interpreteable as an estimated Engel elasticity for manufacturing products. The number 0.06 below the Engel elasticity is an estimated standard error of that long-run coefficient.

W1COST in the steady-state expression represents unit labour cost in Norwegian manufacturing relative to the foreign price level.[5] The interpretation is that when this variable increases, the price of domestic products will as a tendency increase relative to the price of foreign product. The coefficient -0.31 is therefore proportional to a price elasticity, and has the expected negative sign. As the coefficient standard error is 0.2 the implied t-value of the relative price variable is -1.53, which implies a Type-I error probability of 7 percent on the relevant one-sided test.

2.3.4 VALUE ADDED IN PRODUCTION OF OTHER GOODS

The supply sector called production of other goods, *YFP2* has value added in the building and construction sector as a main component. The detailed results for the model equation is found in section 6.3.2, while the solved out static long-run solution (omitting deterministic terms) is:

$$log(YFP2) = \underset{(0.07)}{0.65}\,(DOMD) - \underset{(0.08)}{0.13}\,log(W23COST) + \underset{(0.07)}{0.15}\,log(YFP2J)) \tag{2.20}$$

showing an estimated elasticity with respect to domestic demand of 0.65. The long rund "price elasticity" is -0.13, i.e.m the coefficient of $log(W23COST)$, which has same interpretation as $log(W1COST)$ in the model equation for manufacturing industry.[6]. In addition, the variable $log(YFP2J)$ has been included to capture that changes in the demand for investment goods may have a larger impact on $YFP2$ than we are able to represent by the use of the domestic demand $DOMD$ alone.[7]

[5] In terms of NAM variables, *W1COST* is given as: $W1COST = (WCFP1 * ZYFP1)/(CPIVAL * PPIKONK)$.

[6] $W23COST = (WCFP231 * ZYF)/(CPIVAL * PCKONK)$.

[7] $YFP2J = 0.3 * JBOL + 0.2 * JFPN + 0.3 * JO + 0.3 * JOIL$.

The estimated coefficient of the export market indicator, (MII) is estimated with a positive coefficient if it is included, However, it is statistically insignificant, and has therefore been omitted for simplicity in the active model equation.

2.3.5 VALUE ADDED IN PRIVATE SERVICE PRODUCTION AND RETAIL TRADE

Section 6.3.3 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 simplified long-run relationship is:

$$log(YFP3NET) = \underset{(0.37)}{1.2}(0.85log(DOMD)) + 0.15log(MII)) - \underset{(0.08)}{0.24}\,log(W23COST), \quad (2.21)$$

where we note that the elasticity with respect to domestic demand ($DOMD$) is higher than for the two other $YFP1$ and $YFP2$, i.e., the estimated elasticity is $1.2 \cdot 0.85 = 1.02$.

2.3.6 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.

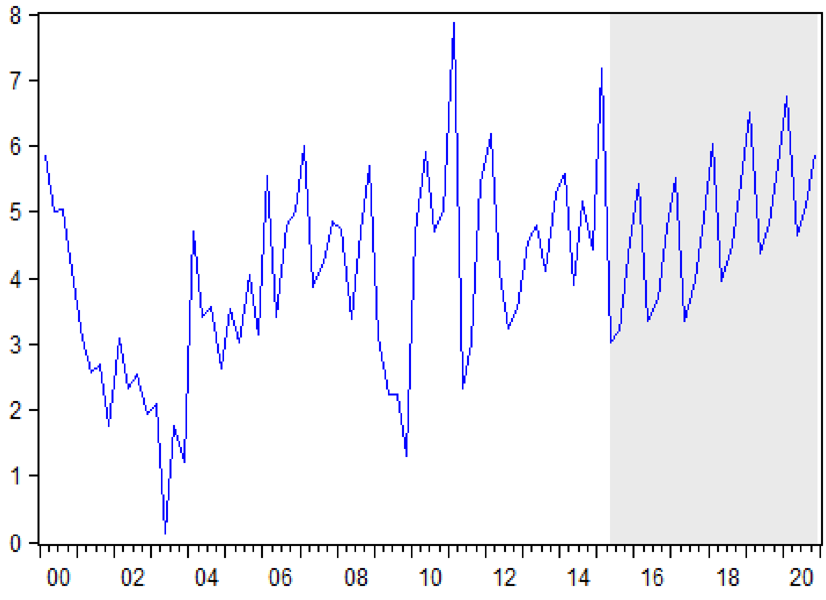


Figure 2.8: Changes in inventories in percent of GDP. Shaded area represent values from dynamic simulation of NAM, i.e. forecasts

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 2.8 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.

2.4 THE WAGE-PRICE MODULE

It seems to hold quite generally that wages do not change constantly, but follow a pattern over time. This is particularly evident in Norway, where collective agreements play an important role in for wage regulations. Wage agreements typically remain in effect for a fixed period of time, and wages in different industries are adjusted in different months of the year. Therefore, the temporal pattern of wage setting is not well captured by the dominant assumption in current macroeconomics literature, namely that of "Calvo contracts", in which wage changes are stochastic and the probability of a new settlement is the same in each time period. Instead, the Norwegian system of national wage setting (as different from the level of the individual) is much more consistent with the principle of "staggered wages" as introduced into macroeconomics by Taylor (1980).

However, wage staggering by itself only accounts for the temporal pattern of wage changes. Synchronization of wage wage changes between the different sectors is another matter, and involves a common understanding and legitimaty of the wage norm or reference wage for example.

Figure 2.9 gives a graphical illustration of some of the main relationships of a national system of wage formation of characterized by wage-leadership and wage-followership, variously known as pattern wage bargaining, see e.g., Calmfors and Seim (2013).

The Norwegian version of the pattern wage bargaining has roots back to the early 1900s see e.g., Nymoen (2017). The figure indicates a system with relatively strong coordination, since wage setting in manufacturing (the wage rate is labelled W_1) is anchored to manufacturing firms ability to pay (the variable *Wage-Scope*), while the wage rates in private service production (W_2) and in

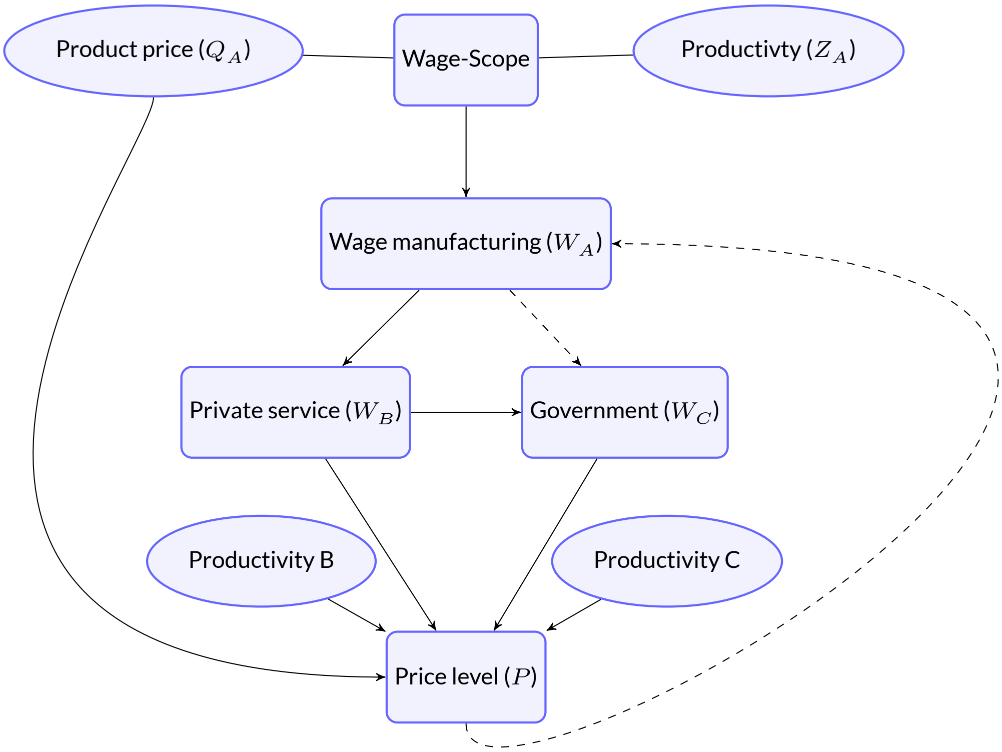


Figure 2.9: Wage and price level formation with one wage-leader, manufacturing (labelled A), and two wage-followers one private (labelled B) and the government sector (labelled C).

the government sector (W_3) are determined by wage-following behaviour.

Historically, a recognized problematic effect of not having enough wage coordination has been that wage-wage, and wage-price, spirals can cause high and increasing inflation. A rapid increase in the consumer prices has never been popular among union leaders, since it undermines the purchasing power of the agreed money wage. For a small open economy, domestic inflation (wage-price spirals) can also undermine a policy that targets a high employment level, since it threatens the international cost competitiveness of Norwegian import and export competing firms (then the problem is not inflation as such, but that it is consistently higher than foreign inflation). A third facet of weak coordination is wage-wage inflation, which gradually became a problem during the 1970s in some countries with with a high unionization rate but with relatively weak confederate organizations.

The degree of wage coordination achieved has probably varied a good deal over the last decades, in Norway as elsewhere. So there is a danger of over-simplifications. However, returning to Figure 2.9, it captures some of the main ideas of the Norwegian national system of wage setting, namely that the sustainability of the national real wage level can be increased by having a system where the bargained wage in the manufacturing sector regulates the trend development of wages in all other sectors of the economy. This is the thinking that Figure 2.9 represents.

The manufacturing wage, denoted W_A in the figure, is sustainable if it is strongly associated with the wage-scope in manufacturing, which is defined as the value of labour productivity:

$$\text{Wage-Scope} = Z_A \times Q_A,$$

where Z_A is valued added in real terms per hour worked, and Q_A is the price (index) of value added. In practice both of these variables are strongly trending. Hence, if the manufacturing wage W_A, as a rule, is set in proportionality to the Wage-Scope, the wage level will also trend, but at the same time the implied wage-share in manufacturing will have a constant long-run mean. Markets forces and institutions may combine in the determination of the long-run wage-share (ie, in the fixing of the proportionality factor). If W_A is too high compared to the wage-scope, the return to capital may become too low to attract investments in capacity, new product development and technology. This consequence is likely to be understood by the bargaining parts. Conversely, if W_A becomes under-regulated relative to the wage-scope, the conception of fairness of the wage, which is important in reaching a collective agreement between equally powerful partners, is likely to lead to wage compromises that correct the previous under regulation.

In summary, a main premise of the system is that firms and workers are able, through collective bargaining, to reach compromises about annual wage adjustments that balance the concerns about required profitability, and about fairness in the workers' share of the wage-scope. The theory does not depend on the normal (ie equilibrium) wage-share being a completely invariant parameter. On the contrary, the model needs to be able to adjust the normal wage-share when required. Historically, adjustments have taken place, either through compromise (collective rationality) or through conflict, to eg, changed global marked conditions (higher required return to capital for example), danger of mass unemployment due to negative external shocks (not limited to manufacturing), or changes in labour market conditions and institutions.

Having established W_A from the wage-scope and the normal wage-share, it can take the role of a wage norm which can be followed in other bargains. This step might work in practice, because the maintenance of relativities is another dimension of fairness that influence actual wage negotiations. In Figure 2.9, we indicate that the conception of fairness of wage first might regulate the wage (W_B) in the private service sector. Then, the wage in government administration (W_C) is adjusted to maintain a normal relativity to W_2. Hence, labour productivity in the two wage-following sectors do not influence (W_B,W_C). However, productivity does influence by how much prices are adjusted (ie mark-up price setting), as indicated by the lines from the two productivity nodes to the node label Price level.

In the empirical model below, the variable used to represent the price level, P, is the consumer price index. In a small open economy, P depends directly on foreign prices, and that link is represented by the line from the Q_A-node to the node for P in the figure. In the empirical model, we need to be more realistic, and we use an import price index in the econometric modelling of P.

There are also other important aspects of price setting that are lost in a stylized diagram. For example, since a large part of the cost of providing public is financed by taxes, the impact of W_3 and Z_C on the domestic price level is much smaller than from unit labour costs in private service production, and from the prices of imported consumer products. Hence, it is easy to imagine that most of the inflation driving forces are on the left-hand side of the figure, rather than on the right-hand side.

Another remark is that the lines in the graph may give the impression that one-way causation is a defining characteristic of the system. Again, that would be an over-simplification. Specifically, the model must (to be realistic) allow cost-of-living considerations to enter the picture, as they are always relevant in real world wage setting. We have indicated a feed-back loop by the dashed line from the P-node to the W_A-node. It can be interpreted in two different ways. First, it can represent a short-run effect (ie, between the change in cost of living and the change in W_A). Second, it can represent a long-run effect (ie, P is a variable in the cointegrating relationship for W_1). The two interpretations have different implications for the properties of the system (including its stability).

Finally, there are additional linkages and feed-back mechanisms that can be empirically relevant: The agreement in the manufacturing sector may regulate the wages of public sectors works directly, as indicated by the dashed line. There may for example be mutual causation between W_2 and W_3 (not drawn in the graph). Gjelsvik et al. (2015) developed an empirical model of indicated wage leader-followership pattern. Using advanced econometric methods they found support for relative stability of the pattern, in particular with respect to the change in monetary policy early in the new millennium and to the increased labour immigration inflow from EU/EFTA countries, North America, Australia and New Zealand and non EU Eastern Europe (measured in percent of the population ages 15-74). The the wage module in NAM has been develop to be broadly consistent with the results in Gjelsvik et al. (2015).

The leader-followership module in NAM, and the associated model equations for price adjustments, can be seen as a particular special case of an Incomplete Competition Model (ICM) of the supply side. Chapter 8 gives a self-contained introduction to ICM, with emphasis on the implications this modelling approach for the medium term equilibrium properties of a complete macro model. One main implication is that the medium term equilibrium is implied to be more responsive to shocks to the product and labour markets than if wage and price are modelled by Phillips curves, which is the custom in macro models, even today.

Hence, while we can maintain the idea about an equilibrium rate of unemployment in NAM, the equilibrium can be seen as being influenced by aggregate demand. It is not a natural rate of unemployment, of a NAIRU, in the usual meaning of these terms. The natural rate/NAIRU equilibrium is determined by supply-side parameters and in such a way that only one inflation rate (think of it as given by foreign inflation for simplicity) is consistent with the natural-rate/NAIRU. In NAM, there is in principle a region of equilibrium unemployment rates that are consistent with the same steady-state inflation rate.

In NAM a system with (modified) pattern wage formation has been implemented for the main production sectors of the model. Abstracting from dynamic and deterministic terms, the estimated (long-run) equation for the hourly wage cost in manufacturing, $WFP1$ can be simplified to:

$$log(WFP1(1+T1FP1)) = -0.15ln(UR) + ln(PYFP1 \cdot ZYFP1) \quad (2.22)$$

where $T1FP1$ is the payroll tax-rate, UR is the unemployment percentage (registered), $PYFP1$ is the value added deflator in manufacturing (basic values) and $ZYFP1$ is average labour productivity for wage earners.

The estimated elasticity with respect to unemployment is -0.15, which is quite representative for the empirical literature. In the earlier NAM versions, where the key wage rate has been for the private business sector, the corresponding parameter was estimated to -0.12. The long-run relationship in (2.22) is embedded an equilibrium correction variable in the dynamic equation for the manufacturing wage. The detailed results in section 6.4.8 show that the relative change in the hourly manufacturing wage rate ($\Delta ln(WFP1_t)$) depends on "within year" CPI-increases ($\Delta_3 ln(CPI_{t-1})$) as well as wage changes ($\Delta_3 ln(WFP1_{t-1})$). For example the quarterly wage change is negatively correlated with wage growth over the three previous quarters, which is typical or staggered wage growth, see Nymoen (1989a) for early evidence on Norwegian wage data.

(2.22) has the hourly wage cost ($WCFP1$) on the left hand side. The implication is the the wage long-run elasticity with respect to the payroll tax-rate ($T1FP1$) is -1. Hence, if there is a permanent increase in the payroll tax-rate, the nominal hourly wage is adjusted (over a period of time) so that the hourly wage-cost is left unaffected.

In the wage-module, hourly wages in the two other private sectors (building construction and production of other commodities (sector 2), and private service production(sector 3)) are pooled into a wage rate called $WFP23$. The motivation is that in order to represent the national system of wage setting it is more important to have a single (though "composite") wage follower in the private business sector. The estimated long-run equation for $WFP23$ takes the form (cf. section 6.4.9):

$$log(WFP23) = log(WFP1) - 0.04ln(UR) - 0.02IMR \quad (2.23)$$

where IMR is the gross immigration rate.

The model equation for the hourly wage rate in the government sector is even simpler, see section 6.4.12. The long run version is a simple relativity between the government wage rate WO and the $WFP23$ wage rate.

As noted above, the underlying assumption on the production side of the economy is monopolistic competition. The theoretical implication for price setting is that firms adjust prices in order to maintain a normal profitability level. Of course, when adjusting their prices, firms must try to take the consequences for demand into account and therefore so called mark-up pricing is not absolute, but depends on the degree of product market competition. In technical terms, product demand is *elastic* if a one percent increase in the price leads to a large relative reduction in demand (almost horizontal demand schedule), and *inelastic* if demand change very little as a response to a price increase (almost horizontal demand schedule).

Macro economists usually distinguish between sectors characterized by elastic demand, which represent a limitation on the possibility of cost based pricing, and other sectors with relatively limited elasticity meaning that increased wage costs can be rolled over to prices without large consequences for firms' sales possibilities. Norwegian economists are used to the dichotomy between competitive sectors and the sheltered sectors, and in NAM we follow that custom by thinking of the manufacturing sector as competitive and other commodity production and private service production as sheltered.

The model equations for the value added in manufacturing ($PYFP1$) and in the "sheltered" are found in section 6.4.1 and 6.4.2. The estimation results give support to the view that there is a difference in the competitive markets that the firms operate in, in that an increase in wage cost per our is incompletely passed on to $PYFP1$, while it is completely passed through to $PYFP23$.

As noted above,the representation of 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 6.4.19 imply that the long-term (steady-state) elasticity of PB with respect to a permanent positive shock to the exchange rate is 0.7. 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 estimated impact elasticity of the foreign producer price is 1.0, while it is 0.5 for the nominal exchange rate.

Based on the model equations for wage setting and value added price indices, and the import price model equation, the deflators of mainland Norway GDP in basic and market basic prices are explained in the model. As a final step in the wage-price module, headline CPI (and CPI adjusted for taxes and energy) are modelled by conditioning on the mentioned GDP and import deflators (cf. section 6.4.7).

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.

2.5 HOURS WORKED, EMPLOYMENT AND THE RATES OF UNEMPLOYMENT

If we take as a starting that firms' outputs are strongly influenced by product market demand, it follows that labour demand will mirror the fluctuations in product demand. In comparison, labour supply has a weaker connection with the product markets, at least in the medium term time perspective. Therefore in particular increases in unemployment are typically conditioned by drops in product demand.

NAM contains model equations for these relationships. Demand for labour in Mainland-Norway (measured both in hours worked and in employed persons), is strongly related to the demand in import competing and export competing product markets. The public sector (government administration) is naturally 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 6.6.1 - 6.6.6.

As noted above, wage income is the largest component or private disposable income, and a main factor behind aggregated domestic demand. In turn, hours worked affect wage income, as for example a one percent increase in real wage incomes can be achieved by both a one percent increase in the consumer real wage, and by a one percent increase in hours worked. Hence, product markets and labour markets have a tendency to be strongly synchronized, in the medium run.

As already noted, there are two variables that measure the unemployment rate in NAM. The registered unemployment (UR) rate, and the Labour Force Survey measure ($UAKU$). They are given by the two definition equations:

$$UR = \frac{REGLED * 100}{AKUSTYRK} \tag{2.24}$$

$$UAKU = \frac{AKULED * 100}{AKUSTYRK} \tag{2.25}$$

where the variable *REGLED* is the number of registered unemployed, and *AKULED* is the number of unemployed in the Labour Force Survey (AKU). The variable *AKUSTYRK* is the size of the Norwegian labour force, which is measured according to the Labour Force Survey.

In NAM, *REGLED* and *AKULED* are modelled as separate equations, see section 6.7.2 and 6.7.1. As can be expected, the driving factors of the two variables are overlapping. For example, employment growth affects both measures negatively, while the partial effect of population growth is to increase the number of unemployed persons.

