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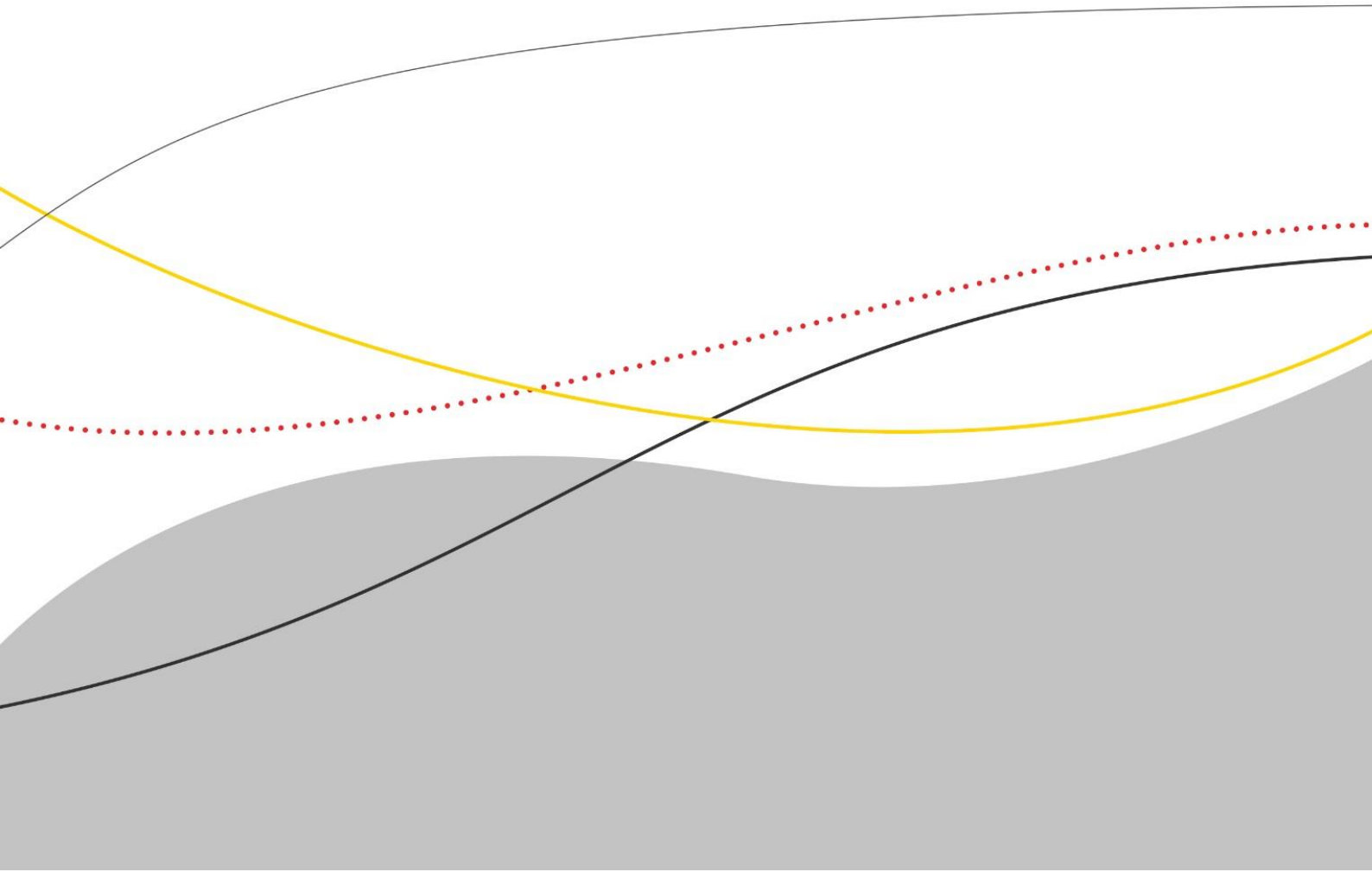
Magnus Saxegaard



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Forord

I det løpende analysearbeidet bruker Finansdepartementet økonomiske modeller for å utarbeide fremskrivninger av økonomien og statsfinansene, og for å anslå virkningene av den økonomiske politikken. Det gir et godt utgangspunkt for å analysere økonomiske sammenhenger og vurdere hvordan den økonomiske politikken bør innrettes.

Fra tid til annen er det nyttig å gjennomgå analyseapparatet og vurdere muligheter for eventuelle forbedringer og videreutvikling. Finansdepartementet har på denne bakgrunn bestilt en utredning av bruk av makroøkonomiske modeller i andre finansdepartementer det er naturlig for Norge å sammenligne seg med. Utredningen ble utført av Magnus Saxegaard, som blant annet har bakgrunn fra IMF.

Rapporten viser at flere finansdepartement har satt søkelyset på sine makromodeller. Spesielt har de andre nordiske landene utviklet eller er i ferd med å utvikle nye makroøkonomiske modeller. Det finske finansdepartementet har tatt i bruk en såkalt dynamisk, stokastisk, generell likevektsmodell (DSGE-model), mens det svenske finansdepartementet er i ferd med å utvikle en slik modell. Det danske finansdepartementet annonserte nylig at de vil utvikle en ny modell med "mikrofundert atferd" og en mer eksplisitt behandling av forventningsdannelsen. Også i Nederland utvikles det en ny liknende makromodell til bruk i finansdepartementet, mens det britiske finansdepartementet har satt bort både utvikling og kjøring av sin modell til Office for Budget Responsibility.

Saxegaard gjennomgår kort de ulike modellene og hvilke hensyn som har vært tillagt vekt i valg av modell, herunder hva slags type analyse modellene skal brukes til, hvordan arbeidsprosessene er lagt opp, og hvilken tilgang man har på ressurser og ekspertise.

Rapporten er et nyttig innspill for å lære av andre land.

Et foreløpig utkast av notatet ble diskutert i Finansdepartementets rådgivende utvalg for modell- og metodespørsmål i desember 2016.

Februar 2017

Hans Henrik Scheel

Finansråd

Innhold

1 Introduction

The Advisory Panel on Macroeconomic Models and Methods (MMU) was established in May 2011 with a remit to provide the Ministry of Finance with technical advice about models and techniques used to analyze macroeconomic developments. In that context, a team from the Economics Department at the Norwegian Ministry of Finance under the leadership of Yngvar Dyvi prepared a report on the appropriate short- and medium-run modelling toolkit for the Ministry of Finance that was presented to the MMU in December 2015.[1] At the same time, representatives from Sweden, Denmark, Finland, the UK, and the Netherlands have given presentations about the use of models in their respective ministries (or institutions tasked with developing models for the Ministry of Finance). To bring this work together it was proposed in the April 2016 meeting of the MMU that a survey of macroeconomic models used for fiscal policy analysis in different policy institutions be prepared.[2] This report, which was written over a five-week period in November/December 2016, is a response to that request.

This is not the first report that includes a survey of macroeconomic models in use at different policy institutions. The report by Dyvi et al. (2015) includes a brief overview of the models used by the Danish Ministry of Finance (ADAM), the Swedish Ministry of Finance (KIMOD), the Bank of England (COMPASS), the European Commission (QUEST), Norges Bank (NEMO), as well as a more detailed description of the model currently used by the Norwegian Ministry of Finance (MODAG). A 2015 report by the Swedish National Institute of Economic Research (NIER) on the appropriate modelling toolkit for the Swedish Ministry of Finance includes an assessment of KIMOD, the European Commission model (QUEST), the model used by the US Federal Reserve (FRBUS), the RAMSES model used by the Swedish Riksbank, the NiGEM model developed by the National Institute for Economic and Social Research (NIESR) in the UK, the model used by the ECB (NAWN), the KOOMA model recently developed by the Finnish Ministry of Finance, and the MOSES model of the Swedish economy developed by Bårdsen et al. (2012).[3]

The current report differs from the aforementioned studies both in terms of focus and coverage. The coverage is limited to models used by ministries of finance (or institutions tasked with developing models for the Ministry of Finance) in a select number of comparator countries, namely Sweden, Denmark, Finland, the Netherlands, Canada, the UK, and New Zealand. For comparison purposes frequent references are also made to the Norwegian model MODAG. References are also made to the new models under development by the NIER, the CPB Netherlands Bureau for Economic Policy Analysis, the New Zealand Treasury, and the Danish Ministry of Finance. The focus of the report is a number of key technical, institutional, and practical themes the author considers important for the effective use of models for macro-fiscal policy analysis and forecasting in ministries of finance, the similarities and differences between the models in these areas, and how these have influenced the choice of model. Some of these themes have been covered in previous

[1] Dyvi et al. (2015).
[2] The presentations, background papers, and meeting minutes are available on the MMU website.
[3] Hjelm et al. (2015a).

reports, though less with the aim of comparing different models.[4] The aim is not primarily to compare different *types* of model as this has been done extensively elsewhere. Neither is the main aim to provide a recommendation about the appropriate modelling framework for the Norwegian Ministry of Finance, though some normative statements are unavoidable and a conclusion with some final thoughts on the way forward is included.