In the model, there is a definition equation for the labour force:

$$AKUSTYRK = AKULED + AKUSYSS, \tag{2.26}$$

while *AKUSYSS*, which is the number of employed persons in the Labour Force Survey, is modelled by an econometric equation which is a bridge between how employment is measured in the National accounts data and in the Labour Force Survey (AKU). The model equation for *AKUSYSS* is found in section 6.7.3. One variable that intervenes between *AKUSYSS* and the National accounts data, is the number of short-term labour immigrants (*KAIER*). It is included in the National accounts data, but not in the Labour Force Survey measure of employment.

2.6 THE MARKET FOR FOREIGN EXCHANGE

Several important asset prices are endogenous in NAM. 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 2.7 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 2.2.3. In NAM, the stock exchange price index is modelled as a function of foreign stock prices, see Chapter 2.9 and the detailed estimation results in 6.12.1 and 6.12.2.

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.

FRAME 5: 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).

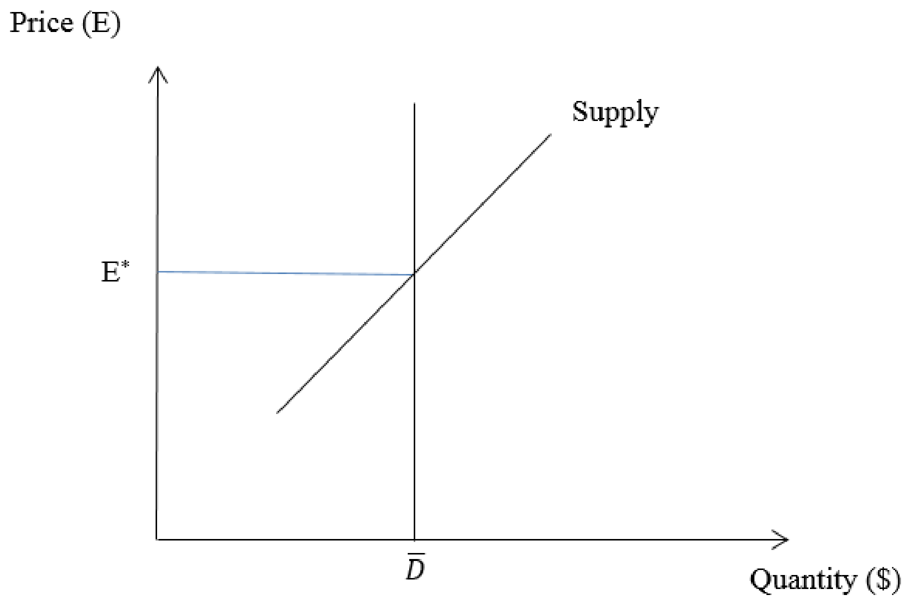


Figure 2.10: The market for foreign exchange, represented by a single foreign currency, USD ($). The price of foreign currency is the number of kroner per USD and is denoted E in the figure. $\bar{D}$ is the net demand of foreign currency by the domestic central bank. When $\bar{D}$ is exogenously determined, E^{*} is the equilibrium price

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 2.10 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:

$$r_t = i_t - i_t^f - f(E_t) \tag{2.27}$$

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.

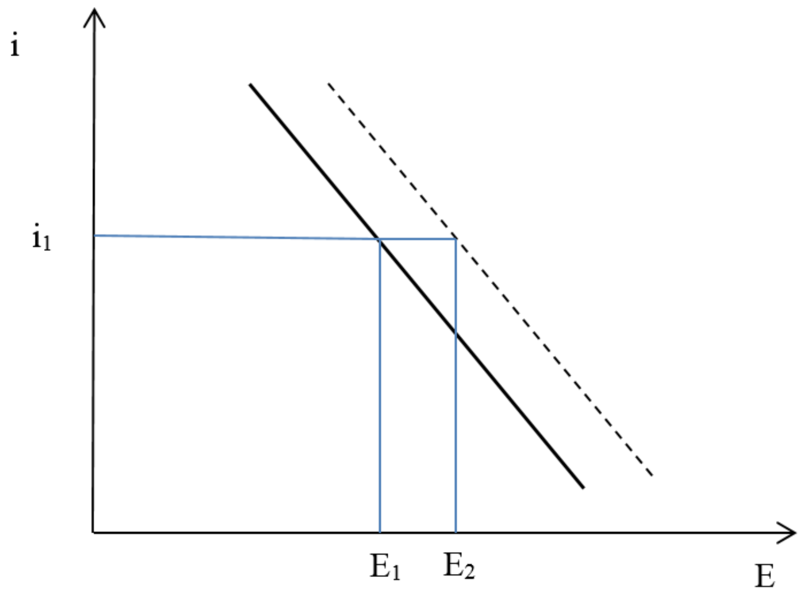


Figure 2.11: The Ei-curve shows equilibrium combinations of the interest rate and the nominal exchange rate in the FEX market.

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 2.11 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 2.10. 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

$$\bar{D} = S\left[E,\, \left(i - i^f - \alpha\left(E\right),\, P,\, P^f,\, Z\right)\right] \tag{2.28}$$

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 (2.28) 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.

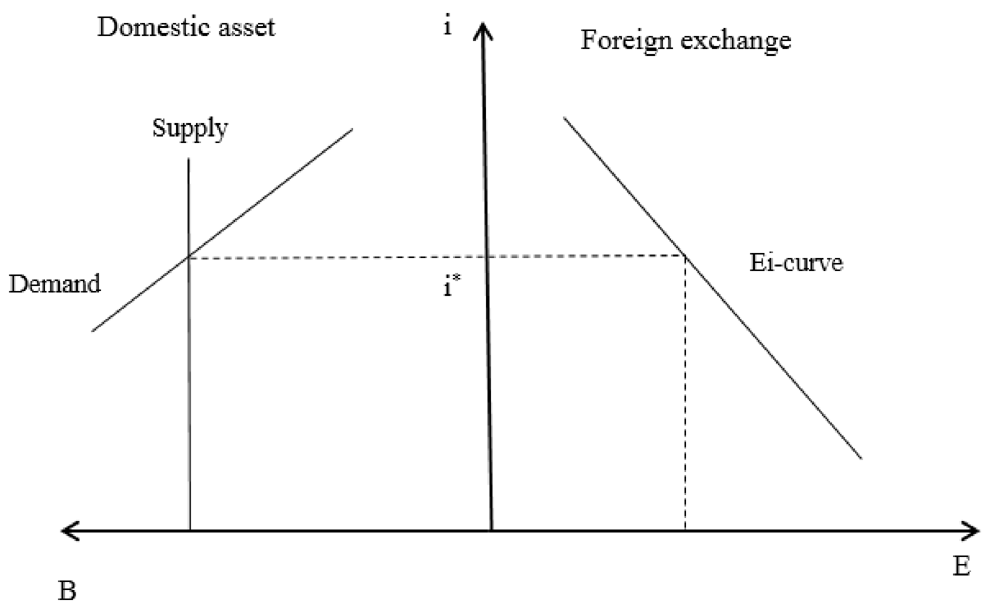


Figure 2.12: Joint equilibrium in the market for foreign exchange and in the domestic asset market.

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 (2.28) 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 (2.28), 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 2.12 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 6.5.1, 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 2.12, 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.

2.7 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.

2.7.1 HOUSING PRICES AND THE MACRO ECONOMY

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 2.13 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

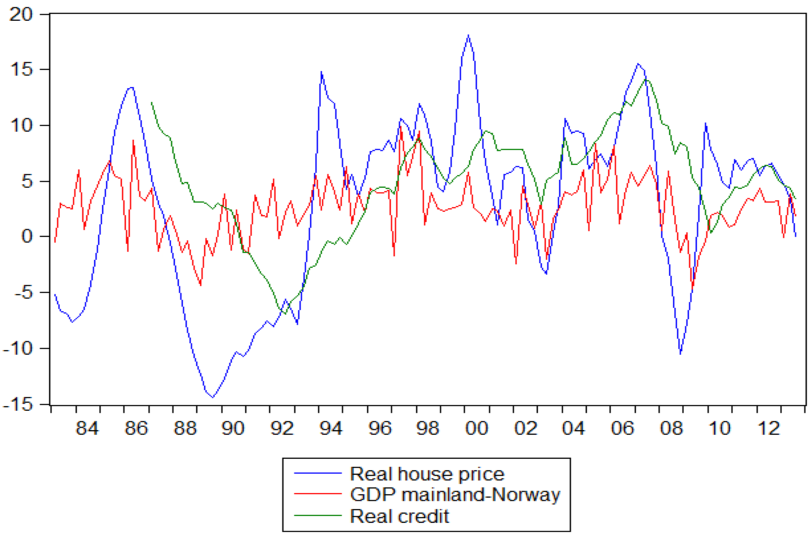


Figure 2.13: Four quarter percentage change: real house price index, real GDP Mainland-Norway and real credit (C2-indicator).

not limited to the almost immediate reduction in consumption and increase in savings witch led to reduced GDP growth. 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.

2.7.2 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

$$MRS = P\left[(1-\tau) - \frac{\dot{P}_c}{P_c} - \delta - \frac{\dot{P}}{P}\right]. \tag{2.29}$$

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. (2.29) 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

$$Q = P_h\left[(1-\tau)i - \frac{\dot{P}_c}{P_c} - \delta - \frac{\dot{P}}{P}\right] \tag{2.30}$$

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:

$$\frac{P}{Q} = \frac{1}{UC} \tag{2.31}$$

where the user cost, UC, is defined as

$$UC = (1-\tau)i - \frac{\dot{P}_c}{P_c} + \delta - \frac{\dot{P}}{P}. \tag{2.32}$$

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 (2.31) would read:

$$\frac{P}{Q} = \frac{1}{UC} \tag{2.33}$$

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

$$Q = Y^{B_0 \beta_y} H^{\beta_h}, \beta_y > 0 \text{ and } \beta_h < 0$$

where Y denotes regular income and H represents the housing-stock, (2.31) becomes

$$P = \frac{B_0 Y^{\beta_y} H^{\beta_h}}{UC} \tag{2.34}$$

The expressions represented by (2.33) and (2.34) 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 (2.34) is similar to an inverted demand equation, and we now have seen how it can be derived from a life-cycle model.

2.7.3 THE EMPIRICAL MODEL OF HOUSING PRICES AND CREDIT

In NAM we take the inverted demand function (2.34) as the main theoretical reference. However, the stylized relationship need to be modified somewhat in order to become become part of a useful empirical model. First, we replace it with the specific generalization:

$$p = \beta_0 + \beta_y y + \beta_h h - \beta_x x_t \tag{2.35}$$

where p,y and h are natural logarithms of the corresponding variables P,Q and H, while x_t denote a vector of variables that may be additional empirical determinants of the demand for housing. The interest rate, and the other components in the expression for UC, belong to the x_t vector. Households' anticipations about their wage income, and the availability and cost of credit are other candidates for inclusion in the vector with additional determinants of the demand for housing services (see below).

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 2.14 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

$$p = \beta_0 + \beta_d d + \beta_y y + \beta_h h - \beta_x x \tag{2.36}$$

$$d = \gamma_0 + \gamma_1 ph + \gamma_2 y + \gamma_h h + \gamma_i((1-\tau)i - \frac{\dot{P}_c}{P_c})) \tag{2.37}$$

In a world of credit marked imperfections and changing degrees of liquidity, it is possible that one or more of the factors in x_t operate in a non-linear way. For example, a relevant hypothesis

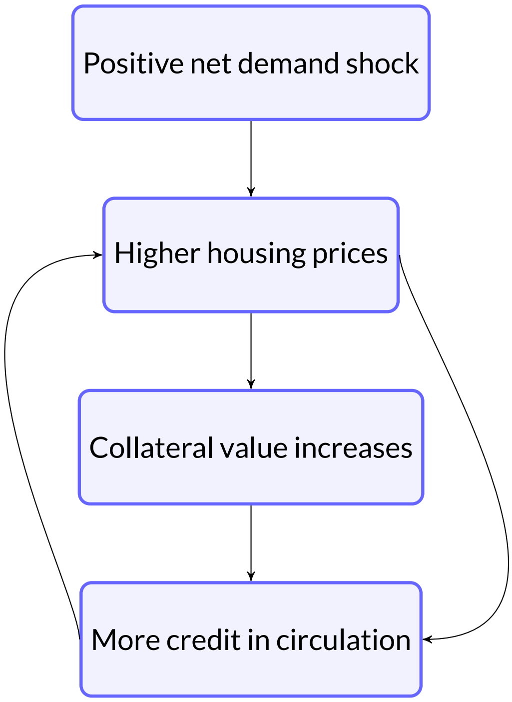


Figure 2.14: Two-way interaction between housing prices and credit

is that households who have preference for liquidity will reduce their exposition in 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 5 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
$T2CAPH$ Tax rate on capital income to households.	

Moreover, 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 HK in NAM, is already a real variable, so we only simplify the notation by denoting the stock of housing capital by H in (2.34).

Using the variables in the NAM database, we measure the after tax real-interest rate $(1-\tau)i-\frac{\dot{P}_c}{P_c})$ as:

$$ri = (1 - T2CAPH)RL - INF$$

where INF is the annual rate of inflation based on CPI.

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 (based on history, but it can be changed by the model user).

The results form econometric modelling give support of two cointegration relationships that are modifications of (2.36) and (2.37) along the lines just described:

$$log(PH/CPI) = 0.6log(BGH/CPI) + 1.6(log(YHP/CPI)) - log(HK)) - 0.2rynl \quad (2.38)$$

$$\begin{aligned} log(BGH/CPI) = {} & 0.95log(PH/CPI) - 0.95(log(YDCD/CPI) - log(HK)) \\ & - 0.1ri \end{aligned} \quad (2.39)$$

Chapter 6.8 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 (2.38) and (2.39) are both highly significant, confirming that the two are relevant cointegration relationships.

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 2.15, 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.

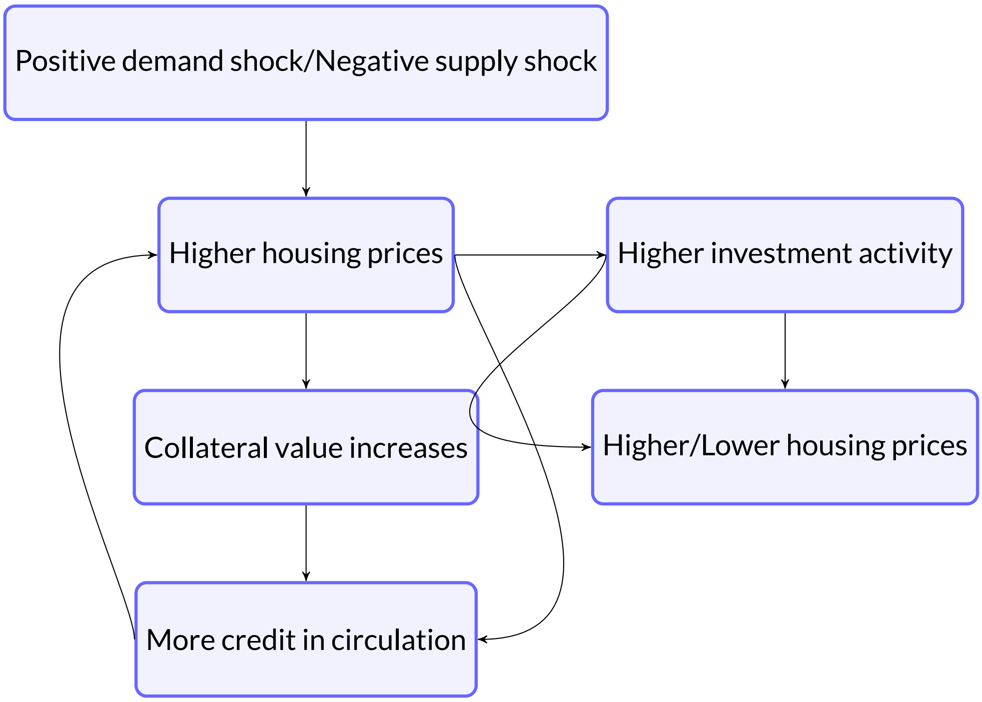


Figure 2.15: House price and credit system extended with effects of investments, which over a period of time will have a notable effect on the supply of housing.

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 6: 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 6.9.1.
For completeness, NAM also contains equations for C2 to firms, see Chapter 6.9.2, and to Norwegian municipalicities, see Chapter 6.9.3.

2.8 INTEREST RATES

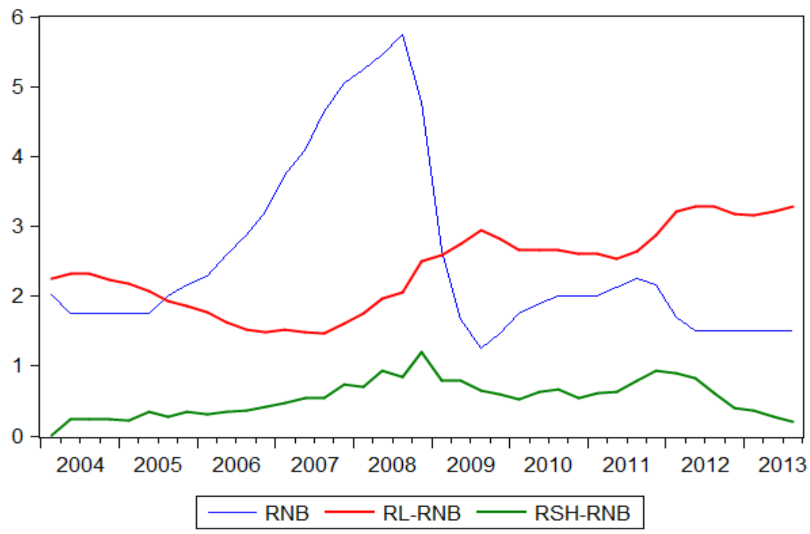


Figure 2.16: The policy interest rate (RNB); the difference between the interest rate on loans from Norwegian finance institutions to households and the policy rate (RL-RNB). The difference between the 3-month money market interest rate and the policy rate (RSH-RNB).

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.[8] NAM includes an estimated "policy reaction function", which is documented in capter 6.10.4. 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

[8] 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.

lasting impact of the financial crisis 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 2.16 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 6.10.5. 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 6.10.3 shows 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 6.10.1 and table 6.10.2 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.

2.9 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 6.12.2 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 6.12.1, the results for the Norwegian MSCI are reported. We find that $\Delta log(PA_t$ 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.

3 A FLOW CHART VIEW OF THE MODEL

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 are formed in that process. In this chapter we give an impression of some of the dependencies of the economy that are captured by the model. The discussion is informal and supported by so called flow charts. The discussion can be a useful background to model usage (scenario analysis and forecasting).

3.1 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 3.1 illustrates some of the relationships in NAM. In Figure 3.1 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 3.1, 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

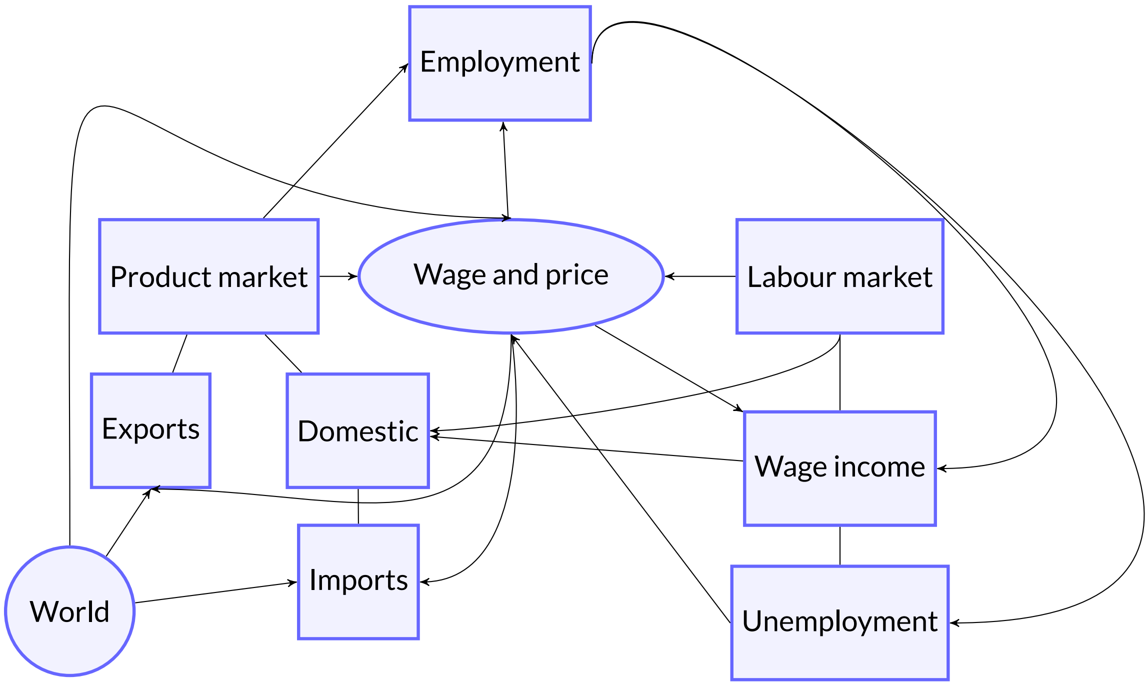


Figure 3.1: Illustration of relationships and joint-dependencies between product markets and the labour market.