The key themes (in no particular order of importance) covered in this report include the following:

(i) Theoretical foundations: *How well-grounded is the model in economic theory?*

(ii) Empirical foundations: *How data-driven is the model?*

(iii) Comprehensiveness: *How comprehensive is the main model?*

(iv) Fiscal policy: *How is government modelled and what are the fiscal transmission channels?*

(v) Model use: *How is (or how much of) the model is used?*

(vi) Institutional framework: *Who develops and uses the model?*

(vii) Resource costs and knowledge management: *How resource-intensive are the models and how is knowledge about the models preserved?*

There are of course many other areas, not least treatment of the labor and financial markets, where the models differ and that are of interest to policy makers. Some of these will be covered briefly in the next section. Others were not feasible to cover in the time available, but may be interesting to discuss at a later stage.

The analysis in this report relies primarily on the author's reading of publicly-available documentation about the different models as well as presentations made to the MMU. A detailed set of questions were also sent to the institutions responsible for the development and use of the models. Responses (as well as comments on an earlier version of this report) were received from the following:

- Thomas Bergman (Swedish Ministry of Finance)
- Gøran Hjelm (NIER, Sweden)
- Tom Pybus (UK Office for Budget Responsibility)
- Albert van der Horst (CPB Netherlands Bureau for Economic Policy Analysis)
- Niels Vermeer (Ministry of Finance, the Netherlands)
- Jukka Railavo (Finnish Ministry of Finance)
- Bing-Sun Wong (Canadian Department of Finance)
- Kam Szeto (New Zealand Treasury)
- Peter Eibye Bache (Danish Ministry of Finance)

[4] For example Dyvi et al. (ibid) and Hjelm et al. (ibid) provide a detailed assessment of, respectively, MODAG and KIMOD relative to a set of requirements similar to the themes discussed in this report.

In addition, the report has benefitted greatly from conversations with, and comments from, Amund Holmsen, Frank-Emil Jøssund, Yngvar Dyvi, Pål Sletten, Kristin Solberg-Watle, Leif Brubakk, Eilev Jansen, Ådne Cappelen, Olivier Blanchard, Mads Kieler, and members of the MMU.

The remainder of this report is structured as follows. Section 2 gives a brief overview of the main characteristics of the different models covered in this report. Section 3 analyses the models in the context of the eight themes outlined above, and Section 4 concludes.

2 Main Model Characteristics

Most ministries of finance surveyed in this report used (or previously used) a large macroeconometric model (LMM) as their primary tool for macro-fiscal forecasting and policy analysis. The exception is the Finnish Ministry of Finance which since 2011/12 has been using a small open economy Dynamic Stochastic General Equilibrium (DSGE) model. Nearly all institutions also employ econometric models including Vector Autoregressive (VAR) models and indicator/factor models for near-term forecasting. Other models are often used to provide input into the primary model or for specific purposes, including the long-term forecasting models DREAM in Denmark and SNOW and DEMEC in Norway, the NiGEM model for forecasting global developments, and the TAXUS model in the Netherlands and the HM Revenue & Customs model in the UK for forecasting tax revenues.

MODAG has since the 1980s been the primary forecasting model used by the Norwegian Ministry of Finance.[5] The model, which is developed and maintained by Statistics Norway, is embedded in an input-output system of the Norwegian economy and describes developments in 15 onshore industries and 3 separate public sectors. The long-run relations in MODAG are broadly consistent with economic theory, but as in other LMM models the dynamic adjustment to the long run (based on error-correction terms) is mainly data driven and in that sense atheoretical. In the short-run GDP is determined largely from the demand side of the economy, with supply factors (relative prices and wage setting) becoming more important in the long-run. Wage formation follows the Norwegian main-course model where wages across all sectors tend towards the long-run wage in the tradable sector that is determined by world prices and labor productivity. The model differs from other LMM models in this survey in that the steady-state level of unemployment is not uniquely determined by the description of firms' price-setting behavior and wage formation in the model. Thus, unlike models with a Phillips curve, unemployment is not required to adjust to a particular level for inflation to stabilize. This is consistent with empirical evidence on the system of collective wage bargaining in Norway (see e.g. Bårdsen and Nymoen, 2003). With the exception of the system of consumer demand which is estimated using Full-Information Maximum Likelihood (FIML), most of the models behavioral relations are estimated individually using a combination of OLS and two-stage least squares (2SLS).

The Swedish Ministry of Finance started using **KIMOD** as a tool for forecasting and policy analysis around 2008. The equilibrium part (medium to long term) of the model, which is

[5] The description of MODAG draws heavily on the description in Dyvi et al. (2015).

Table 1. Main Model Characteristics

Country	Developing Institution	Name	First version	Type	Size 1/	Industries 2/	Frequency	Endogenous monetary policy	Endogenous fiscal policy 3/	Model-consistent expectations 4/	Documentation
Norway	Statistics Norway	MODAG	1980s	LMM	2692/150	15/3	Annual	Yes	No	No	Boug and Dyvi (2008)
Sweden	National Institute of Economic Research	KIMOD	2004	LMM	40/5	1/1	Quarterly	Yes	Yes	Yes	Bergvall et al. (2007)
Denmark	Statistics Denmark	ADAM	1972	LMM	2500/90	11/1	Annual	No	No	No	Danmarks Statistik (2012)
Finland	Ministry of Finance	KOOMA	2011/12	DSGE	23/0	1/1	Quarterly	Yes	Yes	Yes	Obstbaum and Pietiläinen (2013)
The Netherlands	CPB	SAFFIER	2004	LMM	3000/25	4/1	Quarterly/ Annual	No	No	No	Kranendonk and Verbruggen (2007)
United Kingdom	Office for Budget Responsibility	…	1970s	LMM	500/30	2/1	Quarterly	No	No	No	Office for Budget Responsibility (2013)
Canada	Ministry of Finance	CEFM	1986	LMM	560/128	1/3	Quarterly	Yes	No	No	Robidoux and Wong (1998)
New Zealand	Ministry of Finance	NZTM	2002	LMM	200/8	1/1	Quarterly	Yes	No	No	Ryan and Szeto (2009)

1/ Number of endogenous variables/estimated equations. For the OBR Model both endogenous and exogenous variables are included as the exogenous variables (the exact number of which is unclear) are included in the code with their own equation. For the KOOMA model size refers to the number or measurement variables/equations.
2/ Private/public sector.
3/ SAFFIER includes a set of dummies that allows it to be used either in "balanced budget mode" (endogenous fiscal policy) or with exogenous fiscal policy.
4/ The term "model-consistent" is used instead of forward-looking as several of the LMM models surveyed in this report including forward-looking expectations that are proxied using current and past values of variables or using survey data.

developed and maintained by the NIER, differs from most other LMM models in that it includes a theoretically-consistent steady state with relatively strong microfoundations based on utility-maximizing overlapping generation (OLG) representative agents and profit-maximizing firms, forward-looking (rational) expectations, flexible prices, and (in the medium term) real rigidities in the capital and labor markets. Modelling of the labor market follows the search and matching literature which gives rise to a Beveridge curve that determines unemployment as a function of labor market tightness (job vacancy rate). Wage bargaining, on the other hand, is characterized by "right to manage" where (in contrast to Nash bargaining) firms unilaterally choose the level of production (and thus labor demand) after negotiating with workers over wages. As is standard in the search and matching literature, equilibrium unemployment is caused by inefficiencies in the (costly) process of matching vacancies and unemployed workers. Dynamics are handled in a separate more ad- hoc model which takes equilibrium developments as given and relies on a combination of error-correction terms and leads and lags to capture short-run movements in the data. The model's relatively strong microfoundations imply, however, that many of the parameters are difficult to extract from the data. As a result, parameterization relies to a greater extent than other LMM models on calibration. KIMOD's size and complexity means it is no longer used by the Ministry of Finance for producing forecasts, and will eventually be replaced by a smaller DSGE model currently being developed by the NIER. It remains, however, integral to the forecasting work and policy analysis done by the NIER.