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 dependencies 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 3.1, 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 8.6.1 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 3.2 by the line with two-way arrows between the ellipses representing Wage and price setting and the Real exchange rate.

3.2 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 3.2.Theoretically, in the portfolio approach that we make use of in chapter 2.6, 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

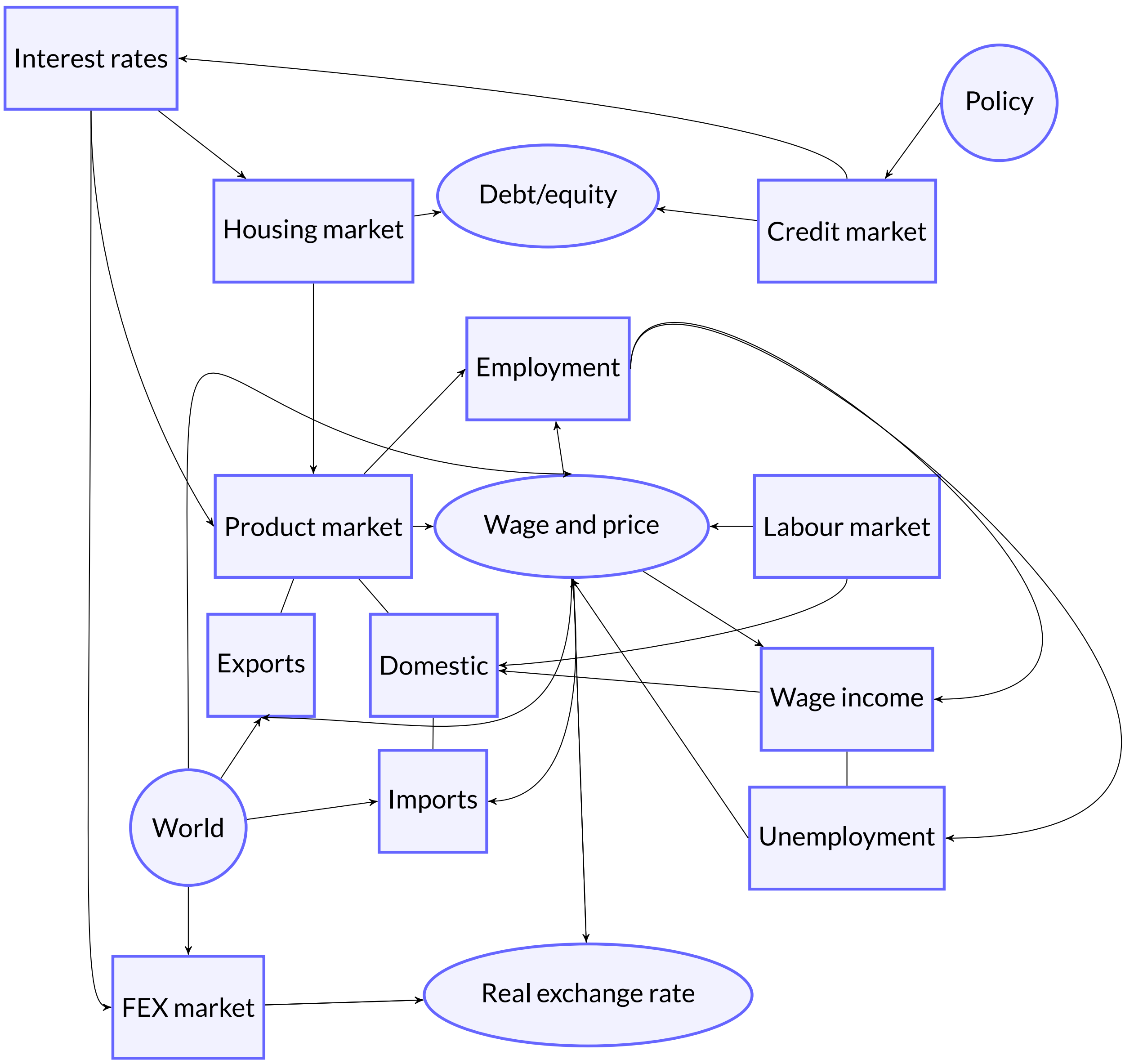


Figure 3.2: Illustration of relationships and joint-dependencies, extended by asset markets (foreign exchange and housing) and credit.

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 3.2.

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 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 2.7.3 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 2.7.3 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.[1] Hence, we should in principle have added lines from Wage and price inflation to Policy in Figure 3.2, 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 3.1 and 3.2 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.

[1]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).

Another, very important model feature which is “hidden” in the diagrams, is that most 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 4 contains some examples NAM usage, and therefore of simulation results.

4 USING NAM IN PRACTICE

In this chapter, we give a characterisation of NAM, in terms of size and coverage (of the economy), and we provide a few examples of how NAM can be used in analyses of the Norwegian economy, for scenario analyses and forecasting.

4.1 MODEL SIZE

The (January) 2019 version of the model contains 208 endogenous variables. A special version used by The Financial Supervisory Authority of Norway has 13 additional endogenous variables. 83 of the 208 variables are determined by estimated model equations. With the exception of dozen of equations that are of a very technical or auxiliary nature, the estimated model equations are reported in Chapter 6. The rest of the endogenous variables are determined by identities and by definition equations.

There is a relatively few variables that that need to be projected outside the model. The main variables that need careful consideration by the model user are variables that represent the foreign sector, the oil sector and the public sector (government administration). The growth in the Norwegian population (age interval 15-74) in an important variable for labour supply we have not endogenized in the current version of the model.

An important policy variable which is endogenous in the default version of the model is the policy interest rate. The reason for this choice is that flexible inflation targeting rule, is possible to approximate in model that has a relative broad representation of variables for the nominal path and real parts of the Norwegian economy.

Fiscal policy in Norway is different, and is less regulated by rules than monetary policy. Due to the considerable fiscal policy independence represented by the Norwegian "oil-fund", there is really no binding fiscal policy rule in Norway. [1]. 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. In the present version of the model

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-

[1] 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/`

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 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.

As noted aboven, 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. As explain in the next section, in practice, using NAM comes down to running and editing a computer program file in Eviews. Therefore it is also very easy for model users to define new endogenous variables to fit the purposes of the analysis. A user can also choose to make changes in the opposite direction. For example by switching off the interest rate rule equation of the model. Either temporarily, as under the financial crisis, or even permanently.

4.2 NAM IN EVIEWS

NAM is implemented as a program file (recognized by the filename extension ".prg") in the econometric software package Eviews.[2] The current version of NAM runs on EViews 10 (and EViews 9 and 8). The NAM prg-file serves several functions. The first is to load a number of files with quarterly data that are needed to estimate the model's equations, and to complete the model with definition relationships. Model data bank maintenance and regular updates all series, is a main task connected to keeping NAM as a relevant and operational model. This is the task of the model developer. The model user do not need to spend time "getting the the data into the model". It is taken care of automatically in the NAM-prg file.

Figure 4.1 shows how the top section of a NAM-prg file typically looks after it has been opened in Eviews. The "Dashboard" section in particular contains main switches with Eviews commands that fixes the workfile range (%STARTWF and %ENDWF, usually set by the model producers) and several useful sample starts and sample ends which the model user can change to fit her purpose.

In the example shown, the workfile range is set to 1966q1-2040q4. This means that the earliest start of any time series can be is the first quarter of 1966, and the end quarter of any (long) time series can be the fourth quarter of 2040.

The third switch sets the final period of the estimation period. Naturally it is a switch that a model user will often want to change, for example to investigate how sensitive the model solution (i.e., dynamic simulation) is to the sample period used. In this case, %STOP is set to 2018q3. The fourth switch is %FSTART, which sets the start quarter if the model is used for forecasting. Since %STOP = "2018q3" and %FSTART = "2018q4" in this example, the forecast will be based on a sample that ends one quarter before the start of the simulation start in 2018q4.

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

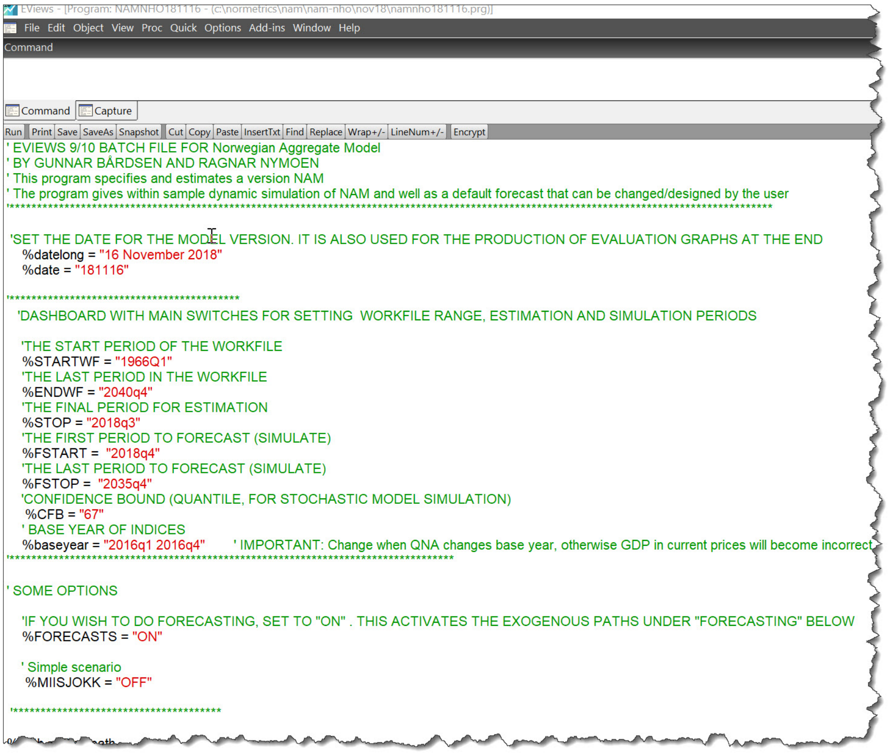


Figure 4.1: Screen capture of the start section of a NAM-prg file. Showing *Dashboard* with main switches for e.g. estimation sample length and start and stop of simulation period. Note: In Eviews a line with comments begins with '.

%FSTOP = "2035q4" sets the last period of the forecast period to the fourth quarter of 2035. %FSTOP must be a quarter within the range of the workfile.

I NAM, the default is that forecasts are based on stochastic simulations. This means that forecast intervals (variously known as fan charts) will be part of the output. The switch %CFB = "67" sets confidence degree of the forecast to 67 percent (corresponding to $\pm$ one standard deviation if the error terms of the model are approximately normally distributed.

The last switch on the main dashboard is %baseyear which sets the base year of the price indices of the model. The default is to keep this switch unchanged between changes in the base year of the (quarterly) National accounts, as noted in the comment to the left of the switch.

Below the dashboard there is short section labelled "SOME OPTIONS". The switch for choosing forecasting or not is standard option. By choosing "ON" the NAM-prg file, when run, will execute a user-determined section where the exogenous variables are projected over the period specified with %FSTART and %FSTOP on the dashboard,in this example from 2018q4 to 2035q4. NAM is then simulated dynamically (and stochastically) over that period, the forecasted series (with confidence bounds) stored in the workfile. Tables with the forecasts and graphs are also produced (see below).

In the example in Figure 4.1 there is only switch for scenario analysis, in this case a shock to the variable MII which is the export market indicator of the model.

In order manifestations of the NAM-prg file there can be a list of switches here, for shift anal-

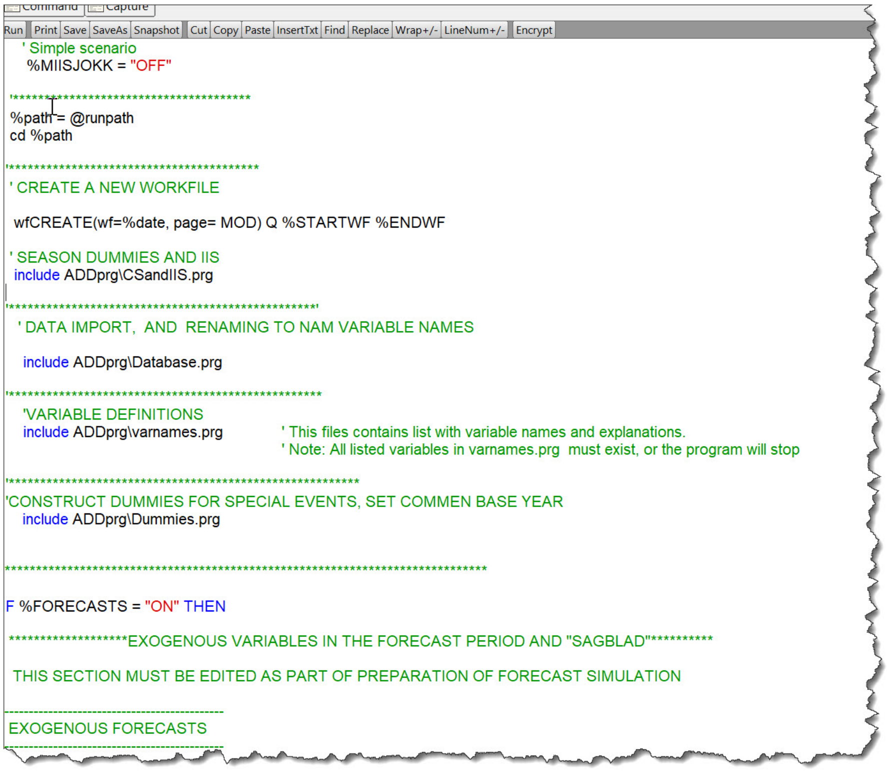


Figure 4.2: Screen capture of the a section of a NAM-prg file with data input, creation of variables leading up to the section where exogenous model variables are projected of forecast is chosen as an option in the dashboard section.

ysis that can been prepared by the model builders of model user.

Figure 4.2 shows how a user will typically find the the next sections of a NAM-prg file may. First, for technical reasons, there are two lines:

```
%path = @runpath
cd %path
```

which secure that the main NAM-prg file expects to find child prg-files in subdirectories to the same main directory (and is therefore best left unchanged).

The next two lines

```
' CREATE A NEW WORKFILE
wfCREATE(wf=%date, page= MOD) Q %STARTWF %ENDWF
```

creates teh Eviews workfile used for the NAM session, with the range specified in the dashboard part.

The lines that start with *include* run Eviews prg files in the subdirectory *ADDprg*. The first file, CSandIIS.prg generates (centered) seasonals and indicator variables for all the observations in the workfile. These indicators are used in the construction dummies for special events and for structural breaks. Unused indicators are deleted when the all the dummy variables have been created.

Database.prg is the main file for data import. The data files that are loaded here are either recognized directly as EViews databases, or they can be transformed to such databases. [3]

The fole *varnames.prg* holds the variables names of all the main variables of the model. The list of variable names corresponds to the variable names in Chapter 5 and is useful for creating legends in plots and tables.

In *Dummies.prg* the dummies mentioned above is constructed, and the now redundant full set of indicator variables from the CSandIIS.prg stage is deleted).

Usually a user will not need to consider the content of the prg files, although the files are open for inspection. Instead, the user will want to think about the how the exogenous variables are to be projected over the forecast horizon which was set in the dashboard. Hence in a typical NAM-prg file, with the %FORECAST shift set to ON, the next section which is executed is the EXOGENOUS part of the NAM-prg, as indicated by the last lines in screen capture in Figure 4.2. In 4.3 we show a few examples of how the EXOGENOUS part of the program file can be edited.
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 4.3. 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 5, which contains an overview of the most important data symbols used, and the corresponding data definitions in NAM.

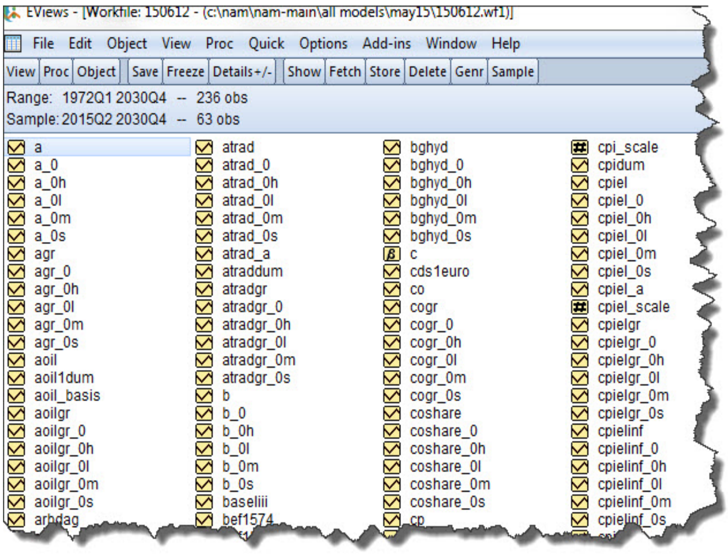


Figure 4.3: Screen capture of section of an Eviews workfile produced by running a NAM-prg file.

Note that the screen-capture shows there is not one single *A* variable object in the workfile. There are several. 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

[3]The file format of the OxMetrics family of econometric software is an example of a format which is recognized as a database.The econometrics program PcGive is a manifestation of a coherent approach to dynamic econometric modelling,Doornik and Hendry (2013a,b), Hendry and Doornik (2014). [4]

solved either for within sample analysis or forecasting, or for both. Scenario analysis is a third usage, as mentioned above.

I Figure 4.3 a workfile that has been genrated for forecasting is shown. 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, for example 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).

FRAME 7: 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.

4.3 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.

A necessary requirement in any model based forecast is to first update the time series of the endogenous variables, so that the forecast can be conditional on a time period, call it T, as close as possible to real time. In the example we look at, the period we condition on, also called the period of initialization, is the third quarter of 2018, which you can write as 2018q3 or 2018(3) in EViews.

In Figure 4.1 above, the lines:

```
' THE FIRST PERIOD TO FORECAST (SIMULATE)
%FSTART = "2018q4"
```

reflects exactly this point: If the first period to forecast is 2018q4, all the endogenous variables must have time series that ends in 2018q3, not earlier.[5] In NAM, the include-program *Database.prg* updates the large majority of endogenous variables to $T-1$. However, a few variables will invariably have a slower update process than the others. Hence, after *Database.prg* has been run, a

[5] It may be the case that some endogenous variables enter with two or more. But this is an exception, so in practical work one can just as well assume that all endogenous variables must have time series that end in $T-1$

handful of the variables will have their last observation in $T-2$ or even earlier. This practical side of forecasting is called the *ragged edge problem*. In the NAM-prg file, there is a separate section where the ragged edge problem is fixed. Although the ragged edge problem can be technically solved by the model producer, it needs to be checked by the forecaster, since expert knowledge often can improve these starting values for the model based forecasts

While the endogenous variables must have values up to and including period T, a H-period ahead model based forecast requires valued for the exogenous variables for the period $(T+1)$,$(T+2)$,...$(T+2)$. In the NAM-prg file, there is section where the forecast user can either code her projection for the exogenous variables with the aid of Eviews command, or ready made projections can be added to the NAM workfile (from imported files).

```
IF %FORECASTS = "ON" THEN
'-------------------------------------------
' EXOGENOUS FORECASTS
'-------------------------------------------

' Consumer prices in the Euro area (PCEURO)

 SMPL 2018q4 2018q4
 SERIES PCEURO = PCEURO(-4)*(1.017)
 SMPL 2019q1 2019q4
 SERIES PCEURO = PCEURO(-4)*(1.018)
 SMPL 2020q1 2020q4
 SERIES PCEURO = PCEURO(-4)*(1.019)
 SMPL 2021q1      2021q4
 SERIES PCEURO = PCEURO(-4)*(1.020)
 SMPL 2022q1 %ENDWF
 SERIES PCEURO = PCEURO(-4)*(1.02)
 SMPL @ALL

 ' OIL PRICE IN USD pr barrel (SPOILUSD)

  SMPL 2018q4 2018q4
  SPOILUSD = 78.5
```

Figure 4.4: Screen capture showing lines with code in the EXOGENOUS part of a NAM-prg file.

Figure 4.4 shows some lines of code where the exogenous variable for foreign consumer prices (PCEURO) os prolonged into the forecast period with the aid of annual growth rates. We see that the first period is 2018q1. Routinely, all exogenous projections fills in the whole workfile range, although the normal published forecast horizons will be much shorter. The motivation for choosing a relatively long solution period when working witht the forecast preparation may be that it is of interest to check that the model gives sensible solutions also for the period after the end of the horizon of the published model forecast.

When the NAM-prg file has been run (executed) with the forecast switch "ON", the EViews workfile contains forecasts for all the model's endogenous variables. The forecasts are available in different form: As time series variables, for example *A_0* and *A_0m* as mentioned above, in graphs and in tables.

Figure 4.5 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

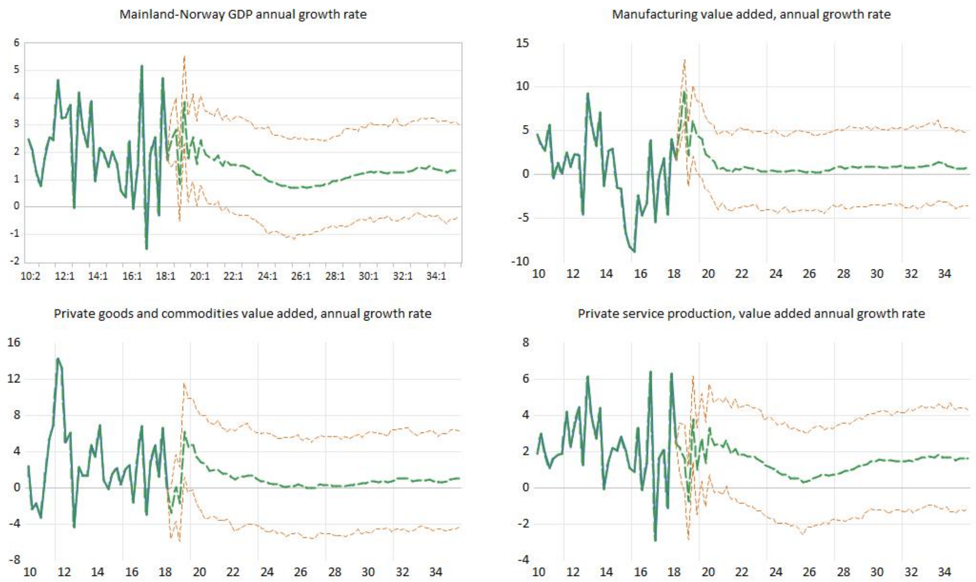


Figure 4.5: NAM forecast for annual growth percentages in value added in Mainland-Norway and in three production sectors. Forecast start is 2018q4 and the last forecast period is 2034q4. The forecasts are shown with $+/-$ 2 forecast standard errors as dotted lines.

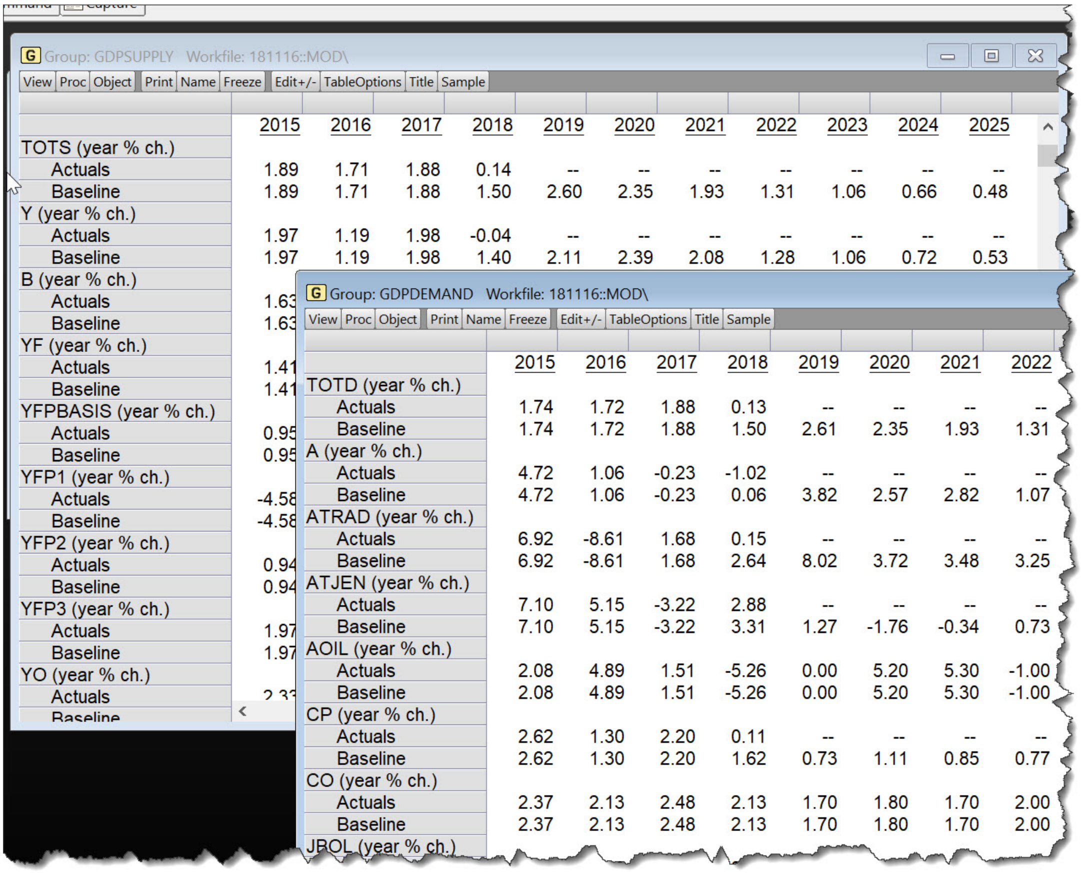
and retail trade (*YFP3*).

The graphs include actual growth rates for the period 2008q4-2034q1, since that was the start and end of the forecast period set in the dashboard. The start of the forecasts in 2018q4 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). Note that the forecasted growth rates in the graphs rather 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 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 4.6 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,



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
TOTS (year % ch.)											
Actuals	1.89	1.71	1.88	0.14	--	--	--	--	--	--	--
Baseline	1.89	1.71	1.88	1.50	2.60	2.35	1.93	1.31	1.06	0.66	0.48
Y (year % ch.)											
Actuals	1.97	1.19	1.98	-0.04	--	--	--	--	--	--	--
Baseline	1.97	1.19	1.98	1.40	2.11	2.39	2.08	1.28	1.06	0.72	0.53
B (year % ch.)											
Actuals	1.63										
Baseline	1.63										
YF (year % ch.)											
Actuals	1.41										
Baseline	1.41										
YFPBASIS (year % ch.)											
Actuals	0.95										
Baseline	0.95										
YFP1 (year % ch.)											
Actuals	-4.58										
Baseline	-4.58										
YFP2 (year % ch.)											
Actuals	0.94										
Baseline	0.94										
YFP3 (year % ch.)											
Actuals	1.97										
Baseline	1.97										
YO (year % ch.)											
Actuals	2.33										
Baseline											

	2015	2016	2017	2018	2019	2020	2021	2022
TOTD (year % ch.)								
Actuals	1.74	1.72	1.88	0.13	--	--	--	--
Baseline	1.74	1.72	1.88	1.50	2.61	2.35	1.93	1.31
A (year % ch.)								
Actuals	4.72	1.06	-0.23	-1.02	--	--	--	--
Baseline	4.72	1.06	-0.23	0.06	3.82	2.57	2.82	1.07
ATRAD (year % ch.)								
Actuals	6.92	-8.61	1.68	0.15	--	--	--	--
Baseline	6.92	-8.61	1.68	2.64	8.02	3.72	3.48	3.25
ATJEN (year % ch.)								
Actuals	7.10	5.15	-3.22	2.88	--	--	--	--
Baseline	7.10	5.15	-3.22	3.31	1.27	-1.76	-0.34	0.73
AOIL (year % ch.)								
Actuals	2.08	4.89	1.51	-5.26	0.00	5.20	5.30	-1.00
Baseline	2.08	4.89	1.51	-5.26	0.00	5.20	5.30	-1.00
CP (year % ch.)								
Actuals	2.62	1.30	2.20	0.11	--	--	--	--
Baseline	2.62	1.30	2.20	1.62	0.73	1.11	0.85	0.77
CO (year % ch.)								
Actuals	2.37	2.13	2.48	2.13	1.70	1.80	1.70	2.00
Baseline	2.37	2.13	2.48	2.13	1.70	1.80	1.70	2.00
JBOL (year % ch.)								

Figure 4.6: 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 5.

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 2.1 contains more details.

Figure 4.6 shows that apart from small differences in 2018 and 2019 (rounding errors) the two growth rates are identical, showing that NAM produces GDP-forecasts that are consistent with basic accounting relationships.

4.4 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.

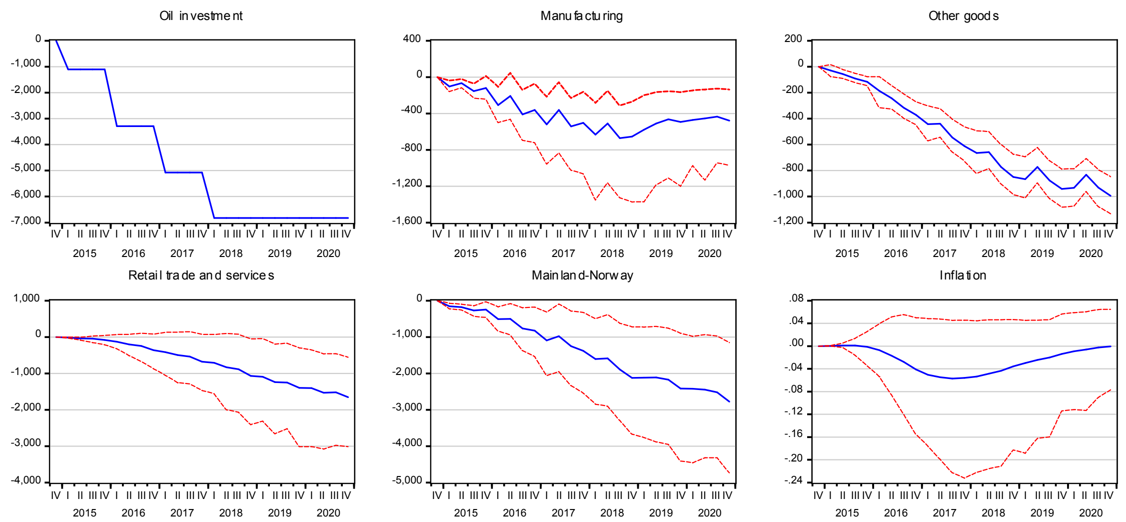


Figure 4.7: The effects of reduced capital formation in oil and gas production and transportation on Mainland-Norway GDP: Value added in three production sectors and inflation. The units on the vertical axes are million kroner in 2012 prices, except for the inflation graph where the units are percentage 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.

The graph to the right in the first row of panels in Figure 4.7 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 4.7 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 4.7 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.

5 VARIABLE LISTS

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.

5.1 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.

AKULED Number of unemployed persons, Labour force Survey, Thousand persons.

AKUSYSS Number of employed persons, Labour force Survey, Thousand persons.

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 BY NPISHs. FIXED PRICES, MILL. NOK

CP PRIVATE CONSUMPTION BY HOUSEHOLDS AND NPISHs. FIXED PRICES, MILL. NOK.

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

KAIER Number of short term labour immigrants. Thousand persons.

KORRSPH Households' new deposits in pension funds. 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.

LAVGSUB NET PRODUCT TAXES AND SUBSIDIES, MILL.NOK [1]

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.

LY GDP (MARKET VALUES), 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.

NHOURS LENGTH OF NORMAL WORKING WEEK, HOURS.

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.

NORPOOL NORWEGIAN ELECTRICITY PRICE, NORPOOL, OSLO TRADING AREA.

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

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

PA MSCI EQUITY PRICE INDEX, NORWAY.

PATJEN EXPORT PRICE INDEX, SERVICES

PATRAD EXPORT PRICE INDEX, TRADITIONAL GOODS

PAOIL EXPORT PRICE INDEX, OIL AND GAS

PASKIP EXPORT PRICE, SHIPS ANS OIL PLATFORMS

PAW MSCI EQUITY PRICE INDEX, WORLD.

PB IMPORT PRICE INDEX.

PCKONK FOREIGN CONSUMER PRICE INDEX (TRADE WEIGHTED)

PCEURO EURO AREA CONSUMER PRICE INDEX

PCKNR DEFLATOR OF PRIVATE CONSUMPTION

PCPO Price of commercial property, office (high quality), OSLO

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.

PYFP1 VALUE ADDED DEFLATOR, BASIC VALUES, MANUFACTURING AND MINING.

PYFP1 VALUE ADDED DEFLATOR, BASIC VALUES, PRODUCTION OF OTHER GOODS,D SERVICES AND RETAIL TRADE.

PYO 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.

T1FP1 EMPLOYMENT ("PAYROLL")TAX RATE, MANUFACTURING AND MINING.

T1FP23 EMPLOYMENT ("PAYROLL")TAX RATE, PRODUCTION OF OTHER GOODS, SERVICES AND RETAIL TRADE.

T2CAPF TAX RATE ON INCOME, FIRMS

T2CAPH TAX RATE ON CAPITAL INCOME, HOUSEHOLDS

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.

UAKU UNEMPLOYMENT RATE MEASURED FROM LABOUR MARKET SURVEY.

VOLUSA IMPLICIT VOLATILITY, STOCK OPTIONS MARKETS, USA.

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

WF WAGE PER HOUR, MAINLAND NORWAY, NOK.

WFP WAGE PER HOUR, PRIVATE MAINLAND NORWAY, NOK.

WFP1 WAGE PER HOUR, MANUFACTURING AND MINING, NOK.

WFP23 WAGE PER HOUR, PRODUCTION OF OTHER GOODS, SERVICES AND RETAIL TRADE, 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.

WO WAGE PER HOUR, LOCAL AND CENTRAL ADMINISTRATION, NOK.

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

YD PRIVATE DISPOSABLE INCOME,HOUSEHOLDS AND NPISHs, MILL. NOK.

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

YDNOR DISPOSABLE INCOME FOR NORWAY, MILL. NOK.

YDORG DISPOSABLE INCOME, FOR NPISHs (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 AND RETAIL TRADE, BASIC VALUES, FIXED PRICES, MILL. NOK.

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

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.

ZYFP1 AVERAGE LABOUR PRODUCTIVITY MANUFACTURING AND MINING. VALUE ADDED (BASIC VALUES), DIVIDED BY HOURS WORKED BY WAGE EARNERS. MILL. NOK.

ZYFP23 AVERAGE LABOUR PRODUCTIVITY IN PRODUCTION OF OTHER GOODS, SERVICES AND RETAIL TRADE. VALUE ADDED (BASIC VALUES), DIVIDED BY HOURS WORKED BY WAGE EARNERS. MILL. NOK.

5.2 DEFINITION VARIABLES AND IDENTITIES

A Total exports, fixed prices.

A = ATRAD + AOIL + ATJEN + ASKIP

AKUSTYRK Labour force, Labour Force Survey measure. Thousand persons. AKUSTYRK = AKULED + AKUSYSS

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, Mill. NOK. 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

LX Trade balance. Mill. Nok

LX = PATRAD* ATRAD+ PATJEN* ATJEN + PAOIL*AOIL+PASKIP *ASKIP - PB*B

LXR Current account. Mill. Nok

LXR = LX + RUBAL

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

PYFP1INF PYFP1 percentage change.

PYFP1INF = ((PYFP1 - PYFP1(-4)) / PYFP1(-4))*100

PPIINF PPIKONK percentage change.

PPIINF = ((PPIKONK - PPIKONK(-4)) / PPIKONK(-4))*100

RBOWFIVEY Actuarial five year real interest rate.

RBOWFIVEY = RBO- WHINF

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) + KORRSPH

SAVINGPORG SAVINGS, NPISHs, MILL. NOK.

SAVINGORG = 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+KORRSPH)

SPORG NPISH 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

UAKU Unemployment, Labour Force Survey measure, percent.
UAKU = (AKULED*100)/AKUSTYRK

UR Registered rate of unemployment, percent.
UR = (REGLED*100)/AKUSTYRK

WCFP1 WAGE COSTS PER HOUR, MANUFACTURING AND MINING, NOK. WCFP1 =WFP1*(1+T1FP1)

WCFP23 WAGE COSTS PER HOUR, PRODUCTION OF OTHER GOODS, SERVICES AND RETAIL TRADE, NOK. WCFP23 =WFP23*(1+T1FP23)

WHINF WH, percentage change.
WHINF= ((WH / WH(-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-T2CAPF)(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

ZYF 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))

6 DETAILED ESTIMATION RESULTS

6.1 IDENTIFICATION, ESTIMATION AND SPECIFICATION

The model contains blocks with simultaneous equations, for example for housing prices and credit. For these sub-systems identification can be addressed in the two well known steps: First, identification of the cointegration relationships, and second, of the short-run dynamics, cf. Hsiao (1997). Estimation can also be done in two steps: First the coefficients of the identified cointegration relationships case be estimated by FIML. Second, treating the coefficient estimates as known, the short run model equations can be estimated by FIML, 2SLS or OLS (if the structure is recursive).

The rest of the model consists of single equation modules estimated by OLS, and the interpretation is then agents form and act on contingent plans, represented as conditional expectation functions, where agents form and act on contingent plans. The parameters of interest of these equations are therefore regression parameters, and they are identified. Survey based measures of expectations are counted as part of the information set that we can condition on in order to specify empirical model equations.

The results are reported with explicit transformations of the original data series in section 5. Instead of the conventional mathematical expressions the transformations are given in Eviews code. The Eviews User's Guides[1] give the details, but examples of the most used transformations are listed in Table 6.1.

Table 6.1: 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,

[1]See Eviews (2014) and Eviews (2016) ,

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.

Three other indicator variables that are common across model equations are KNRBREAKQ1, KNRBREAKQ2 and KNRBREAKQ3, which capture breaks in the seasonal pattern in many series, commencing in 2015q1.

6.2 COMPONENTS OF AGGREGATE DEMAND

6.2.1 EXPORTS OF TRADITIONAL GOODS

Table 6.2: Dependent Variable: DLOG(ATRAD). LS estimation. Sample size: 123 (1988Q1 2018Q3).

	Coefficient	Std. Error	t-Statistic	Prob.
D2LOG(MII))	0.590312	0.144421	4.087445	0.0001
D3LOG(ATRAD(-1))	-0.669909	0.075953	-8.820078	0.0000
ECM_{ATRAD}	-0.276184	0.060928	-4.532926	0.0000
Constant	2.126575	0.466780	4.555840	0.0000
CS1	-0.040882	0.011832	-3.455349	0.0008
CS2	-0.032362	0.010854	-2.981459	0.0035
CS3	-0.047382	0.011456	-4.136110	0.0001
ACOSTCUT	-0.106664	0.018811	-5.670197	0.0000
R-squared	0.628839	Mean dependent var		0.008150
Adjusted R-squared	0.602793	S.D. dependent var		0.062471
S.E. of regression	0.039372	Akaike info criterion		-3.561186
Log likelihood	228.0129	Hannan-Quinn criter.		-3.477603
F-statistic	24.14307	Durbin-Watson stat		2.147034

Notes:

$ECM_{ATRAD} = LOG(ATRAD(-1)) - 1.1LOG((CPIVAL(-5)PCKONK(-5))/CPI(-5))$
$-0.83LOG(MII(-1))$

Additional notes

- ACOSTCUT is given in the EViews program file.

6.2.2 EXPORTS OF SERVICES

Table 6.3: Dependent Variable: DLOG(ATJEN). LS estimation. Sample size: 158 (1979Q2 2018Q3).