ADAM is the primary model used by the Danish Ministry of Finance for forecasting and policy analysis. The model, which is developed by Statistics Denmark, shares several features with MODAG. These include the extensive use of error-correction terms to describe the dynamic adjustment to a steady-state described by long-run relations that are broadly in line with economic theory, backward-looking expectations, a fully-specified input-output system, production that is driven by aggregate demand in the short run and supply factors in the long run, and individual estimation of the model's behavioral relations. However, unlike MODAG interest rates are determined from abroad given Denmark's exchange rate peg and an assumption of perfect capital mobility. Moreover, wage formation is modelled using a Phillips curve where wage growth is a function of inflation and the deviation of unemployment from its steady-state level. The use of ADAM by the Danish Ministry of Finance is currently limited to ensuring projections are consistent with national account identities and definitions, though the model continues to be used extensively by Statistics Denmark. Work has recently started on development of a new more microfounded model with forward-looking expectations that can be used by the Ministry of Finance to analyze the behavioural impact of policy changes, and to describe the structural evolution of the economy which is a key determinant of fiscal policy in Denmark.[6]

Since 2004 **SAFFIER** has been the model used by the CPB to produce the macroeconomic forecasts on which the annual budget is based, and to conduct

[6] Further details are available on the Danish Ministry of Finance website.

policy analysis (e.g. the economic impact of political parties' electoral platforms). The model, which is developed in house by the CPB, differs from other LMMs in that a quarterly version is used for forecasts and policy analysis up to two years ahead whereas an annual version is used for medium-term scenarios. Unlike MODAG and ADAM the model does not break down the forecast into individual industries. However, like MODAG and ADAM long-run relations are broadly in line with economic theory, expectations are backward looking or exogenous, behavioral relations are estimated individually, aggregate demand is demand-driven in the short-run but determined by the economy's supply potential in the long-run, and error-correction terms are used to capture the economy's dynamic adjustment to the steady state. Unemployment in equilibrium is determined by wage bargaining by labor unions and labor demand (and price setting) by firms. As in KIMOD, wage bargaining is characterized by "right to manage" where firms unilaterally choose the level of production (and thus labor demand) after negotiating with workers over wages. A project is currently underway to develop a "flexible" DSGE model that will replace SAFFIER as the CPB's primary model for forecasting and policy analysis.

The Finnish Ministry of Finance has since 2011/12 used the DSGE model **KOOMA** that was developed in house as one of its tools for policy analysis. Though the intention is to eventually use the model for forecasting its current use is mainly as a cross-check on sectoral-level forecasts produced using partial equilibrium time-series tools. The model, which has yet to be fully documented, is a fairly standard small open economy DSGE model with a fixed exchange rate. However, unlike the typical DSGE model, modelling of the labor market follows the search and matching literature which gives rise to equilibrium unemployment and real rigidities in the labor market, while the coverage of the public sector is somewhat more elaborate than in the canonical model with distortionary as well as lump sum taxes. To date the Ministry has not estimated the model which instead is calibrated to match the main moments in the data.

The Office for Budget Responsibility (OBR) uses a LMM model originally developed by the UK Treasury in the 1970s as its main vehicle for producing economic forecasts. The model differs from other LMM models described in this report in that the forecast combines a 'top-down' approach (in the sense that GDP is determined directly) with a 'bottom-up' aggregation of expenditure components. In particular, though the model specifies that GDP is equal to the aggregate sum of expenditure components, this is combined with a top-down approach where high frequency data and survey indicators are used to forecast GDP in the short term, while an estimate of the output gap, a forecast of potential output, and an assessment of how quickly growth will return to potential, is used to provide a forecast of real GDP over the medium term. The supply side of the economy, including the main labor market aggregates, is determined outside the model. Like in other LMM models the behavioral relations are broadly consistent with economy theory and estimated individually. Unlike MODAG and ADAM, the model does not include a full industrial-level breakdown of the forecast, though the exogenous North Sea oil sector is treated separately.

The Canadian Department of Finance has used the Canadian Economic and Fiscal Model (**CEFM**) that was developed in house as their primary model for forecasting and policy analysis since 1986. Like in KIMOD the estimated long-run behavioral relations in the model are closely related to those derived using a model with relatively strong microfoundations including utility maximizing representative households and profit maximizing firm. Unlike in KIMOD, however, the CEFM model does not include forward-looking (rational) expectations. Neither does it include a theoretical model of equilibrium unemployment, which instead is derived as a function of structural factors and the average size of cyclical gaps. Wage formation is driven by developments in labor productivity. The model does not include an industry-level breakdown of the forecast. However, reflecting Canada's federal system the forecast is broken down into the three levels of the government. To ensure consistency with the theoretical structure a portion of the steady-state model is calibrated while the short-term dynamics (captured using a series of error-correction terms) are estimated empirically.

The New Zealand Treasury Model (**NTZM**) was developed in house by the New Zealand Treasury, and has been used as their primary forecasting and policy analysis since 2002. As in KIMOD and CEFM, the NTZM models the long-run steady state of the economy and the dynamic adjustment to the steady state separately. The steady state-model includes a "production" block with relatively strong microfoundations that describes the input and output decisions of a representative profit-maximizing firm. The demand side of the steady-state model and the labor market are broadly consistent with economic theory but with weaker microfoundations. The model's short-run dynamics are handled using a combination of error-correction terms and lags. With the exception of steady-state wages (which is determined in the production block of the model), the labor market in the steady-state model (including equilibrium unemployment) is largely exogenous. In the dynamic model, wage growth is modelled using an expectations-augmented Phillips curve (inflation expectations are taken from the term structure of interest rates). Unlike other LMM models the production block of the model is estimated as a system using FIML. The remainder of the model is calibrated. A project is currently underway to develop a smaller LMM model similar to the LENS model of the Canadian economy developed by Gervais and Gosselin (2014).[7]

3 Key Themes

3.1 Theme 1: Theoretical Foundations

Most LMM models surveyed in this report describe relations between macroeconomic aggregates that may be consistent with economic theory but are not derived from an explicit treatment of economic agents' preferences, constraints, and

[7] The LENS model shares several characteristics with the Fed's macroeconomic model (see footnote 8). In particular, it is based on a set of estimated behavioral relations with relatively strong theoretical foundations including forward-looking expectations and adjustment costs.

expectations about the future. Exceptions to this are KIMOD and (to a lesser extent) the CEFM and NZTM models which include long-run steady state models with relatively strong microfoundations. By contrast most DSGE models derive the models' behavioral relations using a microfounded model which includes households and firms that maximize their objective functions subject to resource constraints and expectations about the future. Moreover, the behavioral relations in DSGE models are derived in general equilibrium ensuring that the behavior of economic agents over the business cycle is internally consistent.

It is important to be clear about what is meant by "equilibrium" in this context. The general equilibrium concept in DSGE models is broader than in models with a perfectly-competitive equilibrium characterized by flexible prices and wages, and business cycles where the economy is assumed to be in a state "disequilibrium". Indeed, DSGE models emerged partly due to a desire to explain business cycles as an equilibrium phenomenon consistent with households and firms doing as well as they can given the constraints they face and the economic environment created by the behavior of others (Woodford, 2009).[8]

One perceived benefit of the microfoundations on which DSGE models are based is robustness to the critique by Robert Lucas (Lucas, 1976) that the parameters of reduced-form behavioral relations in LMM models cannot be considered invariant to changes (or expectations of future changes) in macroeconomic policy, and are likely to break down when such changes occur. Both the Finnish Ministry of Finance with the KOOMA model and the CPB in describing their future model development plans point to robustness to the Lucas critique as among the reasons for the choice of a DSGE model as their primary modelling tool. The CPB and the Danish Ministry of Finance also point to the lack of forward-looking expectations as one of the main weaknesses of SAFFIER and ADAM. Similarly, Bergvall et al. (2007) and Robidoux and Wong (1998) note that the relatively strong microfoundations in KIMOD and CEFM make them more suitable than other LMM for policy analysis where the Lucas critique is likely to be of particular concern.