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(MII)	0.556636	0.251976	2.209083	0.0287
$ECM_{ATJEN}(-1)$	-0.180774	0.056887	-3.177796	0.0018
DLOG(ATJEN(-1))	-0.279195	0.074119	-3.766836	0.0002
DLOG(ATJEN(-4))	0.314520	0.068731	4.576131	0.0000
Constant	1.561583	0.491428	3.177641	0.0018
CS1	-0.033360	0.012575	-2.652971	0.0088
CS2	0.015149	0.013051	1.160753	0.2476
CS3	0.044117	0.012368	3.567173	0.0005
R-squared	0.548587	Mean dependent var		0.007527
Adjusted R-squared	0.527521	S.D. dependent var		0.073964
S.E. of regression	0.050841	Akaike info criterion		-3.070929
Sum squared resid	0.387718	Schwarz criterion		-2.915860
Log likelihood	250.6034	Hannan-Quinn criter.		-3.007953
F-statistic	26.04145	Durbin-Watson stat		2.023752

Notes:
$ECM_{ATJEN} = log(ATJEN) - 0.5LOG(REX) - 0.55log(MII)$

6.2.3 EXPORTS OF SHIPS, OIL PLATFORMS AND AIRPLANES

Table 6.4: 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	0.528197	S.D. dependent var	0.072158	
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	

6.2.4 PRIVATE CONSUMPTION

Table 6.5: 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:
$ECM_{CP} = LOG(CP(-1)) - 0.61 * LOG(YDCD(-1)/CPI(-1))$
$-0.10LOG((PH(-1)HK(-1))/CPI(-1)))$
$f(RUH) = (1/(1 + EXP(-3.0(RUH(-1)/(YDCD(-1) + RUH - 1)) - 0.13))))$

6.2.5 HOUSING STARTS

Table 6.6: 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

6.2.6 GROSS CAPITAL FORMATION, HOUSING

Table 6.7: 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			

6.2.7 GROSS CAPTIAL FORMATION, PRIVATE BUSINESS

Table 6.8: Dependent Variable: DLOG(JFPN). LS estimation. Sample size: 123 (1988Q2 2018Q3)

DLOG(JFPN(-1))	-0.500993	0.052668	-9.512253	0.0000
RL(-1)-@PCY(PYF(-1)	-0.003366	0.002470	-1.362342	0.1757
D5LOG(YFPBASIS)	1.170234	0.196513	5.954982	0.0000
LOG((YDFIRMS/PYF)/JFPN(-1))	0.202894	0.048758	4.161261	0.0001
JFPNDUM	0.435487	0.114226	3.812502	0.0002
ACOSTCUT	0.057526	0.031088	1.850417	0.0668
Constant	-0.184972	0.037763	-4.898284	0.0000
R-squared	0.708437	Mean dependent var		0.003157
Adjusted R-squared	0.693356	S.D. dependent var		0.159880
S.E. of regression	0.088534	Akaike info criterion		-1.955629
Log likelihood	127.2712	Hannan-Quinn criter.		-1.890620
Durbin-Watson stat	1.919232			

Notes:

$JFPNDUM$ is given in the EViews program file

$ACOSTDUM$ is the same dummy as used in the model equation for ATRAD

6.3 COMPONENTS OF AGGREGATE SUPPLY

6.3.1 VALUE ADDED IN MANUFACTURING

Table 6.9: Dependent Variable: DLOG(YFP1). LS estimation. Sample size: 151 1981Q3 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(YFP1(-1))	-0.160983	0.046216	-3.483285	0.0007
LOG(YFP1DEM1(-1))	0.001074	0.000334	3.217212	0.0016
LOG(YFP1DEM2(-1))	0.052825	0.013148	4.017843	0.0001
LOG(YFP1PRICE)	-0.050148	0.026775	-1.872963	0.0632
DLOG(DOMD)	0.123711	0.092857	1.332271	0.1850
DLOG(MII)	0.400415	0.125224	3.197595	0.0017
DLOG(ARBDAG)	0.623002	0.059334	10.49988	0.0000
DLOG(YFP1DEM1)	-0.116436	0.057528	-2.023988	0.0449
DLOG(YFP1DEM2)	0.205273	0.049689	4.131174	0.0001
DLOG(YFP1(-1))	-0.116436	0.057528	-2.023988	0.0449
DLOG(YFP1(-4))	0.205273	0.049689	4.131174	0.0001
Constant	1.148532	0.414927	2.768031	0.0064
CS1	0.045000	0.012503	3.599186	0.0004
CS2	0.060982	0.014964	4.075248	0.0001
CS3	0.016044	0.017491	0.917273	0.3606
KNRBREAKQ1	-0.023029	0.011291	-2.039578	0.0433
R-squared	0.936478	Mean dependent var	0.001962	
Adjusted R-squared	0.929939	S.D. dependent var	0.075382	
Log likelihood	378.3350	Hannan-Quinn criter.	-4.765130	
Durbin-Watson stat	2.298281			

Additional notes

- $YFP1DEM1 = (JOIL1/J) * ((SPOILUSD * CPIVAL)/CPI)$
- $YFP1DEM2 = 0.7 * log(DOMD) + 0.3 * log(MII).$
- $YFP1PRICE = log(WCFP1) - log(ZYFP1) - log(CPIVAL * PPIKONK)$

6.3.2 VALUE ADDED PRODUCTION OF OTHER GOODS

Table 6.10: Dependent Variable: DLOG(YFP2). LS estimation. Sample size: 11 (1983Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(YFP2(-1))	-0.397108	0.073072	-5.434472	0.0000
LOG(YFP2PRICE)	-0.057753	0.033793	-1.709053	0.0897
LOG(DOMD(-1)	0.264649	0.055862	4.737587	0.0000
LOG(YFP2J(-1))	0.0576948	0.03006 1.92	0.05	
DLOG(DOMD)	0.241330	0.120015	2.010836	0.0463
DLOG(YFP2(-1))	-0.101245	0.071341	-1.419164	0.1581
DLOG(YFP2(-4))	0.222540	0.063623	3.497804	0.0006
DLOG(ARBDAG)	0.426176	0.071425	5.966739	0.0000
Constant	0.267295	0.201085	1.329265	0.1860
CS1	0.028271	0.018810	1.502997	0.1351
CS2	-0.044464	0.026673	-1.666990	0.0978
CS3	0.075374	0.025022	3.012301	0.0031
R-squared	0.932615	Mean dependent var	0.006392	
S.E. of regression	0.028271	Akaike info criterion	-4.223470	
Log likelihood	337.3409	Hannan-Quinn criter.	-4.133775	
Durbin-Watson stat	1.9699			

Additional notes

- $YFP2PRICE = log(WCFP23) - log(ZYF) - log(CPIVAL * PCKONK)$
- $YFP2J = 0.3 * JBOL + 0.2 * JFPN + 0.3 * JO + 0.3 * JOIL$

6.3.3 VALUE ADDED IN PRIVATE SERVICE PRODUCTION

Table 6.11: Dependent Variable: DLOG(YFP3NET). LS estimation. Sample size: 121 (1989Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(YFP3NET(-1))	-0.374012	0.071069	-5.262679	0.0000
LOG(YFP3PRICE)	-0.124153	0.024543	-5.058524	0.0000
LOG(YFP2DEM(-1))	0.508926	0.078516	6.481826	0.0000
DLOG(DOMD)	0.288589	0.089092	3.239225	0.0016
D3LOG(YFP3NET(-1)	-0.261930	0.067571	-3.876392	0.0002
DLOG(YFP3NET(-4))	0.118074	0.072616	1.625992	0.1069
DLOG(ARBDAG)	0.313324	0.048867	6.411786	0.0000
Constant	-2.003070	0.269440	-7.434198	0.0000
CS1	0.022973	0.011496	1.998227	0.0482
CS2	0.078212	0.010018	7.807529	0.0000
CS3	0.058222	0.011102	5.244351	0.0000
KNRBREAKQ1	-0.024622	0.008875	-2.774455	0.0065
KNRBREAKQ2	-0.031866	0.008742	-3.645016	0.0004
KNRBREAKQ3	-0.055273	0.009847	-5.612874	0.0000
R-squared	0.906866	Mean dependent var	0.007924	
Adjusted R-squared	0.895550	S.D. dependent var	0.045193	
S.E. of regression	0.014606	Akaike info criterion	-5.506342	
Sum squared resid	0.022826	Schwarz criterion	-5.182863	
Log likelihood	347.1337	Hannan-Quinn criter.	-5.374965	
F-statistic	80.14444	Durbin-Watson stat	2.279329	

Additional notes

- $YFP3PRICE = log(WCFP23) - log(ZYF) - log(CPIVAL * PCKONK)$
- $YFP3DEM = 0.85 * log(DOMD) + 0.15 * log(MII)$.

6.3.4 IMPORTS

Table 6.12: 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.

6.4 WAGE AND PRICE SYSTEM

6.4.1 VALUE ADDED DEFLATOR IN MANUFACTURING

Table 6.13: Dependent Variable: DLOG(PYFP1). OLS estimation. Sample size: 147 (1982Q1 2018Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
ECM_{PYFP1}	0.051330	0.016819	3.051931	0.0027
DLOG(WCFP1/ZYFP1)	0.075651	0.040098	1.886649	0.0613
D3LOG(WCPFK(-1)/ZYFP(-1))	0.168884	0.044895	3.761742	0.0002
D3LOG(PYFP1(-1))	-0.303791	0.056805	-5.347949	0.0000
DLOG(CPIVAL)	0.297871	0.123479	2.412322	0.0172
DLOG(PPIKONK)	0.336855	0.292575	1.151347	0.2516
DLOG(PB)	0.107697	0.121195	0.888630	0.3758
PYFP1DUM95Q1	0.085476	0.030015	2.847761	0.0051
CS1	0.008224	0.007272	1.130875	0.2601
CS2	0.021529	0.008053	2.673357	0.0084
CS3	0.003030	0.007519	0.403034	0.687
Constant	0.116684	0.034963	3.337363	0.0011
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			

Notes:

$ECM_{PYFP1} = LOG(WCFP1(-1)/ZYFP1(-1)) - LOG(PYFP1(-1))$
$-0.15 LOG(WCFP1(-1)/(PPIKONK(-1) * CPIVAL(-1)))$

Additional notes

- PYFP1DUM95Q1 is given in the code of the Eviews program file for NAM estimation and simulation.

6.4.2 VALUE ADDED DEFLATOR IN PRIVATE PRODUCTION OF COMMODITIES AND SERVICES

Table 6.14: Dependent Variable: DLOG(PYFP23). OLS estimation. Sample size: 94 (1995Q2 2018Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
ECM_{PYFP23}	0.116182	0.044735	2.597087	0.0111
DLOG(WCFP23ZYFP23)	-0.447042	0.071292	-6.270587	0.0000
DLOG(PB)	0.104311	0.050016	2.085559	0.0400
WCOORD(-1)	-0.009674	0.002691	-3.594704	0.0005
CS1	-0.003741	0.004237	-0.882924	0.3798
CS2	-0.007467	0.004438	-1.682595	0.0961
CS3	-0.005896	0.003840	-1.535288	0.1284
Constant	0.090825	0.026741	3.396467	0.0010
R-squared	0.472864	Mean dependent var	0.006800	
Adjusted R-squared	0.423251	S.D. dependent var	0.014687	
S.E. of regression	0.011154	Akaike info criterion	-6.063208	
Log likelihood	293.9708	Hannan-Quinn criter.	-5.964849	
Durbin-Watson stat	1.739554			

Notes:

$ECM_{PYFP23} = LOG(WCFP23(-1)/ZYFP23(-1)) - log(PYFP23(-1))$

6.4.3 DEFLATOR OF PRIVATE MAINLAND-NORWAY GDP (BASIC VALUE)

Table 6.15: Dependent Variable: LOG(PYFPB). OLS estimation. Sample size: 75 (2000Q1 2018Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
LOG(PYFP1/PYF23)	0.160504	0.002075	77.33904	0.0000
LOG(PYFP23)	1	–	–	–
Constant	-0.000507	0.000253	-2.007824	0.0484
R-squared	0.999916	Mean dependent var	-0.191568	
Adjusted R-squared	0.999913	S.D. dependent var	0.153891	
S.E. of regression	0.001433	Akaike info criterion	-10.21907	
Sum squared resid	0.000148	Schwarz criterion	-10.12637	
Log likelihood	386.2150	Hannan-Quinn criter.	-10.18205	
Durbin-Watson stat	1.506550			

6.4.4 VALUE ADDED DEFLATOR IN GOVERNMENT SECTOR

Table 6.16: Dependent Variable: DLOG(PYFPB). OLS estimation. Sample size: 95 (2000Q1 2018Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
D2LOG(WO)	0.038658	0.029982	1.289373	0.2007
KNRBREAKQ1	-0.005540	0.005239	-1.057512	0.2932
KNRBREAK2	0.045897	0.005271	8.707268	0.0000
KLNRBREAK3	-0.064090	0.005206	-12.31108	0.0000
CS1	0.013989	0.003994	3.502731	0.0007
CS2	0.004896	0.004796	1.020752	0.3102
CS3	-0.002806	0.007587	-0.369829	0.7124
Constant	0.010602	0.001248	8.494252	0.0000
R-squared	0.784822	Mean dependent var	0.010550	
Adjusted R-squared	0.767509	S.D. dependent var	0.019672	
S.E. of regression	0.009485	Akaike info criterion	-6.397655	
Sum squared resid	0.007828	Schwarz criterion	-6.182592	
Log likelihood	311.8886	Hannan-Quinn criter.	-6.310753	
Durbin-Watson stat	2.137271			

6.4.5 DEFLATOR OF MAINLAND-NORWAY GDP (BASIC VALUE)

Table 6.17: Dependent Variable: LOG(PYFB). OLS estimation. Sample size: 75 (2000Q2 2018Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
LOG(PYFP1/PYO)	0.123444	0.003160	39.06309	0.0000
LOG(PYFP23/PYO)	0.640256	0.006669	96.00979	0.0000
LOG(PYO)	1	—	—	—
Constant	-0.000235	0.000217	-1.085931	0.2811
R-squared	0.999183	Mean dependent var	-0.579600	
Adjusted R-squared	0.999167	S.D. dependent var	0.439581	
S.E. of regression	0.012685	Akaike info criterion	-5.872378	
Sum squared resid	0.025425	Schwarz criterion	-5.796141	
Log likelihood	479.6626	Hannan-Quinn criter.	-5.841425	
Durbin-Watson stat	1.637749			

6.4.6 DEFLATOR OF MAINLAND-NORWAY GDP (MARKET VALUE)

Table 6.18: Dependent Variable: LOG(PYF). OLS estimation. Sample size: 162 (1978Q2 2018Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
LOG(PYFP1/PYO)	0.165222	0.014961	11.04343	0.0000
LOG(PYFP23/PYO)	0.687218	0.018857	36.44320	0.0000
LOG(PYO)	1	—	—	—
LOG(1+T3)	0.665236	0.106319	6.256996	0.0000
Constant	-0.083489	0.013669	-6.107959	0.0000
R-squared	0.999183	Mean dependent var	-0.579600	
Adjusted R-squared	0.999167	S.D. dependent var	0.439581	
S.E. of regression	0.012685	Akaike info criterion	-5.872378	
Sum squared resid	0.025425	Schwarz criterion	-5.796141	
Log likelihood	479.6626	Hannan-Quinn criter.	-5.841425	
Durbin-Watson stat	1.637749			

6.4.7 CONSUMER PRICE INDEX

Table 6.19: Dependent Variable: DLOG(CPI). OLS estimation. Sample size: 162 (1978Q4 2019Q1)

	Coefficient	Std. Error	z-Statistic	Prob.
ECM_{CPI}	-0.037705	0.004786	-7.878113	0.0000
DLOG(CPIEL)	0.032033	0.003372	9.498497	0.0000
DLOG(CPIEL(-1))	0.002536	0.003244	0.781761	0.4356
DLOG(PCKONK)	0.263834	0.065918	4.002432	0.0001
DLOG(PYF)	0.067408	0.015141	4.452013	0.0000
DLOG(PYF)	0.069666	0.016044	4.342084	0.0000
DLOG(PYF(-2))	0.067625	0.015977	4.232730	0.0000
T3(-1)	0.096942	0.027892	3.475666	0.0007
CS2	0.004538	0.000963	4.710437	0.0000
CS3	-0.002230	0.000799	-2.791864	0.0059
Constant	-0.009837	0.003961	-2.483628	0.0141
CPIDUM	1	—	—	
R-squared	0.875940	Mean dependent var	0.009142	
Adjusted R-squared	0.868594	S.D. dependent var	0.009313	
S.E. of regression	0.003376	Akaike info criterion	-8.484604	
Sum squared resid	0.001732	Schwarz criterion	-8.294012	
Log likelihood	697.2530	Hannan-Quinn criter.	-8.407221	
F-statistic	119.2460	Durbin-Watson stat	1.496153	

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.

6.4.8 WAGE PER HOUR IN MANUFACTURING

Table 6.20: Dependent Variable: DLOG(WFP1). OLS estimation. Sample size: 186 (1972Q1 2018Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
ECM_{WFP1}	-0.090954	0.023837	-3.815639	0.0002
D3LOG(CPI(-1))	0.875337	0.101405	8.632090	0.0000
D4LOG(PYFP1)+D4LOG(ZYFP1)	0.113711	0.044186	2.573469	0.0109
D3LOG(WFP1(-1))	-0.758065	0.039614	-19.13638	0.0000
DLOG(1+T1FP1)	-0.219718	0.218413	-1.005978	0.3158
DLOG(NH)	-0.894941	0.439774	-2.035001	0.0434
DUM95Q1	-0.102309	0.030361	-3.369744	0.0009
WCOORD	-0.023807	0.005187	-4.589954	0.0000
DUM15Q2	-0.039766	0.030105	-1.320907	0.1883
DUM15Q3	0.113853	0.029978	3.797846	0.0002
CS1	0.020321	0.006622	3.068699	0.0025
CS2	0.029747	0.007549	3.940367	0.0001
CS3	0.020328	0.006949	2.925247	0.0039
Constant	0.012303	0.007360	1.671535	0.0964
R-squared	0.848778	Mean dependent var	0.015902	
Adjusted R-squared	0.836397	S.D. dependent var	0.072584	
S.E. of regression	0.029359	Akaike info criterion	-4.141256	
Durbin-Watson stat	2.193858			

Notes:

$$ECM_{WFP1} = LOG(WCFP1(-1)) - LOG(ZYFP1(-1)) - LOG(PYFP1(-1)) + 0.15LOG(UR(-1)))$$

6.4.9 WAGE PER HOUR IN PRIVATE COMMODITY AND SERVICE PRODUCTION

Table 6.21: Dependent Variable: DLOG(WFP23). OLS estimation. Sample size: 95 (1995Q1 2018Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
$ECM_{WFP23})$	-0.287125	0.070285	-4.085156	0.0001
DLOG(WFP1)	0.877367	0.019552	44.87304	0.0000
WCOORD	-0.003978	0.002223	-1.789413	0.0772
DUM95Q1	-0.005522	0.009756	-0.566033	0.5729
DUM95Q2	-0.015216	0.010151	-1.498954	0.1376
DUM95Q3	0.027488	0.010551	2.605310	0.0109
WCOORD	-0.004437	0.002270	-1.954644	0.0540
CS1	0.007976	0.003903	2.043334	0.0442
CS2	0.014960	0.004799	3.117216	0.0025
CS3	0.000877	0.004546	0.192887	0.8475
Constant	0.013612	0.002835	4.800670	0.0000
R-squared	0.989689	Mean dependent var	0.011668	
Adjusted R-squared	0.988584	S.D. dependent var	0.088805	
S.E. of regression	0.009488	Akaike info criterion	-6.377231	
Durbin-Watson stat	2.381560			

Notes:
$ECM_{WFP23} = LOG(WCFP23(-1)) - LOG(WFP1(-1)) + 0.04LOG(UR(-1)$
$+0.02IMR$

6.4.10 WAGE PER HOUR IN MAINLAND-NORWAY

Table 6.22: Dependent Variable: LOG(WF). LS estimation. Sample size: 97 (1995Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(WFP1)	0.139734	0.003085	45.29795	0.0000
LOG(WFP23)	0.559345	0.003979	140.5829	0.0000
LOG(WO)	0.30088	–	–	–
R-squared	0.999995	Mean dependent var	5.462358	
R-squared	0.999997	Mean dependent var		5.451612
Adjusted R-squared	0.999997	S.D. dependent var	0.315568	
S.E. of regression	0.000582	Akaike info criterion	-12.04135	
Sum squared resid	3.21E-05	Schwarz criterion	-11.98827	
Log likelihood	586.0057	Hannan-Quinn criter.	-12.01989	
Durbin-Watson stat	1.036694			