As pointed out by Woodford (2003) the strong theoretical foundations in DSGE models also have the benefit that business cycles resulting from shocks that hit the economy can be given a structural interpretation. This makes it possible to use the model to tell a theoretically consistent story about the evolution of both historical data and the model forecast that can be useful for communication purposes.[9] This

[8] Some LMM models, notably the Fed's macroeconomic model (FRB-US) shares many characteristics with modern DSGE models including endogenous expectations, economic decisions based on optimization problems, and implied long-run dynamics that satisfy transversality conditions and are thus consistent with an equilibrium model. Moreover, unlike the LMM models in this survey that employ arbitrary lags or partial equilibrium error correction terms to account for short-run dynamics, cyclical fluctuations in the FRB-US model are modeled as an integral part of the dynamic optimization problems of the various agents using adjustment costs. For further details see Brayton et al. (2014).

[9] Prominent macroeconomist Paul Romer (Romer, 2016) argues, however, that the overreliance on a multitude of unobservable shocks (or "imaginary forces" as Romer calls them) rather than the dynamics inherent in the behavioral relations in the model to explain most of the fluctuations in macroeconomic variables is a significant weakness of these

aspect was highlighted by the Swedish Ministry of Finance and the NIER, as well as the CBP, as one of the main reasons to develop a DSGE model as their primary modelling tool. Similarly, the OBR pointed to the relatively "loose" theoretical structure of their model as one reason why it was not used for scenario analysis.

Other users of LMM models see the lack of microfoundations in LMM models as less of a problem. Boug (1999) and Danmarks Statistik (2012), for example, note that empirical support for the Lucas critique and rational (model consistent) expectations are limited.[10] Many LMM models instead include forward-looking expectations (e.g. about future inflation or interest rates) that are determined outside the model using market information or empirical VAR models, and thus have stronger empirical support.[11] Moreover, Dyvi et al. (2015) argues that the lack of consensus surrounding what motivates behavior makes a reduced-form model that imposes fewer restrictions preferable, especially as these restrictions are often guided more by the need to keep the model tractable.

In addition, as noted by Pedersen (2012) it remains an open question whether DSGE models have simply replaced the partially ad-hoc assumptions about the reduced-form relationship between macroeconomic aggregates (e.g. price dynamics) in LMM models with ad-hoc restrictions on the behavior of economic agents that, once confronted with the data, may themselves be sensitive to regime change (e.g. the frequency of price changes by firms). Added to this, Geweke pointed out more than two decades ago (Geweke, 1985) that aggregate representative agent macro models typically fail to consider the challenges associated with aggregating preferences and production technologies of heterogeneous households and firms. In fact Yongsung et al. (2015) show that when a representative agent DSGE model is estimated on data simulated using a heterogeneous agent model, estimates of several key preference matters vary depending on the policy regime, and can therefore not be considered policy invariant.

Moreover, the microfoundations in DSGE models (and LMM models like KIMOD) have the drawback that they typically result in a lack of flexibility. In particular, the general-equilibrium nature of DSGE models means adding new mechanisms or variables cannot be done as easily as in partial-equilibrium LMM models. Danmarks Statistik (2012), for example, touts the ease with which parameters or behavioral equations in ADAM can be changed, a fact which may help explain the use of slightly different variants of the model in different ministries and the private sector. Similarly, the OBR notes that the flexibility of their LMM model makes it easy to

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models. As the experience with Norges Bank's DSGE model (NEMO) shows, however, the persistence of shocks (and thus their importance for the dynamics of the model) can be reduced gradually over time as improvements to the model are made.

[10] Statistics Norway has an active research program aimed at testing the empirical relevance of rational expectations in Norway (see e.g. Boug et al., 2016; Krogh, 2015; Nymoen et al., 2013; Boug et al., 2010; and Boug et al., 2006).

[11] As noted by Ådne Cappelen in written comments on this report, the FRB-US model is an example of a LMM model where the user can choose between VAR-based or model-consistent expectations.

incorporate judgement into their forecast. On the other hand, the CPB notes the amount of work necessary to add new elements to a DSGE model as a major drawback. As a compromise they have decided to develop a "loosened and enriched" DSGE model that allows for non-optimal and inconsistent behavior across markets (e.g. households' behavior in the labor market may be inconsistent with their consumption choices) as well as a richer lag structure, even though this will result in a weakening of the model's microfoundations.

The microfoundations in DSGE models also mean the resources needed for model development rises exponentially with size, a fact which might help explain why DSGE models tend to be significantly smaller and more aggregated than LMM models (an aspect we return to below). Hjelm et al. (2015a), for example, argues that the ability to handle a large amount of variables needed as an input to public finance calculations is one of the main reasons for the extensive use of LMM models across ministries of finance. Similarly, the CPB argues that a pure DSGE model makes it "unfeasible to include the level of detail required by our customers".

The looser theoretical structure of LMM models is also often justified by the need to have a model that can provide accurate forecasts of the economy. Robidoux and Wong (1998) for example, argue that "a tradeoff often exists between having a model that performs well in forecast mode and having one with theoretically desirable simulation properties". Moreover, Hjelm et al. (ibid) notes that "DSGE models are relatively time-consuming to use effectively in a forecasting environment". The extent to which LMM models outperform DSGE models in terms of forecasting is, however, a matter of debate (see e.g. Edge, Kiley, and Laforte, 2010).

3.2 Theme 2: Empirical Foundations

Sound empirical foundations are critical not only for accurate forecasting and policy analysis, but for credibility. Ideally, the models in this report should be estimated using full-information methods that take into account all relevant cross restrictions. In reality the computational burden means that most LMM models are estimated equation-by-equation using a combination of OLS and two-stage least squares (2SLS). The exceptions are KIMOD which because of its forward-looking expectations is primarily calibrated, and the MODAG and NZTM models which rely on a combination of FIML, OLS, 2SLS, and calibration.[12] The sole DSGE model in this survey, KOOMA, is entirely calibrated.

While the practice of estimating LMM models equation-by-equation is understandable from a practical point of view, it is not without risks. In particular, Johansen (2002) notes that the statistical implications of combining several small models estimated separately using limited-information methods (e.g. 2SLS) into one larger model are largely unexplored. More broadly, Christopher Sims in a seminal

[12] In correspondence, Gøran Hjelm at the NIER noted that the additional data available after the move to a quarterly version of KIMOD in 2012/13 means the model could in principle be estimated equation-by-equation, though this has not been done.

paper argued that “while individual demand equations developed for partial equilibrium use may quite reasonably involve an array of restrictions appropriate to that use, it is evident that a system of demand equations built up incrementally from such partial-equilibrium models may display very undesirable properties” (Sims, 1980).[13] In the same vein, Blanchard (2016) argues that “experience from past equation-by-equation models has shown that their dynamic properties can be very much at odds with the actual dynamics of the system.” Indeed, both the CPB and the Danish Ministry of Finance point to the lack of system estimation as one of the main weaknesses of their existing models and a reason for replacing then with models that can, to a greater extent, be estimated as a system.

On the other hand, Ray Fair reports in a comparison of different limited- and full-information methods for estimating his LMM model for the US that “the estimates are fairly close to each other” (Fair, 1994, pp. 226-227). Moreover, Eitrheim et al. (2005) point out that the practice of combining small models estimated separately using limited-information methods has the advantage that each sub model is robust to misspecified relations elsewhere in the system. Finally, Danmark’s Statistik (2012) notes that in ADAM the potential problem of individually estimated equations not working well together is somewhat mitigated by continually tweaking the estimation until the properties of the overall system are deemed satisfactory.

In correspondence Ådne Cappelen at Statistics Norway also argued that the gains from having a disaggregated model that makes it possible to study different sectors of the economy more than outweighs the costs of not being able to estimate all the parameters using FIML or other full-information methods. Put differently, Eitrheim et al. (2005) conjecture that “biases [arising from more aggregated specifications where gross coefficients pick up the combined effects of the included explanatory variables and correlated omitted variables] are more harmful for policy makers than the simultaneity bias one may incur by combining submodels”.

In contrast, although the KOOMA model is currently calibrated, most DSGE models are typically estimated using full-information Bayesian maximum likelihood.[14] Indeed the intention is that the DSGE model under development by the NIER and the CPB will be parameterized in this fashion.