6.4.11 WAGE PER HOUR IN PRIVATE MAINLAND-NORWAY

Table 6.23: Dependent Variable: LOG(WFP). LS estimation. Sample size: 97 (1995Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(WFP1)	0.208336	0.003236	64.38636	0.0000
LOG(WFP23)	0.791664	0.034067	26.38470	0.0000
R-squared	0.999995	Mean dependent var	5.462358	
Adjusted R-squared	0.999995	S.D. dependent var	0.310081	
S.E. of regression	0.000685	Akaike info criterion	-11.72345	
Sum squared resid	4.51E-05	Schwarz criterion	-11.69691	
Log likelihood	569.5875	Hannan-Quinn criter.	-11.71272	
Durbin-Watson stat	0.813338			

6.4.12 WAGE PER HOUR IN GOVERNMENT ADMINISTRATION

Table 6.24: Dependent Variable: DLOG(WO). LS estimation. Sample size: 96 (1995Q4 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(WO(-1))-LOG(WFP23(-1))-0.4	-0.458330	0.063681	-7.197285	0.0000
DLOG(WFP23)	0.898848	0.034067	26.38470	0.0000
0.4*OPPGJ(-1)+0.6OPPGJ(-2)	0.015275	0.007291	2.095216	0.0390
CS1	0.016393	0.006583	2.490152	0.0146
C2	0.034335	0.009051	3.793348	0.0003
C3	0.071003	0.008647	8.211394	0.0000
KNRBREAKQ3	0.061125	0.008688	7.035443	0.0000
R-squared	0.986349	Mean dependent var	0.010840	
Adjusted R-squared	0.985263	S.D. dependent var	0.105892	
S.E. of regression	0.012855	Akaike info criterion	-5.790518	
Sum squared resid	0.014542	Schwarz criterion	-5.576822	
Log likelihood	285.9449	Hannan-Quinn criter.	-5.704138	
Durbin-Watson stat	2.400114			

6.4.13 WAGE IN CENTRAL CIVIL ADMINISTRATION (ANNUAL WAGE)

Table 6.25: Dependent Variable: LOG(WHGSC). LS estimation. Sample size: 45 (2008Q1 2019q1)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(WO)	0.970716	0.026902	36.08315	0.0000
KNRBREAKQ1	0.030622	0.008189	3.739280	0.0006
KNRNREAKQ2	0.021428	0.009795	2.187731	0.0347
KNRBREAKQ3	-0.008428	0.010398	-0.810564	0.4225
Constant	-4.802791	0.302566	-15.87353	0.0000
LOG(ARBDAG)	1.008358	0.050280	20.05492	0.0000
KNRDUMQ3	-0.042235	0.024545	-1.720718	0.0890
R-squared	0.983962	Mean dependent var		4.831449
Adjusted R-squared	0.981906	S.D. dependent var	0.115116	
S.E. of regression	0.015485	Akaike info criterion	-5.374385	
Sum squared resid	0.009351	Schwarz criterion	-5.133497	
Log likelihood	126.9237	Hannan-Quinn criter.	-5.284584	
F-statistic	478.5577	Durbin-Watson stat	1.889482	

6.4.14 WAGE IN LOCAL ADMINISTRATION (ANNUAL WAGE)

Table 6.26: Dependent Variable: DLOG(WHGL). LS estimation. Sample size: 77 (2000Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(WHGL(-1))-LOG(WHGSC(-1))+RELWKOM	-0.601306	0.129734	-4.634918	0.0000
DLOG(WHGSC)	0.743214	0.071734	10.36074	0.0000
WHGLDUM	0.860084	0.345513	2.489300	0.0151
KNRBREAKQ1	0.013728	0.005045	2.721397	0.0082
KNRBREAKQ2	0.017135	0.007212	2.375983	0.0202
KNRBREAKQ2	-0.016683	0.006773	-2.463198	0.0162
R-squared	0.889223	Mean dependent var	0.009066	
Adjusted R-squared	0.881422	S.D. dependent var	0.026143	
S.E. of regression	0.009003	Akaike info criterion	-6.507896	
Sum squared resid	0.005754	Schwarz criterion	-6.325261	
Log likelihood	256.5540	Hannan-Quinn criter.	-6.434844	
Durbin-Watson stat	1.793475			

Notes:
RELWKOM and WHGLDUM are defined in the code of the EViews program file.

6.4.15 NATIONAL WAGE (ANNUAL)

Table 6.27: Dependent Variable: LOG(WH). LS estimation. Sample size: 93 (1996Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(WF)	0.300	0.075869	3.957690	0.0002
LOG(WH(-4))	0.600	0.075869	3.957690	0.0002
LOG(ARBDAG)	0.274198	0.075017	3.655137	0.0004
LOG(ARBDAG(-1)	0.045104	0.023135	1.949621	0.0545
KNRBREAKq1	-0.017836	0.006407	-2.783943	0.0066
KNRBREAKq1	-0.004847	0.006859	-0.706579	0.4817
KNRBREAKq3	-0.029997	0.007102	-4.223918	0.0001
R-squared	0.997880	Mean dependent var		4.567353
Adjusted R-squared	0.997732	S.D. dependent var	0.274319	
S.E. of regression	0.013064	Akaike info criterion	-5.765630	
Sum squared resid	0.014677	Schwarz criterion	-5.575004	
Log likelihood	275.1018	Hannan-Quinn criter.	-5.688660	
F-statistic	6746.457	Durbin-Watson stat		0.985020

6.4.16 CPI ADJUSTED FOR ENERGY AND TAXES

Table 6.28: 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			

6.4.17 ENERGY PART OF CPI

Table 6.29: 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			

6.4.18 ELECTRICITY PRICE (NORPOOL SYSTEM)

Table 6.30: 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			

6.4.19 IMPORT PRICE

Table 6.31: 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:

$ECM_{PB} = LOG(PB(-1)/(PPIKONK(-1)CPIVAL(-1)))$
$+0.3LOG(CPIVAL(-1)PCKONK(-1)/CPI(-1))$

Additional notes

- PBDUM is defind in the Eviews program file.

6.4.20 FOREIGN CONSUMER PRICE INDEX (TRADE WEIGHTED)

Table 6.32: 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			

6.4.21 EXPORT PRICE INDEX, SERVICES

Table 6.33: Dependent Variable: DLOG(PATJEN). LS estimation. Sample size: 117 (1990Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(PPIKONK*CPIVAL)	0.420562	0.126501	3.324570	0.0012
D(KNRBREAKQ1)	0.006858	0.010942	0.626723	0.5321
D(KNRBREAKQ2)	-0.025478	0.013381	-1.904046	0.0595
D(KNRBREAKQ3)	-0.021768	0.011810	-1.843215	0.0679
Constant	0.003803	0.002596	1.464886	0.1458
R-squared	0.153708	Mean dependent var	0.005627	
Adjusted R-squared	0.123484	S.D. dependent var	0.029350	
S.E. of regression	0.027478	Akaike info criterion	-4.309047	
Sum squared resid	0.084566	Schwarz criterion	-4.191006	
Log likelihood	257.0793	Hannan-Quinn criter.	-4.261124	
F-statistic	5.085524	Durbin-Watson stat	2.056437	

6.4.22 EXPORT PRICE INDEX, TRADITIONAL GOODS

Table 6.34: Dependent Variable: DLOG(PATRAD). LS estimation. Sample size: 117 (1990Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(WCFP1(-1)/(ZYFP(-1)*PATRAD(-1)	0.079915	0.037391	2.137268	0.0349
LOG(PATRAD(-1))-LOG(PPIKONK(-1)*CPIVAL(-1))	-0.096046	0.035697	-2.690578	0.0083
DLOG(PPIKONK*CPIVAL)	0.514489	0.118343	4.347419	0.0000
D2LOG(SPOILUSD*SPUSD	0.052194	0.012370	4.219251	0.0001
CS1	-0.013781	0.008017	-1.718880	0.0886
CS2	-0.018947	0.007888	-2.402010	0.0180
CS3	-0.029008	0.007559	-3.837676	0.0002
KNRBREAKQ1	0.030498	0.012604	2.419776	0.0172
KNRBREAKQ3	0.020389	0.015418	1.322444	0.1889
Constant	0.033927	0.018129	1.871456	0.0640
R-squared	0.374147	Mean dependent var	0.004197	
Adjusted R-squared	0.315105	S.D. dependent var	0.030458	
S.E. of regression	0.025207	Akaike info criterion	-4.434122	
Sum squared resid	0.067350	Schwarz criterion	-4.174430	
Log likelihood	270.3961	Hannan-Quinn criter.	-4.328690	
F-statistic	6.336893	Durbin-Watson stat	2.208292	

6.4.23 EXPORT PRICE INDEX, OIL AND NATURAL GAS

Table 6.35: Dependent Variable: DLOG(PAOIL). LS estimation. Sample size: 117 (1990Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
DLOG(SPOILUSD*SPUSD)	0.619376	0.041064	15.08309	0.0000
DLOG(SPOILUSD(-1)*SPUSD(-1))	0.185182	0.041015	4.514962	0.0000
KNRBREAKQ1	0.005828	0.026249	0.222032	0.8247
KNRBREAKQ2	-0.052720	0.029729	-1.773386	0.0789
KNRBREAKQ3	-0.007150	0.029535	-0.242096	0.8091
R-squared	0.702434	Mean dependent var	0.012363	
Adjusted R-squared	0.691807	S.D. dependent var	0.104978	
S.E. of regression	0.058279	Akaike info criterion	-2.805363	
Sum squared resid	0.380398	Schwarz criterion	-2.687322	
Log likelihood	169.1138	Hannan-Quinn criter.	-2.757440	
Durbin-Watson stat	2.252393			

6.5 EXCHANGE RATES

6.5.1 NOMINAL EFFECTIVE (TRADE WEIGHTED) EXCHANGE RATE

Table 6.36: 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:
$RSHDIFF = (RSH - @PCY(CPI(-1)) - (RSW - @PCY(PCKONK(-1))$

6.5.2 KRONE/EURO NOMINAL EXCHANGE RATE

Table 6.37: 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			

6.6 HOURS WORKED AND EMPLOYMENT

6.6.1 HOURS WORKED BY WAGE EARNERS IN PRIVATE SECTOR MAINLAND-NORWAY

Table 6.38: Dependent Variable: DLOG(TWPF). LS estimation. Sample size: 148 (197Q3 2017Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
ECM_{TWPF}(-1)	-0.218650	0.046517	-4.700403	0.0000
DLOG(ARBDAG)	0.713275	0.037222	19.16280	0.0000
D2LOG(YFP1+YFP2+YFP3)	0.403401	0.061217	6.589697	0.0000
DLOG(TWPF(-1))-DLOG(TWPF(-4))	-0.173880	0.028378	-6.127247	0.0000
DLOG(WCFP23/PYF)	-0.214499	0.058924	-3.640284	0.0004
CS1	0.043676	0.010120	4.315578	0.0000
CS2	0.078221	0.010596	7.381998	0.0000
CS3	0.039163	0.010087	3.882414	0.0002
Constant	0.130739	0.028533	4.581979	0.0000
R-squared	0.968481	Mean dependent var	0.001879	
Adjusted R-squared	0.966788	S.D. dependent var	0.083807	
S.E. of regression	0.015273	Akaike info criterion	-5.470187	
Log likelihood	441.1448	Hannan-Quinn criter.	-5.399340	
F-statistic	572.2837	Durbin-Watson stat	2.331785	
Prob(F-statistic)	0.000000			

Notes:
$ECM_{TWPF} = ln(TWPF) - LOG(YFP1 + YFP2 + YFP3) + 1.05LOG(WCFP23/PYF)$

6.6.2 HOURS WORKED IN GOVERNMENT ADMINISTRATION

Table 6.39: Dependent Variable: LOG(TWO). LS estimation. Sample size: 64 (2002Q1 2017Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(CO)	0.818	0.0300	40.24	0.0000
Constant	-6.69	0.39	-17.05	0.0000
LOG(ARBDAG)	0.585	0.079	7.31	0.0000
CS1	0.004	0.0054	0.72	0.41
CS2	-0.048979	0.007953	1.79	0.07
CS3	-0.07	0.012	-5.95	0.0000
R-squared	0.98	Mean dependent var	5.4999	
Adjusted R-squared	0.98	S.D. dependent var	0.102604	
S.E. of regression	0.015	Akaike info criterion	-5.42	
Log likelihood	197.62	Hannan-Quinn criter.	-5.346	
F-statistic	551.1	Durbin-Watson stat	1.37	
Prob(F-statistic)	0.000000			

6.6.3 HOURS WORKED IN OIL AND GAS AND INTERNATIONAL TRANSPORT

Table 6.40: 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)

6.6.4 WAGE EARNERS IN PRIVATE MAINLAND-NORWAY

Table 6.41: Dependent Variable: LOG(NWPF). LS estimation. Sample size: 152 (1980Q1 2017Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(NWPF(-1)/ARBDAG)	0.494629	0.013141	37.64006	0.0000
LOG(TWPF)	0.505371	0.013141	37.64006	0.0000
LOG(NH)	-0.246070	0.032335	-7.610124	0.0000
S1	0.009024	0.001782	5.063841	0.0000
S2	0.006424	0.002172	2.957310	0.0036
S3	0.013884	0.003670	3.782756	0.0002
KNRBREAKQ1	-0.011903	0.004603	-2.586205	0.0107
KNRBREAKQ2	0.014989	0.004585	3.268775	0.0014
Constant	3.398562	0.111224	30.55590	0.0000
R-squared	0.996364	Mean dependent var	7.241702	
Adjusted R-squared	0.996188	S.D. dependent var	0.122937	
S.E. of regression	0.007591	Akaike info criterion	-6.872576	
Log likelihood	530.3158	Hannan-Quinn criter.	-6.807923	
Durbin-Watson stat	1.869075			

6.6.5 WAGE EARNERS IN GOVERNMENT ADMINISTRATION

Table 6.42: Dependent Variable: DLOG(NWO). LS estimation. Sample size: 92 (1995Q1 2017Q4)

	Coefficient	Std. Error	t-Statistic	Prob.
LOG(NWO(-1))-LOG(TWO(-1))	-0.191075	0.032332	-5.909727	0.0000
LOG(ARBDAG)	-0.111900	0.037738	-2.965156	0.0039
Constant	0.672458	0.182877	3.677113	0.0004
CS1	-0.002794	0.001723	-1.621454	0.1087
CS2	-0.000461	0.002242	-0.205873	0.8374
CS3	0.012455	0.003704	3.363080	0.0012
KNRBREAKQ1	-0.011600	0.003617	-3.207105	0.0019
KNRBREAKQ2	0.000372	0.003550	0.104926	0.9167
KNRBREAKQ3	0.005811	0.003500	1.660337	0.1006
R-squared	0.459829	Mean dependent var		0.003405
Adjusted R-squared	0.407765	S.D. dependent var		0.007184
S.E. of regression	0.005528	Akaike info criterion		-7.465171
Log likelihood	320.6394	Hannan-Quinn criter.	-7.365602	
F-statistic	8.831893	Durbin-Watson stat	2.097328	
Prob(F-statistic)	0.000000			

6.6.6 WAGE EARNERS IN OIL AND GAS PRODUCTION AND INTERNATIONAL TRANSPORTATION

Table 6.43: 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			

6.6.7 AVERAGE WORKING TIME FOR WAGE EARNERS IN PRIVATE MAINLAND-NORWAY

Table 6.44: 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			

6.6.8 AVERAGE WORKING TIME FOR SELF EMPLOYED

Table 6.45: 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			

6.7 LABOUR FORCE AND UNEMPLOYMENT

6.7.1 LABOUR FORCE SURVEY UNEMPLOYMENT)

Table 6.46: Dependent Variable: AKULED. LS estimation. Sample size: 117 (1990Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-127.6565	26.61350	-4.796684	0.0000
LEDAKU(-1)	0.406430	0.070627	5.754581	0.0000
0.5NW+0.3NW(-1)+0.2NW(-2)	-0.119474	0.018266	-6.540685	0.0000
KAIER	-0.361341	0.104381	-3.461739	0.0008
BEF1574	0.141491	0.018356	7.708151	0.0000
0.5*(UAKU(-6)+UAKU(-7))	-3.763162	1.158506	-3.248288	0.0015
AKULEDDUM3	0.564277	0.360819	1.563878	0.1208
CS1	19.91617	1.728468	7.472612	0.0000
CS2	10.16944	1.993846	5.100413	0.0000
CS3	8.46617	1.743617	4.855997	0.0000
R-squared	0.872087	Mean dependent var	99.78632	
Adjusted R-squared	0.862612	S.D. dependent var	19.63540	
S.E. of regression	7.278031	Akaike info criterion	6.881401	
Sum squared resid	5720.732	Schwarz criterion	7.093876	
Log likelihood	-393.5620	Hannan-Quinn criter.	6.967664	
F-statistic	92.04058	Durbin-Watson stat	1.607757	

6.7.2 NUMBER OF REGISTERED UNEMPLOYED

Table 6.47: Dependent Variable D(REGLED). LS estimation. Sample size: 117 (1990Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
REGLED(-1)	-0.087881	0.019930	-4.409357	0.0000
D(REGLED(-2))	0.535647	0.033204	16.13194	0.0000
D(NW+NSF)	-0.120277	0.016263	-7.395563	0.0000
(NW(-1)+0.7*NSF(-1).0.9BEF1574	-0.010207	0.002214	-4.609437	0.0000
DTILT	-0.555831	0.052065	-10.67569	0.0000
CS1	6.078862	0.775780	7.835805	0.0000
KNRBREAKQ2	-6.121391	1.569735	-3.899633	0.0002
CRISIS09Q1	10.75639	2.843263	3.783115	0.0003
R-squared	0.910030	Mean dependent var	-0.111144	
Adjusted R-squared	0.904252	S.D. dependent var	8.937363	
S.E. of regression	2.765506	Akaike info criterion	4.938250	
Sum squared resid	833.6344	Schwarz criterion	5.127117	
Log likelihood	-280.8876	Hannan-Quinn criter.	5.014928	
Durbin-Watson stat	1.502978			

6.7.3 EMPLOYMENT IN LABOUR FORCE SURVEY)

Table 6.48: Dependent Variable: AKUSYSS. LS estimation. Sample size: 65 (2003Q1 2019Q1)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-6.504585	2.727618	-2.384713	0.0206
N-KAIER	0.426549	0.073774	5.781806	0.0000
AKUSYSS(-1)	0.57344	0.112634	5.485526	0.0000
CS1	1.999581	3.507941	0.570016	0.5710
CS2	26.50908	3.729409	7.108119	0.0000
CS3	9.478398	3.553020	2.667702	0.0100
KNBREAKQ1	7.155564	6.950264	1.029538	0.3077
KNBREAKQ2	-4.424093	5.116944	-0.864597	0.3910
KNBREAKQ3	-23.99811	6.014595	-3.989980	0.0002
KNBREAKQ3(-3)	-20.64970	5.544245	-3.724529	0.0005
KNBREAKQ3(-6)	-10.68422	8.152239	-1.310587	0.1954
R-squared	0.996813	Mean dependent var	2508.769	
Adjusted R-squared	0.996291	S.D. dependent var	141.0838	
S.E. of regression	8.592010	Akaike info criterion	7.280181	
Sum squared resid	4060.245	Schwarz criterion	7.614702	
Log likelihood	-226.6059	Hannan-Quinn criter.	7.412171	
F-statistic	1911.243	Durbin-Watson stat	1.815121	

6.8 HOUSING PRICES AND CREDIT TO HOUSEHOLDS

Table 6.49: Dependent Variable: DLOG(PH). FIML estimation. Sample size: 119 (1989Q1 2018Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
ECM_{PH}	-0.098060	0.017872	-5.486916	0.0000
DLOG(BGH)	0.695384	0.269360	2.581618	0.0098
DLOG(PH(-4)/CPI(-4))	0.172388	0.087522	1.969642	0.0489
DLOG(BGH(-4)/CPI(-4))	-0.500975	0.194847	-2.571118	0.0101
D(RL)	-0.005184	0.003482	-1.488762	0.1366
$(1+EXP(-40.0*(0.6*UAKU+0.4*UAKU(-1))-THPHAKU))^{-1}$	-0.007771	0.003743	-2.076092	0.0379
LGRAD	0.088174	0.019628	4.492373	0.0000
PHDUM	1.0	.	.	.
CS1	0.028095	0.006883	4.082060	0.0000
CS2	0.034165	0.005770	5.921181	0.0000
CS3	0.014606	0.005431	2.689385	0.0072
Constant	-0.076535	0.018590	-4.117069	0.0000

Notes:
$ECM_{PH} = LOG(PH(-1)/CPI(-1)) - 0.62LOG(BGH(-1)/CPI(-1))$
$-1.6(LOG(YDCD(-1)/CPI(-1)) - LOG(HK(-1)))$
$+0.16((1/(1+EXP(-200.0(RUH(-1)/(YDCD(-1)+RUH(-1))-THPHRUH)))$
$+0.09((1/(1+EXP(-50(0.6*UAKU(-1)+0.4*UAKU(-2)-0.13)))$

Additional notes

- PHDUM and CRISIS08Q4 are given in the code of the EViews program file.
- The threshold parameters THPHRUH and PHPHAKU are also set in the Eviews program file.

Table 6.50: Dependent Variable: FIML estimation. Sample size: 119 (1989Q1 2018Q3)

	Coefficient	Std. Error	z-Statistic	Prob.
ECM_{BGH}	-0.011318	0.003148	-3.595041	0.0003
D3LOG(BGH(-1)/CPI(-1))	0.251200	0.019771	12.70518	0.0000
BGHDUM	1.0	.	.8	.
CS1	-0.015573	0.001641	-9.489021	0.0000
CS2	0.005490	0.001874	2.929778	0.0034
CS3	-0.009999	0.001854	-5.392854	0.0000
Constant	0.007810	0.000875	8.922468	0.0000
System statistics:DL(PH), DL(BGH)				
Log likelihood	-756.9519	Schwarz criterion	-756.9519	
Avg. log likelihood	-3.180470	Hannan-Quinn criter.	13.16881	
Akaike info criterion	13.00759			
Determinant residual covariance	3.88E-09			

Notes:
$ECM_{BGH} = -0.95 * LOG(PH(-1)/CPI(-1)) + LOG(BGH(-1)/CPI(-1))$
$+0.95 * (LOG(YDCD(-1)/CPI(-1)) - LOG(HK(-1)))$
$+0.1RL(-1) * (1 - T2CAPH) - (CPI(-1) - CPI(-5)) * 100/CPI(-5))$

Additional notes

- BGHDUM is given in the code of the EViews program file.

6.9 CREDIT INDICATORS

6.9.1 CREDIT TO HOUSEHOLDS (C2-INDICATOR)

Table 6.51: 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			

6.9.2 CREDIT TO NON FINANCIAL FIRMS (C2-INDICATOR)

Table 6.52: 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
$CRISIS = CRISIS08Q4 - CRISIS09Q3 - CRISIS09Q4 - CRISIS10Q$

6.9.3 CREDIT TO LOCAL ADMINISTRATION (C2-INDICATOR)

Table 6.53: 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:
$f(YF) = LOG(YF + YF(-1) + YF(-2) + YF(-3) + YF(-4))$

6.10 INTEREST RATES AND BOND YIELDS

6.10.1 5 YEAR GOVERNMENT BOND, EFFECTIVE YIELD

Table 6.54: 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:
$ECM_{RBO} = RBO(-1) - 0.33RSH(-1) - (1 - 0.33)RW(-1)$

6.10.2 10 YEAR GOVERNMENT BOND, EFFECTIVE YIELD

Table 6.55: 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:
$ECM_{RBOTENY} = RBOTENY(-1) - RBO(-1) - 0.25$

6.10.3 AVERAGE INTEREST RATE ON TOTAL BANK LOANS

Table 6.56: 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:
$ECM_{RL} = RL(-1) - 0.22RBO(-1) - (1 - 0.22)RSH(-1) - BASELIII + 0.31)$

6.10.4 MONETARY POLICY INTEREST RATE

Table 6.57: 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.

6.10.5 3-MONTH MONEY MARKET RATE

Table 6.58: 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	0.0000https://www.overleaf.com/project/5c07f692d5d2762ae09
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.

6.10.6 5-YEAR FOREIGN GOVERNMENT BOND YIELD

Table 6.59: Dependent Variable: RW. NLS estimation. Sample size: 86 (1997Q1 2018Q2)

	Coefficient	Std. Error	t-Statistic	Prob.
(RW(-1)-RSW(-1)-0.46)	-0.069416	0.029672	-2.339406	0.0218
D(RSW)	0.459143	0.083239	5.515949	0.0000
D(RSW(-1))	-0.196258	0.087791	-2.235511	0.0282
D(RSW(-2))	-0.134102	0.081801	-1.639373	0.1051
RWDUM	0.975314	0.155923	6.255112	0.0000
RWSTEP14Q2	-0.372053	0.165827	-2.243618	0.0277
R-squared	0.453407	Mean dependent var	-0.05706	
S.E. of regression	0.227182	Akaike info criterion	-0.048241	
Log likelihood	9.074347	Hannan-Quinn criter.	0.032159	
F-statistic	75.67358	Durbin-Watson stat	1.687551	
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.

6.11 INCOME COMPONENTS (HOUSEHOLDS)

6.11.1 WAGE INCOME TO HOUSEHOLDS

Table 6.60: Dependent Variable: LOENNH. LS estimation. Sample size: 35 (2010Q1 2018Q3)

	Coefficient	Std. Error	t-Statistic	Prob.
Constant	-2250.929	3682.015	-0.611331	0.5456
WF*(1.14)(TWF+TWOSJ)	1.065710	0.011236	94.85152	0.0000
CS1	-2250.594	1136.001	-1.981155	0.0568
CS2	-3148.579	1146.457	-2.746356	0.0101
CS3	-3759.357	1134.865	-3.312603	0.0024
R-squared	0.996807		Mean dependent var	339686.5

6.11.2 INCOME FROM OPERATING SURPLUS TO HOUSEHOLDS

Table 6.61: 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			

6.11.3 INCOME FROM INTEREST, HOUSEHOLDS

Table 6.62: 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			

6.11.4 INTEREST PAYMENTS, HOUSEHOLDS

Table 6.63: 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			

6.11.5 TAXES ON INCOME AND WEALTH, HOUSEHOLDS

Table 6.64: 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.

6.12 STOCK PRICES (MSCI)

6.12.1 MSCI EQUITY PRICE INDEX, NORWAY

Table 6.65: 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

6.12.2 MSCI EQUITY PRICE INDEX, WORLD

Table 6.66: 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)				

6.13 HOUSING CAPITAL STOCK

Table 6.67: 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:
$f(HS) = HS + 0.6HS(-1) + 0.3HS(-3)$

7 EMPIRICAL MACROECONOMIC MODELLING

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

7.1 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.[1] Hence for a theoretical model of the relationship between Y and X we can write

$$\underbrace{Y_i}_{solution} = \underbrace{h(X_i)}_{calibrated} + shocks_i \tag{7.1}$$

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

In (7.1), 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

$$remainder_i = \underbrace{y_i}_{observed} - \underbrace{g(x_i)}_{explained} \tag{7.2}$$

[1] 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.

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 (7.2) is generic: Empirical econometric models are really decompositions of observed data rather than causal entities. At first sight, this 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 (7.2). 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.

The characteristics of empirical econometric models can also be illustrated with the aid of the diagram in Figure 7.1.

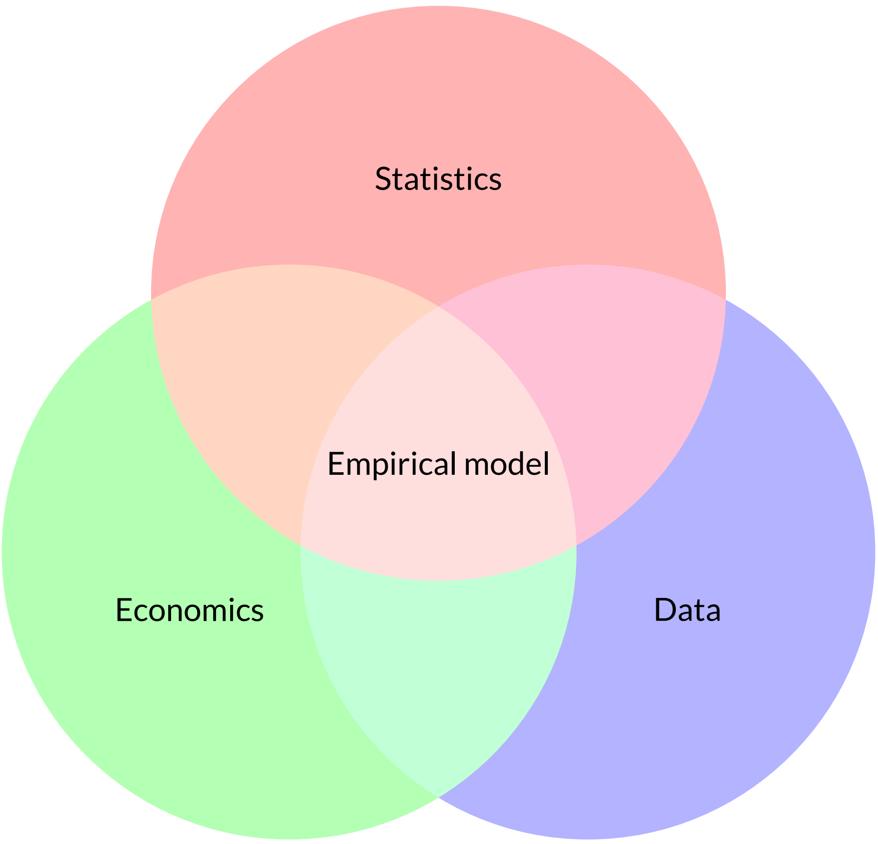


Figure 7.1: Illustration of an empirical macroeconometric model as the intersection of information fields of statistical theory, economic theory and the information in observed data

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 (7.2)). Both Chapter 8 and 2 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.

7.2 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.[2]

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 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).

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

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 (2000) 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.[3]

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.[4]

[3]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.

[4]This line of thought may lead to the following practical argument against large-scale empirical models: Since mod-

7.3 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 approach 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 in-

elling 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.

ternational 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.

7.4 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 macro economy should be derived directly from microeconomics. It has been dominant since shortly after the WW2, and the DSGE models which came 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.

7.5 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).

7.5.1 EQUILIBRIUM CORRECTION MODEL. NOT NAIRU MODEL

NAM is a dynamic model which aims 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 (ECM). 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 type of of macro model, or,slightly more general, a NAIRU model. This follows from how we represent 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. chapter 8.3. 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. [5].

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 (a view often formalized by a downward-sloping long-run Phillips-curve). The implication is instead that the relationship between the steady states of inflation and of unemployment is much weaker than in the standard macroeconomic theory where some version of a wage Phillips curve is a 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. As noted, Chapter 8 develops this perspective in more detail.

7.6 THE CONCEPT OF A DATA GENERATING PROCESS

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 specifi-

[5] 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

cation 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 for structural breaks.

However, 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.

FRAME 8: 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

$$x_t = \alpha + x_{t-1} + \epsilon_t \tag{7.3}$$

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. (7.3) 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 (7.3): r - 1 =0, where r denotes the root.

Due to the unit root, (7.3) is a non-stationary process. The differenced series $\Delta x_t =: x_t - x_{t-1}$ is however stationary since the process becomes simply

$$\Delta x_t = \alpha + \epsilon_t \tag{7.4}$$

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.

7.7 VARS, COINTEGRATED VARS AND STRUCTURAL MODELS

The Vector autoregressive system, VAR, represents a common ground for multivariate dynamic econometric modelling. It can be rationalised theoretically by the theory of reduction of a high dimensional joint density function, Hendry and Doornik (2014, Ch. 6), or as a linearization and "discretization" of a structural system of differential equations, Bårdsen et al. (2004). Non-stationarity in the form of unit-roots is easy to integrate (as a restriction on the roots of the companion form matrix), and cointegration can be tested.

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.

The relationship between the VAR and structural models, can be briefly presented as in the following three paragraphs.

7.7.1 THE STATISTICAL SYSTEM

Our reference point will often be a linearized and discretized approximation as a data-coherent statistical system representation in the form of a VAR:

$$\Delta \mathbf{y}_t = \mathbf{c} + \mathbf{y}_{t-1} + \sum_{i=1}^{k} {}_{t-i} \Delta \mathbf{y}_{t-i} + \mathbf{u}_t, \tag{7.5}$$

with independent Gaussian errors $\mathbf{u}_t$ as a basis for valid statistical inference about economic theoretical hypotheses. We focus on potential unit-roots that are located at the zero frequency, which means that the rank of the matrix becomes central. If that matrix has full rank, all the variables in the VAR are $I(0)$ and the VAR is stationary (before we consider structural break non-stationarity). Normally, we will expect that two or more variables in the VAR are $I(1)$, which implies that has reduced rank. However, if the rank is large than zero, there is at least one cointegration relationships between the variables.

Given that the rank of has been determined, the statistical model (7.5) to provide the framework for hypothesis testing. 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 (7.5) 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 $\mathbf{u}_t$ as data.[6]

As pointed out by Garratt et al. (2006), the representation (7.5) 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 (7.5) 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

[6] 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).

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.

7.7.2 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:

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

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

7.7.3 THIRD STEP: THE DYNAMIC SEM

The final step is to identify the dynamic structure:

$$\mathbf{A}_0\Delta \mathbf{y}_t = \mathbf{A}_0\mathbf{c} + \mathbf{A}_0{}^{\prime}\mathbf{y}_{t-1} + \sum_{i=1}^{k} \mathbf{A}_{0\,t-i}\Delta \mathbf{y}_{t-i} + \mathbf{A}_0\mathbf{u}_t,$$

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.

Note that we use simultaneous equations model in a broad meaning here: The identified SEM may we be a recursive model strukture for example.

7.8 RELATIONSHIP TO DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODELS (DSGE)

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.[7] 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 equilibrium 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).

[7] 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).

8 WAGE AND PRICE FORMATION AND MEDIUM TERM MODEL PROPERTIES

If the aim of the modelling exercise is to develop a best possible empirical macro model for Norway, the individualistic wage setting set up of the New Keynesian model is something of a non-starter. Instead, a framework more in line with Norwegian institutions, and where collective action plays a role for nominal wage formation, should be adopted as part of the model specification.

The dynamic ICM model mentioned above, is broadly consistent with institutional features of Norwegian wage formation. This is not the case for New Keynesian model of for instance Erceg et al. (2000), where individuals have monopoly power due to labour service specialization, and the real wage is a direct mark-up over the marginal rate of substitution (between material consumption and leisure), cf. the discussion in Krogh (2014, Chapter 1.6).

In this chapter we present some of the important implications that the specification of wage and price setting have for the medium term properties of a macro model. In order to focus on the principal consequences, we can abstract from the pattern wage bargaining aspect, cf. chapter 2.4.

8.1 THE SUPPLY SIDE OF MACRO MODELS

A main issue of an medium term empirical macro model is the specification of the supply side. This is 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.[1]

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 econo-

[1] 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.

metric 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 $x_t \equiv \ln(X_t)$.

8.2 THE LABOUR MARKET AS A SOCIAL INSTITUTION, IMPLICATIONS FOR THE SPECIFICATION OF WAGE EQUATIONS

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 interests. [2] 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

[2] 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.

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". [3].

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 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'. [4]

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 8.3. 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.

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

[4]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.

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 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.

8.3 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.

8.3.1 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 9), we have the price setting relationship for firm i

$$Q_i = \frac{El_Q Y_i}{El_Q Y_i - 1} \frac{W_i(1 + T1_i)}{Z_i}, \tag{8.1}$$

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.

$El_Q Y i$ 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 9: 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:

$$Q = \frac{El_Q Y}{El_Q Y - 1} \frac{W(1 + T1)}{Z} \tag{8.2}$$

8.3.2 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 (8.2), 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:

$$(V - V_0)^{\mho}\Pi^{1-\mho} \tag{8.3}$$

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 (8.3), 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.[5] 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

[5] 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 10.

FRAME 10: 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".[6]

[6] OECD (2012, p. 15)

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

$$\mho \frac{V'_W(\frac{RW}{P_q(1+T1)}, U, A_\nu)}{V(\frac{RW}{P_q(1+T1)}, U, A_\nu) - V_0(\frac{\bar{W}}{P}, U)} = (1-\mho)\frac{\frac{1}{Z}}{(1-RW\frac{1}{Z})}. \tag{8.4}$$

In a symmetric equilibrium, $W = \bar{W}$, leading to $\frac{RW}{P_q(1+T1)} = \frac{\bar{W}}{P}$ in equation (8.4), the aggregate bargained real wage RW^b is defined implicitly as

$$RW^b = F(P_q(1+T1), Z, \mho, U), \tag{8.5}$$

or, using the definition

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

we obtain the solution for the bargained nominal wage:

$$W^b = \frac{Q}{(1+T1)} F(P_q(1+T1), Z, U, \mho) \tag{8.6}$$

Equation (8.6) 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 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.[7] But we

[7] 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.

will not do that. Instead we will interpret a linarized version of (8.6) 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 (8.6) becomes: (8.6), gives:

$$w^b = m_w + q_t + (1 - \delta_{12})(p - q) + \delta_{13} z - \delta_{15} u - \delta_{16} T1. \tag{8.7}$$
$$0 \leq \delta_{12} \leq 1, 0 < \delta_{13} \leq 1, \delta_{15} \geq 0, \;\; 0 \leq \delta_{16} \leq 1.$$

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. [8]

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 (8.6) 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 $(1 - \delta_{12})$—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 (8.6), 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.[9] 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

[8] 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.

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

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.[10]

In the current version of NAM, the theoretical wage-target equation (8.6) 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 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 (8.7) 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 (8.7) 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 (8.2) 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

[10] 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.

fluctuaions in productivity, cf. Barker and Peterson (1987, Ch. 13.5). Upon linearization we have

$$q^f = m_q + (w + T1 - z) \tag{8.8}$$

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

8.3.3 NAIRU

Influential contributions like Layard et al. (1994) and Nickell et al. (2005) have made use of a two-equation system like (8.7) and (8.8) 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 (8.7) can be written as

$$(w^b - q) = m_w + (1 - \delta_{12})(p - q) + \delta_{13} z - \delta_{15} u - \delta_{16} T1, \tag{8.9}$$

and $(w - q^f)$ from (8.8) can be written as

$$(w - q^f) = -m_q - (T1 - z) \tag{8.10}$$

Following our interpretation of the Nash real-wage, (8.9) represents the common real-wage norm coming out of the negotiations. Equation (8.8) 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: $(w - q^f)$, $(w^b - q)$, $(p - q)$ 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

$$(w^b - q) = (w - q^f) = (w - q)^{NAIRU} \tag{8.11}$$

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 8.1.

Equation (8.9) is the downward sloping curve labelled wage setting in Figure 8.1, while (8.10) 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 (8.9) and (8.10) 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

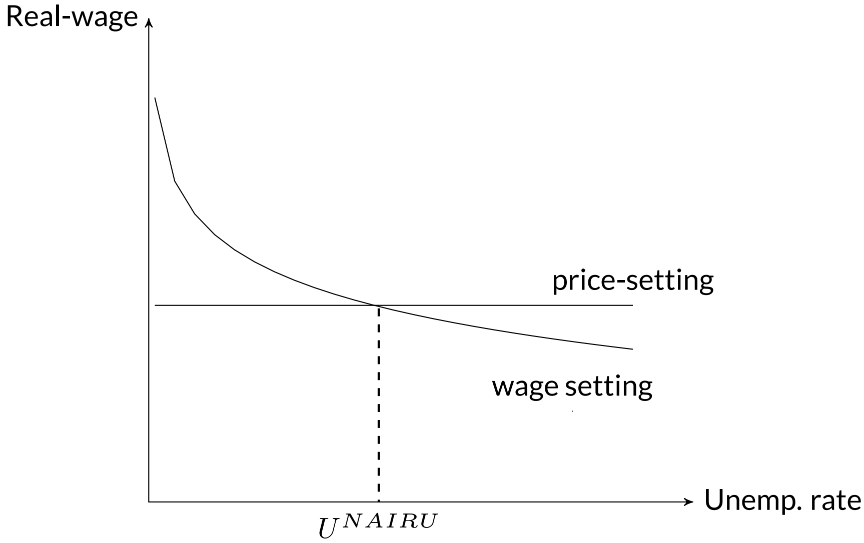


Figure 8.1: Wage and price formation with a unique NAIRU.

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.