Like other full-information methods, Bayesian estimation has the benefit that it takes into account the restrictions imposed by the entire model on the data-generating process. In theory this should avoid some of the risks with estimating models equation-by-equation that we highlighted above. However, as noted by Chari et al. (2009), many DSGE models are poorly identified which can lead to multimodal likelihood functions, and the available data is often not very informative about many of the parameters. As a result, some the parameters in DSGE models are usually

[13] Sims in the same article does, however, acknowledge that models estimated in this way still be useful for policy and forecasting analysis.

[14] In correspondence, Jukka Raivalo at the Finnish Department of Finance noted that the intention is to estimate KOOMA once the model is completely finalized. He cautioned, however, that based on the Bank of Finland’s experience the volatility and number of structural breaks in Finnish data means this will not be an easy task.

calibrated while others are estimated using relatively tight prior distributions. As Blanchard (2016) notes, the risks is that this ends up driving the results and thus undermining the empirical foundations of the model.

3.3 Theme 3: Comprehensiveness

The models surveyed in this report differ significantly in terms of how detailed a representation they provide of the underlying economy. With the exception of the NZTM model and KOOMA, the structure of the models surveyed in this report is closely linked to the detailed expenditure-based concept of GDP used in the national accounts. MODAG, ADAM, CEFM, SAFFIER, and the OBR model in addition provide a full breakdown of the income side of the national accounts. MODAG and ADAM also provide a detailed industry-level breakdown of the economy based on input-output matrices in the national accounts.

As noted in Dyvi et al. (2015) this level of disaggregation has both costs and benefits. On the one hand, the industry-level breakdown in models like MODAG and ADAM makes it possible to identify how aggregate or industry-specific shocks are transmitted through the economy. This is particularly useful in economies with a heterogeneous industrial sector (e.g. a commodity sector), and where the performance of a particular sector may be of particular political concern (e.g. the competitiveness of the non-commodity tradable sector).

Moreover, the OBR and Dyvi et al. (2015) argue that a detailed breakdown of the expenditure and income side of GDP is necessary for a full description of how general economic conditions (activity, wages, and prices) determine developments in government income and expenditure. Similarly, Ådne Cappelen in written comments to this report notes that a disaggregated model is essential for understanding how fiscal policy impacts the economy. As an example he points to the failure of most aggregate macro models (e.g. DSGE models) to distinguish between employment and hours worked which is necessary to differentiate between the impact of taxation on labor supply at the extensive and intensive margin.

On the other hand, Dyvi et al. (ibid) and the Canadian Department of Finance note that preliminary national accounts figures and model projections at the industry level are typically less accurate and therefore more demanding to interpret than those at the aggregate level. However, the models' dynamic lag structure mean that projections at the industrial level have an impact on future years and can therefore not be ignored in the process of preparing the forecast. Moreover as the CPB notes, the level of disaggregation in some LMM models makes it harder to interpret the output and reduces transparency. In Sweden, Hjelm et al. (2015a) note that the Ministry of Finance and the NIER do not require a large model with a high degree of disaggregation as the model forecast is not used as a direct input into public financial calculations. In fact the Canadian Department of Finance argued that even when the model is used for this purpose, an industry-level breakdown is not necessary as preparation of the budget does not involve a decision about which industry to tax or spend in.

The models also differ significantly in terms of the number of variables/mechanism that are not modelled and treated as exogenous. All the models surveyed in this paper take foreign demand and prices as exogenous. Similarly, as we discuss in the next section all the models take the bulk of government's spending plans as given. Several variables determining labor supply are typically exogenous, including population growth, hours worked per employee, and (in NZTM and SAFFIER) the labor force participation rate.[15] Moreover, in the long-run labor productivity is exogenous in several of the models (ADAM , SAFFIER, and NZTM) though in the short-run it may fluctuate with production and factor intensity. The OBR model differs from the other LMM models in this survey in that the entire supply side of the economy is determined separately from the main model, a factor which no doubt helps explain it smaller size relative to other LMMs in this survey. Finally, the ADAM and SAFFIER models take monetary policy as exogenously determined reflecting their fixed exchange rate regime.

3.4 Theme 4: Fiscal Policy

Reflecting their purpose all the models surveyed in this report include a description of the public sector. There are, however, large differences both within and between model types. The sole DSGE model in this survey, KOOMA, has a relatively simple characterization of fiscal policy. As Hjelm et al. (2015a) notes, this is typical for DSGE models that may have a number of fiscal variables but typically few transmission channels through which fiscal policy can have a significant impact the economy. As a result, the fiscal transmission mechanism in DSGE models is often relatively weak.[16] LMM models, on the other hand typically have a more detailed description of the fiscal sector. Indeed the Canadian Department of Finance point to the need for a detailed coverage of the public sector as one of the reasons for the use of a LMM model as their primary forecasting model.

All LMM models in this report provide a breakdown of government spending into investment, consumption, and transfers. In KOOMA government spending is divided into consumption and transfers.[17] As noted previously, government spending is (with a few exceptions) exogenously determined in all the models. The exceptions include items linked directly to other components of the model (e.g. capital consumption allowances and transfers indexed to inflation, wages, unemployment, or demographic developments), as well as deflators for public spending.

The modelling of public revenues, on the other hand, is more heterogeneous. The treatment in KOOMA is, understandably, the least detailed and only includes taxes

[15] In SAFFIER labor force participation is exogenous in the long-run (determined using a separate microsimulation model for the labor market, MICSIM) but allowed to vary with the cycle.

[16] There are, however, examples of DSGE models that include a rich description of the fiscal sector and thus a stronger fiscal transmission mechanism, notably Coenen et al. (2012) and Kumhof et al. (2010).

[17] Like in most DSGE models, transfers in KOOMA transfers are simply lump-sum transactions between households and the government to balance the government's budget constraint.

on consumption and labor. Among the LMM models MODAG, ADAM, CEFM, and the OBR model include a rich breakdown of public revenues into direct taxes (e.g. labor and corporate income taxes), indirect taxes (e.g. VAT receipts), and non-tax receipts (e.g. interest receipts). As an example, the OBR model includes 26 different direct taxes, 27 different indirect taxes, and 16 different categories of non-tax receipts. In KIMOD, SAFFIER, and the NZTM on the other hand, government revenues are limited to a combination of direct taxes on wage income and dividends/profits, indirect taxes on consumption, social security contributions, and custom duties. MODAG and ADAM in addition include different tax-income brackets which allow them to model marginal tax rates.[18]

The models also differ to the extent government employment is captured. Government employment can be included as a separate component of government consumption as in ADAM, SAFFIER, and the OBR model, or indirectly as an input into government production (which in turn forms part of government consumption) as in KIMOD, MODAG, and the NZTM. Regardless of how it is modelled, the transmission mechanism of government employment is distinct from that of non-wage government consumption. In the SAFFIER model, for example, a shock to government employment has a much greater impact on private consumption, wages, and unemployment than a shock to government non-wage consumption, which mainly operates mainly through investment. More generally, Ådne Cappelen in written comments on an earlier version of this report notes that failure to account for government employment can result in the misleading policy conclusion that there is little fiscal policy can do to stimulate employment and reduce unemployment.

With the exception of KIMOD none of the LMM models surveyed in this report model the way in which government spending in excess of revenue collection is financed. As a result, the potential impact of greater debt financing on household savings and investment is ignored. This omission is common in LMM models where interest payments on government debt are typically calculated outside the model using a separate model and imposed exogenously.

The general equilibrium nature of DSGE models, on the other hand, makes it necessary to specify how any fiscal deficit is financed. KOOMA, like many DSGE models, simply assumes that the government budget is balanced each period using lump-sum transfers. However, DSGE models with a more elaborate description of the public sector often allow governments' to run fiscal deficits financed by issuing debt (see e.g. Coenen et al. 2012 and Peiris and Saxegaard, 2007). As is well-known, in models with non-Ricardian households the timing and nature of future tax increases to repay this debt can have an important impact on behavior.