8.4 COINTEGRATION AND LONG-RUN IDENTIFICATION

We first show how the two theoretical relationships (8.7) and (8.8) 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 (8.7) 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:

$$w_t = m_w + q_t + (1 - \delta_{12})(p_t - q_t) + \delta_{13} z_t - \delta_{15} u_t - \delta_{16} T1_t + ecm_t^b. \tag{8.12}$$

With reference to equation (8.8), 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

$$q_t = m_q + (w_t + T1_t - z_t) - ecm_t^f \tag{8.13}$$

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

The two cointegrating relationships (8.12) and (8.13) 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 (8.12) and (8.13) can then be combined with a definition of the consumer price index p_t,

$$p_t = (1-\zeta)\, q_t + \zeta pi_t + \eta T3_t,\ 0 < \zeta < 1, \quad 0 < \eta \leq 1, \tag{8.14}$$

where the import price index pi_t naturally enters. The parameter ζ reflects the openness of the economy.[11] 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 (8.14) in (8.12), and of (8.13) in (8.14), the system can be specified in terms of w_t and p_t:

$$w_t = m_w + \left\{1 + \zeta \frac{\delta_{12}}{(1-\zeta)}\right\} p_t \tag{8.15}$$
$$- \frac{\delta_{12}\zeta}{(1-\zeta)} pi_t - \frac{\delta_{12}\eta}{(1-\zeta)} T3_t + \delta_{13} z_t - \delta_{15} u_t - \delta_{16} T1_t + ecm_t^b$$

$$p_t = (1-\zeta) m_q + (1-\zeta)\{w_t + T1_t - z_t\} + \zeta pi_t + \eta T3_t - (1-\zeta) ecm_t^f \tag{8.16}$$

By simply viewing (8.15) and (8.16) 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, (8.16) is unaltered, while the wage equation becomes

$$w_t = m_w + p_t + \delta_{13} z_t - \delta_{15} u_t - \delta_{16} T1_t + ecm_t^b \tag{8.17}$$

The long-run price equation (8.16) and the long-run wage equation (8.17) are identified by the order condition.

8.5 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

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

price inflation, changes in unemployment, changes in tax-rates, and previous deviations from the desired wage level consistent with (8.17)

$$\begin{aligned}\Delta w_t - \alpha_{12,0}\Delta q_t = c_1 &+ \alpha_{11}(L)\,\Delta w_t + \alpha_{12}(L)\,\Delta q_t + \beta_{12}(L)\,\Delta z_t \\ &- \beta_{14}(L)\,\Delta u_t - \beta_{15}(L)\,\Delta T1_t \\ &- \gamma_{11} ecm^b_{t-r} + \beta_{18}(L)\,\Delta p_t + \epsilon_{1t},\end{aligned} \tag{8.18}$$

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.

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)):

$$\begin{aligned}\Delta q_t - \alpha_{21,0}\Delta w_t = c_2 + \alpha_{22}(L)\,\Delta q_t + \alpha_{21}(L)\,\Delta w_t + \beta_{21}(L)\,gap_t \\ - \beta_{22}(L)\,\Delta z_t + \beta_{25}(L)\,\Delta T1_t - \gamma_{22} ecm^f_{t-r} + \epsilon_{2t},\end{aligned} \tag{8.19}$$

where

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

Solving equation (8.14) for Δq_t (i.e., the equation is differenced first), and then substituting out in equations (8.18), and (8.19), 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):

$$\begin{bmatrix} 1 & -a_{12,0} \\ -a_{21,0} & 1 \end{bmatrix} \begin{bmatrix} \Delta w \\ \Delta p \end{bmatrix}_t = \begin{bmatrix} \alpha_{11}(L) & -a_{12}(L) \\ -a_{21}(L) & \alpha_{22}(L) \end{bmatrix} \begin{bmatrix} \Delta w \\ \Delta p \end{bmatrix}_t +$$

$$\begin{bmatrix} 0 & \beta_{12}(L) & -\zeta \frac{\alpha_{12}(L)}{1-\zeta} & -\beta_{14}(L) & -\beta_{15}(L) & -\eta \frac{\alpha_{12}(L)}{1-\zeta} \\ b_{21}(L) & -b_{22}(L) & \zeta \alpha_{22}(L) & 0 & b_{25}(L) & \eta \alpha_{22}(L) \end{bmatrix} \begin{bmatrix} gap \\ \Delta z \\ \Delta pi \\ \Delta u \\ \Delta T1 \\ \Delta T3 \end{bmatrix}_t \tag{8.20}$$

$$- \begin{bmatrix} \gamma_{11} & 0 \\ 0 & \gamma_{22} \end{bmatrix} \times \begin{bmatrix} 1 & -(1+\zeta d_{12}) & -\delta_{13} & \zeta d_{12} & \delta_{15} & \delta_{16} & \eta d_{12} \\ -(1-\zeta) & 1 & (1-\zeta) & -\zeta & 0 & -(1-\zeta) & -\eta \end{bmatrix} \begin{bmatrix} w \\ p \\ z \\ pi \\ u \\ T1 \\ T3 \end{bmatrix}_{t-r}$$

$$+ \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}_t ,$$

where we have omitted the intercepts to save space, and have substituted the equilibrium correction terms using (8.15) and (8.16) above. The mapping from the theoretical parameters in (8.18) and (8.19) to the coefficients of the model (8.20) is given by:

$$\begin{aligned} a_{12,0} &= \frac{\alpha_{12,0}}{1-\zeta} + \beta_{18,0}, \\ a_{21,0} &= (1-\zeta)\,\alpha_{21,0}, \\ a_{12}(L) &= \frac{\alpha_{12}(L)}{1-\zeta} + \beta_{18}(L), \\ a_{21}(L) &= (1-\zeta)\,\alpha_{21}(L), \\ b_{2j}(L) &= (1-\zeta)\,\beta_{2j}(L), j = 1,2,5, \\ d_{12} &= \frac{\delta_{12}}{1-\zeta}, \\ e_1 &= \epsilon_1, \\ e_2 &= (1-\zeta)\,\epsilon_2. \end{aligned} \tag{8.21}$$

The model (8.20) 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.

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

The dynamic model in (8.20) can be re-written in terms of real wages $(w-p)_t$ and a real exchange rates defined as $(pi-q)_t$, since $(p-q)_t \equiv (1-\zeta)(pi-q)_t$.

8.6.1 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 (8.20) 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 $(pi_t - q_t) \to rex_{ss}(t)$, and $(w_t + T1_t - q_t) \to wq_{ss}(t)$, 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,

$$\Delta p_t = \Delta pi_t = \pi. \tag{8.22}$$

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.

8.6.2 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 8.1 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*'.[12]

Translated to our conceptual framework, this view corresponds to setting $ecm_t^b = ecm_t^f = 0$ in (8.12) and (8.13), with $\delta_{13} = 1$, and solving for the rate of unemployment that reconciles the two desired wage shares, call it u^{NAIRU} [13]

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

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

$$u^{NAIRU} = \frac{-(m_w + m_q)}{\delta_{15}} + \frac{1-\delta_{12}}{\delta_{15}(1-\zeta)}\zeta(p-pi) + \frac{1-\delta_{12}}{\delta_{15}(1-\zeta)}\eta T3 + \frac{1-\delta_{16}}{-\delta_{15}}T1 \quad (8.23)$$

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 (8.23). 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

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

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

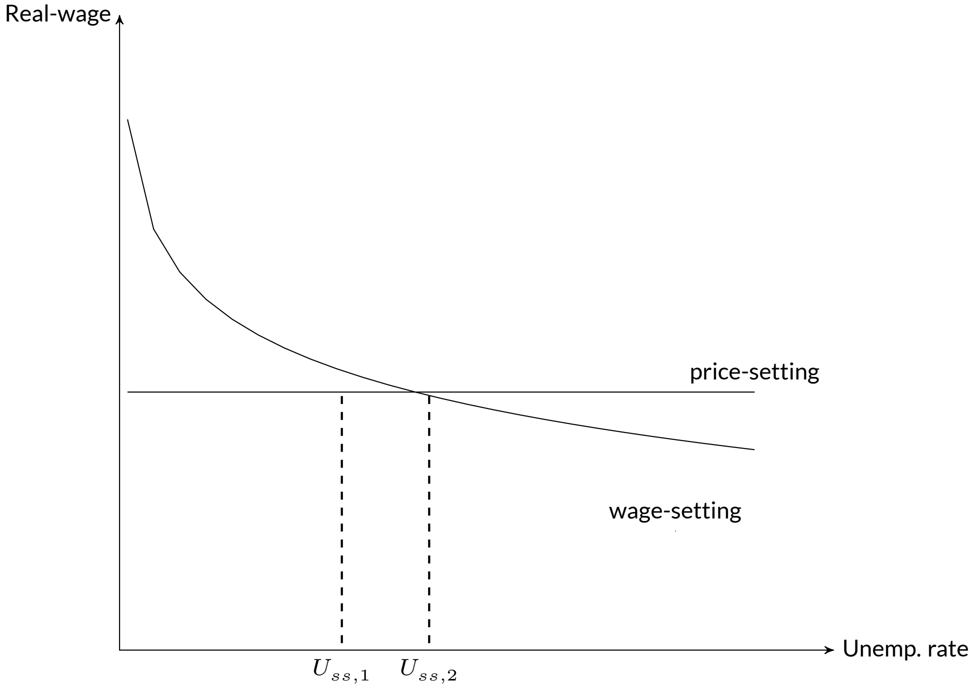


Figure 8.2: Wage and price formation when there is no unique NAIRU, the case in NAM.

from (8.23), 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 subchapter 8.3.3 above. In fact, the expression for u^{NAIRU} in (8.23) will indeed be identical to the expression for the NAIRU we noted could be obtained as the solution to the two static equations (8.9) and (8.10), and which we referred to as U^{NAIRU} in Figure 8.1. Hence, Figure 8.1 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 (8.23) 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 (8.20) 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 (8.20) 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 8.2 refer to the case of non-unique

NAIRU as "the case in NAM". In Figure 8.2 we use the same price-setting and wage-setting curves as in Figure 8.1, 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 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 (8.18) 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 (8.12) we can then write the wage equation as:

$$\begin{aligned}\Delta w_t = {} & k_w + \alpha_{12,0}\Delta q_t + \beta_{18}\Delta p_t - \mu_w u_{t-1} \\ & - \gamma_{11}(w_{t-1} - q_{t-1}) + \gamma_{11}(1-\delta_{12})(p_{t-1} - q_{t-1}) + \gamma_{11}\delta_{16} T1_{t-1} + \epsilon_{1t}\end{aligned} \quad (8.24)$$

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

$$\mu_w = \gamma_{11}\delta_{13} \text{ when } \gamma_{11} > 0 \text{ or } \mu_w = \varphi \text{ when } \gamma_{11} = 0. \quad (8.25)$$

The notation in (8.25) 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 (8.25) 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, (8.24) 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^{phil}_t 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

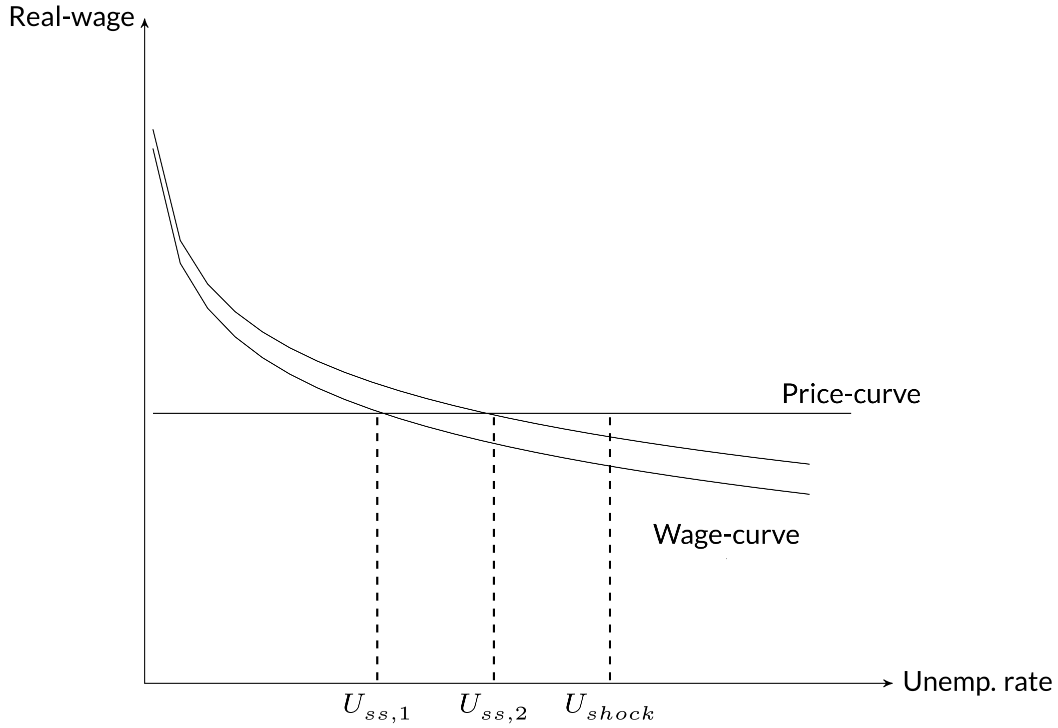


Figure 8.3: Initial stationary situation in $U_{ss,1}$. After a shock to the product market, or the financial market, the economy is at U_{shock}. $U_{ss,2}$ indicates a new stationary state

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 8.2, 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 8.3 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.

8.7 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.[14] 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).

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

$$U_t = c_u + \alpha U_{t-1} - \rho\, rex_{t-1} + \epsilon_{u,t},\ \rho \geqq 0, -1 < \alpha < 1, \tag{8.26}$$

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 (8.26) 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, (8.26) 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:

$$re_t \equiv (1-\zeta)(pi - q)_t, 0 < \zeta < 1 \tag{8.27}$$

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

$$pi_t = g_{pi} + pi_{t-1} + \varepsilon_{pit} \tag{8.28}$$

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

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

see that the random-walk formulation in (8.28) 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 (8.28) as a simple model of a system with fully floating nominal exchange rate. In NAM (8.28) 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 (8.28) 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.

$$z_t = g_z + z_{t-1} + \varepsilon_{at} \tag{8.29}$$

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 8.4 and 8.5 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.

The figure contains four panels with blue graphs of the actuals (i.e., the computer generated data) for $re_t, ws_t, \Delta p_t$ (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 8.4. 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

Figure 8.4: Dynamic simulation of a wage-price model extended by equation (8.26) 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.

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.

While Figure 8.4 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 8.5 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,

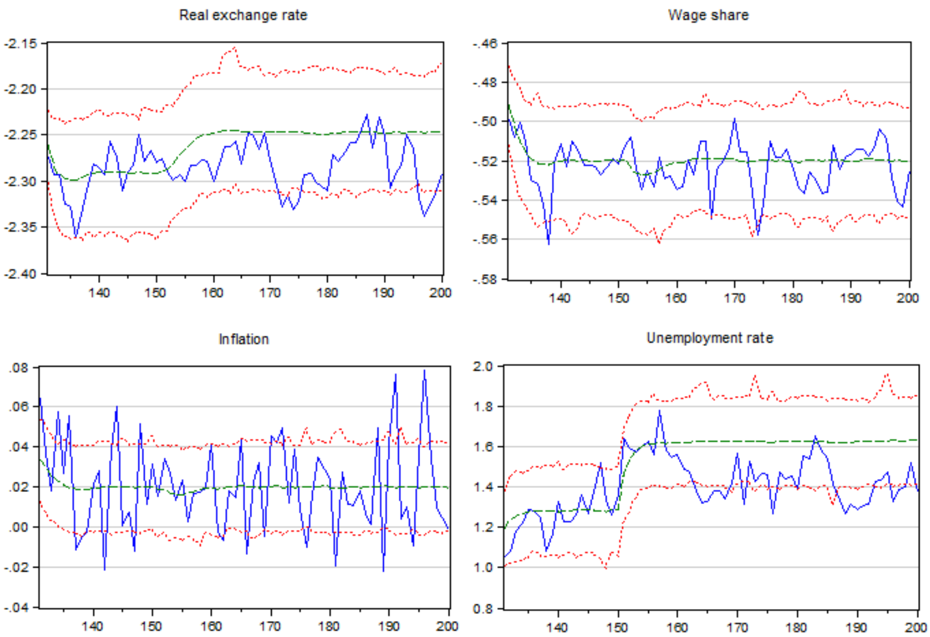


Figure 8.5: Dynamic simulation of a wage-price model extended by equation (8.26) for unemployment, using data from a VAR representation and Monte- Carlo simulation. Illustrating system stability with respect to a permanent shock to unemployment in period 151

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 8.3 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.

8.8 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 2, and the actual estimation results are given in Chapter 6.

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 2.6 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.

8.9 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 (8.18) and (8.19) 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.

A Revision log, 2017-2019

19 June 2019 Re-specified the treatment of two unemployment rates *UAKU* and *UR*. The variables modelled by econometric equations are now *AKUSYSS, AKULED* and *REGLED*, while the two unemployment percentages are given by definitions, and *AKUSTURK* is also a definition variable. Users who focus on *UAKU* can now do that, without having to use add-factors that affect *UR*.

14 June 2019 Revised specification of model equations for value added variables: *YFP1*, *YFP2* and *YFP3NET* No change of interpretation or of qualitative model properties.

24 May 2019 Added trade balance and current account as variables in the model

20 December 2018 Re-specification of wage-price model, see section 2.4 and the detailed estimation results.

A main change in the data base is that the wage rate per hour in the private business sector of Mainland Norway (WFPK in earlier model versions, which was an unofficial wage rate from the KVARTS data bank) is now measured by the new variable *WFP* which is obtained directly from the National accounts data. Likewise, as the wage rate for Mainland-Norway, WFK has been replaced by the wage rate *WF* (also directly from the National accounts).

As documented in section 2.4, *WFP* and *WF* are modelled in terms of the three endogenous three wage rates *WFP1* (manufacturing), *WFP23* (production of other good, services and retail trade) and *WO* (government sector). The module for these three variables is the model's representation of the Norwegian version of pattern wage setting in the system of national wage formation.

The change in the modelling of wage formation, has lead to a similar change in the representation of price formation, with separate model equations for *PYFP1* and *PYFP23*, and *PYFB* and *PYF* being modelled in term of these two variables and *PYO*.

10 December 2018 Re-specification of the model's determination of the registered rate of unemployment (UR) and the labour force survey measure (UAKU), see chapter2.5. The re-specification does not change the qualitative properties of the model.

28 November 2018 Re-specification of module for house price and credit dynamics. Chapter 2.7.3 revised accordingly. Overall impact on model properties has been to reduce amplitude and length of credit expansion/house price cycle.

27 November 2018 Minor re-specifcation of relationship for RW, with non-linear estimation of long-run difference between RW and RSW.

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 added: KORRSPH (households' new deposits in pension funds).

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.

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 MacMillan.

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, Bergen.

Bårdsen, G. and R. Nymoen (2014). *Videregående emner i økonometri*. Fagbokforlaget, Bergen.

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.

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.

Calmfors, L. and A. L. Seim (2013). Pattern Bargaining and Wage Leadership in a Small Open Economy. *Scandinavian Journal of Economics*, *115*(1), 109–140. DOI: 10.1111/j.1467-9442.2012.01731.x.

Calvo, G. (1983). Staggered Prices in a Utility Maximizing Framework. *Journal of Monetary Economics*, *12*, 383–98.

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.

Castle, J. L., J. A. Doornik, D. F. 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.

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 (2013a). *Empirical Econometric Modelling PcGive 14. Volume 1*. Timberlake Consultants, London.

Doornik, J. A. and D. F. Hendry (2013b). *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.

Erceg, J., D. W. Henderson and A. T. Levin (2000). Optimal Monetary Policy with Staggered Wage and Price Contracts. *Journal of Monetary Economics*, *46*, 281–313.

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 (2014). *EViews 8.1 User's Guide I*. IHS Global Inc., 4521 Campus Drive,336, Irvine CA, 92612-2621. USA. Www.eviews.com.

EViews (2016). *EViews 9 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.

Gjelsvik, M. L., R. Nymoen and V. Sparrman (2015). Have Inflation Targeting and EU Labour Market Immigration Changed the System of Wage Formation in Norway? Memorandum 18, Department of Economics, University of Oslo.

Goodhart, C. and B. Hofmann (2007). *House Prices and the Macroeconomy: Implications for Banking and Price Stability*. Oxford University Press, Oxford.

Granger, C. W. J. (1992). Fellow's Opinion: Evaluating Economic Theory. *Journal of Econometrics*, *51*, 3–5.

Granger, C. W. J. (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, Mass.

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,Mass.

Hendry, D. F. and H. M. Krolzig (2000). 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.

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. (2014). *Theoretical and Econometric Aspects of New Keynesian Modeling*. Dissertation for the degree of phd, University of Oslo, Faulty of Social Sciences, Department of Economics. No. 476.

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. (2017). Between Institutions and Global Forces: Norwegian Wage Formation Since Industrialisation. *Econometrics*, *5*(1), 1–54. Doi:10.3390/econometrics5010006.

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.

Taylor, J. B. (1980). Aggregate Dynamics and Staggered Contracts. *Journal of Political Economy*, *88*, 1—23.

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.