Finally, most of the models surveyed in this report treat fiscal policy as exogenous in the sense that they do not within the model impose a rule that ensures the sustainability of the public finances. This reflects their primary purpose of assessing

[18] This feature used to be part of the CEFM model. However, it was removed because the model was found to be unable to properly account for the movement of tax filers between different tax brckets. A micro-data satelitte model is now being used for the same purpose, with the results imposed on the CEFM model simulations.

the real economy implications of an exogenously-determined fiscal policy. The exceptions are KIMOD and KOOMA where the requirement of a well-defined steady state necessitates a fiscal balancing mechanism.[19] As noted above, in KOOMA this is simply an assumption that the government's budget is balanced each period using lump-sum transfers. In KIMOD the labor income tax rate is used to ensure net debt converges to its target in the long-run. In principle any other fiscal policy variable could be used for the same purpose. Moreover, it is worth noting that although DSGE models (and KIMOD) have a well-defined steady state that ensures the sustainability of fiscal policy in the long-run, they can be simulated conditional on a constrained path for some of the endogenous variables, for example to ensure consistency with a fiscal rule that may not be possible to summarize in a fiscal reaction function.

3.5 Theme 5: Model Use

As noted by Hjelm et al. (2015a), models at ministries of finance can be useful for forecasting, policy/scenario analysis, and historical and forecast decomposition (storytelling). To this list one can add ex-post forecast evaluations and quantification of the uncertainty surrounding the forecast.

Most of the models covered in this report are used to forecast the real economy. The exceptions are KOOMA and KIMOD where organizational issues (e.g. the short forecasting timetable and a tradition that forecasts are done in a decentralized fashion by sector experts) mean that the models are not/no longer used for this purpose.[20]

However, there are important differences among the LMM models in terms of how the actual forecast is done. In the OBR the level of output is determined partly outside the model, with the model itself used to forecast the components of GDP and the dynamic adjustment to the steady state. Similarly, though ADAM is capable of producing forecasts for GDP, in practice the Ministry of Finance does this outside the model using empirical models, with the use of ADAM limited to keeping track of national account identities and definitions. The other LMM models in this survey are used to forecast real GDP though, as noted previously, many of the assumptions driving potential growth (e.g. labor productivity and labor force) are exogenous. With the exception of the NIER (whose forecast is not used by the Ministry of Finance), all institutions surveyed in this report note that, in addition to the model, judgement plays an important role in the final forecast.

The DSGE models under development by the NIER and the CPB are also intended to be used to forecast the real economy. A challenge is the fact that DSGE models normally allow for at most one common trend for the non-stationary variables. This is clearly at odds with the data, which often exhibits significant differences in real trends across variables. A pragmatic (though not entirely consistent with the

[19] SAFFIER includes a dummy which allows it to be used in "balanced budget" mode or to target a specific level of debt and the fiscal deficit.
[20] Though no longer used by the Ministry of Finance, KIMOD continues to be used by the NIER for projection purposes and is therefore included in this discussion.

assumptions of the model) approach followed in some institutions that use DSGE models is to simply estimate the model in gap form by detrending the data, and then to superimpose the model simulations on a (potentially time-varying) growth path for the endogenous variables determined outside the model.

For the purpose of near-term forecasting and nowcasting, all the models surveyed in this article are supplemented by empirical models that are able to handle high-frequency data and typically outperform structural models in terms of forecast accuracy at shorter time horizons. The Norwegian Ministry of Finance, the Canadian Department of Finance, the Finish Ministry of Finance, and the New Zealand Treasury, for example, use indicator- and factor-models to produce short-term forecasts. The Swedish Ministry of Finance and the CPB have in addition developed relatively large (19 and 25 variables respectively) Bayesian VAR models that are used directly or as a cross-check on the main model forecast.

The CEFM model appears to be the only model in this survey that is both capable of and used to produce detailed forecasts of public sector revenue. As noted previously, MODAG, ADAM, and the OBR model include the necessary detail to do this, but in practice the models currently don't appear be used for this purpose. In the case of MODAG, this is mainly related to an internal process whereby projections are "locked" relatively early on in the budget process. In the case of the OBR model the various forms of revenue are modelled as endogenous variables imposed on the model, where the forecast of these variables are generated using detailed models operated by HM Revenue & Customs. The other models in this report do not include the necessary details to produce a breakdown of public sector revenue, though it is unclear to what extent their more aggregate forecasts of public revenue are used as an input into other more detailed models.[21] In the case of SAFFIER this likely reflects the fact that the CPB's role is specifically limited to providing real sector projections as an input into the budget process, with the actual budget forecasts produced "in house" by the Ministry of Finance.[22]

With the exception of the OBR model, all the models surveyed in this article are actively used for scenario/policy analysis. As noted previously, DSGE models (and KIMOD) are, in principle, better suited for this purpose given that they are designed to be more robust to the Lucas critique. However, a challenge is the fact that permanent shocks common in fiscal policy (e.g. permanent tax changes) that change the steady state cannot easily be handled in DSGE models that are typically linearized and used to analyze perturbations around a fixed steady state (and macroeconomic policies to minimize those perturbations). The Finnish Ministry of Finance reports that permanent policy changes are simply not analyzed using the

[21] Both the OBR and the CPB note that the production of the real sector forecast involves several iterations to capture the interdependence between real sector and public finance forecasts.

[22] A related point is the extent to which models are used to assess the fiscal stance. In Denmark, for example, fiscal policy is determined on the basis of the economy's structural level. The fact that ADAM does not allow for the determination of the structural level is perceived as a significant weakness and was one of the motivating factors behind the decision to develop a new model.

model. The NIER and the CPB, on the other hand, report that they intend to rely on a combination of stochastic simulations of high-persistence shocks to proxy permanent policy changes and deterministic simulations where the model is used to trace the transition between two steady states characterized by, for example, different tax rates.[23,24]

Another common use of models is to explain the drivers of recent economic developments and the forecast for the economy. As noted in Dyvi et al. (2015), for example, the Norwegian Ministry of Finance would like to use models for this kind of "storytelling", which can be helpful for both internal and external communication. In the case of MODAG, its ability to explain recent development is constrained by the fact that it is, unlike most of the other models in this survey, an annual model. Moreover, MODAG and the other LMM models in this survey lack the microfoundations necessary, and are simply too large, to provide a structural explanation/decomposition of movements in the historical data and the model forecast using the model's residuals/shocks.[25] On the other hand DSGE models, including KOOMA, are ideally suited and regularly used for this purpose.[26]

The NIER notes, however, that while KIMOD is not used for a full historical and forecast decomposition, it is used to analyze the difference between the model forecast and historical data and the final forecast (which incorporates judgement). The Canadian Department of Finance report using their CEFM model for a similar purpose. Moreover, both Dyvi et al. (2015), the CPB, and the OBR note that individual equations in the model can help give a (partial equilibrium) explanation for the movement in individual variables. Finally, by "turning off" certain parts of the model (e.g. monetary policy) or restricting certain outcomes (e.g. developments in net lending) all theory-based models can shed light on the importance of different mechanisms in driving the forecast.

A final potential use of a model is the quantification of uncertainty surrounding the forecast. This uncertainty can take a number of forms, including forecast uncertainty derived from the distribution of past forecast errors, uncertainty due to the model's imperfect characterization of the data-generating process, parameter uncertainty, and uncertainty resulting from different assumptions about the evolution of particular variables (e.g. labor productivity) or agents in the economy (e.g. monetary policy). The CPB for example, uses its model to quantify the uncertainty surrounding their central forecast on a consistent basis. Starting with the 2017 National Budget, The

[23] In a deterministic model agents act as if future shocks are known, while in a stochastic setting only the distribution of shocks is known. Unless the model used for stochastic simulations is linearized to the second order or higher, the two cases are practically the same.
[24] An alternative solution would be to use a Markov-Switching DSGE Model (see e.g. Maih, 2015) that explicitly allow changes in regime (steady-state) over time.
[25] Note, however, the caveat in footnote 9 regarding the interpretation of these shocks which, among other things, may reduce the usefulness of such a decomposition for communication purposes.
[26] See e.g. Kuismanen (2016a)

Norwegian Ministry of Finance has also started using MODAG for this purpose. In all cases, uncertainty is derived from the distribution of past forecast errors.[27]

3.6 Theme 6: Institutional Framework

An interesting aspect of the models discussed in this report is the difference in the institutional framework in which these models operate, i.e. who has developed the model, who maintains it, and who uses it to produce forecasts for the ministry of finance.

On one extreme are KOOMA, the NZTM, and the CEFM which are developed, maintained, and operated by the finance ministries themselves. In the case of the recently-developed KOOMA model this approach was natural given that the previous KESSU model was also developed in-house. More generally, both the Finnish Ministry of Finance and the Canadian Department of Finance emphasize that developing and maintaining the model serves to increase human capital within the institution. Indeed, the Swedish Ministry of Finances notes this as one of the drawbacks of the fact that development of their model is outsourced. The Finnish Ministry of Finance and the Canadian Department of Finance also feel that maintaining and developing the model themselves makes it easier to preserve knowledge about the model and to transfer that knowledge to new people when personnel changes occur. It is also possible that developing a model in-house makes it more likely that it matches the requirements of the finance ministries. Indeed the Danish Ministry of Finance notes that outsourcing development of ADAM to Statistics Denmark has resulted in a model that is ill suited for certain purposes (e.g. the analysis of structural reforms to expand the labor supply). However, there is also a risk that the work pressures and resource constraints make it difficult to shield model developers in ministries of finance from other responsibilities.

On the other extreme is the CPB who developed SAFFIER, is responsible for maintaining it, and uses it to produce forecasts of the real economy with no input from the Ministry of Finance (beyond information about fiscal policy that is used as an input to the model). Feedback from the Dutch Ministry of Finance suggests this institutional setup simply reflects the CPB's long-standing responsibility for producing projections of the real economy. The OBR has the same responsibility in the UK, but in this case responsibility for maintaining and developing the model is shared with the UK Treasury.[28]

MODAG, ADAM, and KIMOD fall in between these two extremes, with responsibility for developing and maintaining the model outsourced to other agencies, while forecasting is done in the ministries themselves. In the case of Norway, Yngvar Dyvi argued in meetings that reliance on Statistics Norway for development and maintenance was particularly useful given MODAG's close correspondence with the national accounts. It also helped ensure that model users at the Ministry of Finance

[27] The OBR also quantifies the amount of uncertainty surrounding their forecast, on the basis of past forecast errors, though this is done outside the main macroeconomic model.
[28] The OBR remains solely responsible for projections however, and has complete freedom over the version of the model that is used to produce the forecast.

were part of a modelling environment outside the Ministry. In Sweden this institutional setup appears to largely reflect a lack of capacity within the Ministry of Finance for developing and maintaining large complicated models, and thus an assessment that outsourcing would increase “the probability that the model will be used, maintained, and simply survive”. The NIER also argues that its broader role as a research institute makes it easier to recruit highly qualified staff with the requisite skills for model development. The Danish Ministry of Finance argues development of ADAM by Statistics Denmark has increased the publicly perceived credibility of the model, albeit at the cost of having a model that is not tailor made to the needs of the Ministry. This in turn has made it necessary at times to make adjustments to the model which among certain commentators has been perceived as “tampering” to obtain political convenient results. In a similar vein, Yngvar Dyvi notes that reliance on an outside institution for development and maintenance of the model can also pose communication challenges, including when differing assumptions (e.g. regarding financing of additional government spending) result in divergent assessments of policy proposals.

3.7 Theme 7: Resource Costs and Knowledge Management

As noted in Hjelm et al. (2015a), resource availability will have a significant bearing on the number, type, and size of models used by an institution like a ministry of finance, as well as the institutional setup discussed previously. It will also have an impact on whether it is feasible to embark on a project to develop a new model. Indeed Hjelm et al. (ibid) argues that “the fact that an existing model has existed for a long time may be reason enough to ensure that it is still used – simply because it takes time and resources to develop a new one”.

Given that most LMM models have been in existence for a long time, information about the resource costs surrounding their development is scarce. An exception is KIMOD where development started in 2002, with the model becoming operational for policy analysis in 2004, and in 2007 for forecasting. It’s likely that the startup costs surrounding some of the larger LMM models covered in this report were higher, though this may have been partly offset by the relatively loose theoretical structure of some of these models.

More is known about the costs of developing DSGE models. The Finnish Ministry of Finance started its modelling project in 2007, and it took a three person team until 2011/12 to make KOOMA operational. Similarly, Norges Bank employed 3 people over 2/3 years to develop their primary model, NEMO. At the Bank of England available documentation suggests seven people were directly involved in development of their new suite of models, including the DSGE model COMPASS, over a 2¼ year period. A further eight people worked on the IT interface and business processes. In Sweden, the work assessing the appropriate modelling framework for the Ministry of Finance and the NIER started in 2014. The official decision to develop a DSGE model was taken in December 2015 with the target date for having a model for policy analysis set to end-2018. Currently, four employees at the NIER are engaged in development of the model, two working full time and the other two half time, though the aim is to increase this to five if staff with

the requisite skills can be recruited. Hjelm et al. (2015a) note that estimating the model and starting to use it for forecasting will likely require four full-time equivalent (FTE) employees a further two years. At the CPB, four people are currently working on the project to develop a new "loosened and enriched" DSGE model. Development of the model, which started in 2015, is anticipated to be completed in 2018.

Maintenance and resource costs are difficult to compare given differences in the frequency with which the models are re-estimated, and in how often the models are used to produce forecasts. The Canadian Department of Finance reports that 2 to 3 employees are actively involved with maintenance and development of the CEFM model (including re-estimation of the model on a yearly basis), though as many as 10-15 employees regularly use the model for forecasting and policy analysis. At the New Zealand Treasury development, maintenance, and use of the NZTM is estimated at two FTEs. At the CPB around 4 employees are able to use and make changes to SAFFIER, which is re-estimated approximately every 5 years. The operational costs of producing projections four times a year are estimated at two FTEs. At the OBR only one person is actively involved in making changes to the model, though development of the model more generally (including re-estimating parts of the model every summer) also absorbs resources from HM Treasury. In Denmark, resource costs related to ADAM are estimated at around 2 FTEs at the Ministry of Finance and 8 FTEs at Statistics Denmark. Resource costs surrounding MODAG appear to be similar, with Dyvi et al. (2015) reporting that maintenance and operation of the model, which is fully re-estimated every 2 to 3 years) absorbs five FTEs at Statistics Norway.[29] A further one FTE divided among three people are involved in the use of MODAG at the Ministry of Finance.

Despite being smaller, maintenance and operational costs surrounding DSGE models are similar, possibly reflecting their general-equilibrium nature of these models which makes it challenging to make changes and to re-estimate the model. At the Finnish Ministry of Finance two staff currently maintain and operate KOOMA, while at the NIER the expectation is that three to four employees working 50 percent of the time with the model will be required to run and maintain the new DSGE model once it is completed. Operating the model is expected to absorb a further one FTE at the Swedish Ministry of Finance.

The inherent complexity of all the models discussed in this report creates challenges surrounding knowledge management. Indeed the Swedish Ministry of Finance at the September 2015 meeting of the MMU noted that model complexity and the resulting overreliance on a few individuals that left the institution was one of the main reasons why KIMOD was no longer in use. In correspondence, Albert van der Horst of the CPB suggested that overreliance on a few key individuals was one of the reasons why the decision was taken to replace SAFFIER with a smaller model. Kam Szeto at the New Zealand Treasury also pointed to overreliance on a limited number of staff able to run the model as a major weakness of the NZTM model. More generally,

[29] This includes work with maintaining and operating the quarterly version of (KVARTS).

Hjelm et al. (2015a) argues that overreliance on a few key individuals threatens the future use of both the LMM models FRBUS at the US Federal Reserve and NiGEM at the NIESR in the UK.

Other institutions surveyed in this report are more sanguine. Both the Canadian Department of Finance and the OBR argue that strict routines surrounding documentation of the model and any changes is a key component of their knowledge management strategy. At the same time, the OBR argues that solving/rewriting the model is a relatively simple process that does not require specialist knowledge and is facilitated by the fact that the model is run in Winsolve (a platform for solving non-linear models with an emphasis on user friendliness). Similarly, the New Zealand Treasury points to the fact that the NZTM is run in TROLL (a powerful platform for solving non-linear models) as a major weakness.[30] Dyvi et al. (2015) argue that the clear and transparent programming of MODAG makes it easy to bring new staff up to speed on the technical aspects of the model, though they acknowledge that the comprehensiveness and size of the model means that using the model for forecasting and policy analysis is more challenging. Finally, the Danish Ministry of Finance notes that a conscious attempt is being made to spread tasks related to using ADAM among a broader group of people, and to organize courses on how to use the model for new employees, in an attempt to reduce risks related to staff turnover.

Resource costs and knowledge management also depend on the extent to which it is possible to draw on knowledge outside the institution, and on how easy it is to recruit personnel with the skills necessary, and interest in working with these models. Indeed, Hjelm et al. (ibid) notes that because of limited resources for model development it makes sense to select a model that allows the institution to draw on an active community of model users and developers.[31] This, coupled with the perception that the LMM approach may complicate recruitment of new PhD graduates and thus exacerbate vulnerabilities related to the departure of key personnel, is the primary reason for why a DSGE model was chosen as the future model of the Swedish Ministry of Finance. At the same time, Dyvi et al. (2015) note that compared to other countries there is a relatively large research community involved with LMM models in Norway, including at Statistics Norway and universities, though they acknowledge that the emphasis on DSGE models in teaching and research may complicate future recruitment.

[30] Among the other models, MODAG, KIMOD, and the CEFM are run in TROLL, while ADAM is run in a GEKKO, a software package designed in Denmark for the purpose of solving and analyzing large time series-based models like ADAM. SAFFIER is run in an in-house software environment called ISIS, though consideration is being given to moving the model to the R software environment. KOOMA, as well as the new DSGE models under development by the CPB and the NIER, are run using a combination of Matlab, Iris, and Dynare.

[31] As an example, Norges Bank was able to draw on support from research institutes, other central banks, and the IMF during its development of the DSGE model NEMO.

4 Conclusion

The picture that emerges from this survey about the use of models in ministries of finance is a complex one. All the models discussed and the frameworks they build on have strengths and weaknesses. How these are weighed against each other will depend critically on the envisaged use of the model, the internal work processes of the institution, the amount and type of expertise inside the institution and in the country more broadly, resource availability, and preferences among policymakers. As a result, the number of conclusions that can be drawn from this survey is limited.

In the author's opinion, however, tentative answers can be offered to some questions that need to be answered in the process of developing a model for macro-fiscal policy analysis and forecasting in a ministry of finance:

1. Would ministries of finance benefit from using a microfounded model?

   Yes, but not because of the Lucas critique. Empirical evidence for the Lucas critique is limited. Moreover, as Blanchard (2016) notes, there are reasons to be skeptical about whether the typical microfounded model provides an accurate description of household and firm behavior at the micro level, and thus whether the parameters of the model are invariant to policy change. Importantly, however, the behavioral relations in microfounded models are derived in a general equilibrium setting and therefore take into account the interaction of different markets and agents in the model across the entire business cycle. Thus in theory microfounded models are able to provide a consistent characterization of the impact of shocks to the economy. That is particularly important in institutions where macroeconomic stabilization is a key policy objective.

   The general equilibrium nature of microfounded models also means it is easier to tell a theoretically consistent story about the evolution of the economy and the drivers of the model forecast. As noted previously, the (over)reliance on a multitude of sometimes hard-to-interpret "structural" shocks in DSGE models to explain dynamics in the data is a challenge, but one that should be possible to overcome gradually with improvements to the model.

2. Is it necessary to have a large disaggregated model?

   The level of detail necessary will depend on the purpose of the model. Though disaggregation is not the only element, it is certainly one aspect of model complexity. Complexity is often cited as one of the main reasons for the overreliance on key individuals and the risk that models fall into disuse. Moreover, as the experience in Sweden shows, making use of large complicated models is often difficult in a ministry of finance where internal work processes frequently require that forecasts are produced at short notice. Moreover, as noted previously, experience from Norway and Canada suggests large disaggregated models do not improve forecast accuracy, but instead complicate the process of producing projections.

However, for policy/scenario analysis it is important that the model is sufficiently disaggregated to give a reasonably accurate picture of the workings of the economy and the impact of macroeconomic policies. To be perceived as useful, the model must also include the elements necessary (e.g. a breakdown between the commodity and non-commodity tradable sectors, and unemployment) to answer questions that may be of interest to policy makers. Though less disaggregated than LMM models, the CPB and the NIER/Swedish Ministry of Finance have made the assessment that DSGE-type models can be made sufficiently detailed to be used for this purpose.

Of course, it is not possible to predict every area where the model may be called on to provide answers. This argues for a modelling framework where new elements are added as needed, possibly in separate versions of the model. The inherent lack of flexibility of microfounded models is a problem in this regard but, in the author's opinion, adding ad-hoc elements that may somewhat undermine the model's microfoundations is a price worth paying for making sure the model remains useful (and broadly consistent with the data).

3. Is it important that a model can be estimated using full-information methods?

   Ideally yes. As noted by Olivier Blanchard (Blanchard, 2016), the dynamics of equations estimated individually can be very much at odds with that of the entire system. At the same time, the argument in Eitrheim et al. (2005) that equation-by-equation estimation increases robustness to model misspecification needs to be taken seriously. Indeed, as Blanchard (ibid.) notes, FIML estimation of DSGE models often yields parameter estimates that are highly implausible on theoretical grounds because of the incorrect specification and flat likelihood function of such models.

   The DSGE literature manages this tradeoff by relying on a combination of Bayesian full-information maximum likelihood, calibration of parameters that are not identifiable through the data, and tight priors for those parts model that are likely to be misspecified. As noted by Blanchard (ibid.), however, the list of calibrated parameters is typically large and relies more on what is "standard" in the literature than on country-specific evidence. Moreover, as previously noted, the reliance on tight priors often means that "what is estimated reflects more the prior of the researcher than the likelihood function" (Blanchard, ibid.).

   The choice between these two approaches is therefore not clear. An alternative could be what Olivier Blanchard in email communication refers to as "a back and forth between equation-by-equation estimation and system estimation/validation". This is consistent with Simon Wren-Lewis' call for using DSGE models as a "theoretical template with which to start econometric work, either on an equation-by-equation basis or on a set of sub-systems" (Wren-Lewis, 2017). Equations clearly rejected by the data would suggest that changes to the theoretical model were necessary, or (if not possible) that adding ad-hoc elements were warranted. However, once the model equations were able to

stand on their own, the author's preference would be to estimate the model as a system to ensure internal consistency.

4. Is it necessary to have a model with a detailed description of the public sector?

   To a certain extent. Clearly, it is important that a model used for macro-fiscal policy analysis and forecasting includes the main fiscal policy instruments including the major categories of taxes and expenditure. It is equally important that the model includes fiscal transmission channels sufficient to ensure that the model gives an accurate impression of the impact of fiscal policy on the economy. As noted by Ida Wolden Bache (Wolden Bache, 2015), DSGE models that include a significant role for fiscal policy are not standard, though they do exist. Coenen et al. (2012), for example, expand the ECB's NAWN model to include non-separable valuable government consumption and public capital as an input into domestic production. Similarly, the IMF's GIMF model (Kumhof et al., 2010) includes overlapping generation households with finite planning horizons that treat an increase in government debt today as an increase in wealth, thus providing a powerful channel for fiscal policy to influence economic activity.

   On the other hand, line item projections of public revenues and expenditure would appear to be better handled in separate satellite models that use real sector projections from the main model (and possibly aggregate measures of revenue) as input. Even in models that have the necessary disaggregation to produce detailed forecasts of the public sector revenue (e.g. MODAG and the OBR model) there is already a de-facto reliance on outside models for this purpose.

   As noted by Ådne Cappelen in written comments on an earlier version of this report there is a potential contradiction between the reliance on satellite models for projecting public sector variables and the call for system estimation in conclusion 3. In other words the use of separate satellite models implies that the modelling framework as a whole is no longer estimated as a system.[32] *Restricting the use of satellite models to variables that can be considered exogenous to the other variables in the system (e.g. discretionary government expenditure) or which are not included in the model (e.g. line item projections of government revenue) would help mitigate this. However, it is clear that practical considerations (e.g. the need to comply with a fiscal rule difficult to summarize in a model) may make this difficult.*

5. Is it desirable to aim for a single model for forecasting and policy/scenario analysis?

[32] A similar critique can be made regarding the use of different models forecasting and policy/scenario analysis discussed in conclusion 5.

No. For the sake of consistency there is clearly a benefit to using the same modeling framework for forecasting and analyzing the impact of policies that have an impact on those projections. At the same time, the OBR demonstrates clearly that it is possible to rely on completely different models for policy and scenario analysis. Indeed it is plausible that relying on models with a less strict theoretical core for projections, and a more microfounded model for policy analysis, reduces the overall complexity of the modelling toolkit. Experience from Norges Bank and the Bank of England (see e.g. Bjørnland et al., 2011) also suggests that relying on a combination of different types of models for projections is likely to improve forecast performance.

6. Who should develop models for ministries of finance?

It depends on who has the necessary expertise and understanding of the modelling requirements of the ministry. In Sweden, for example, it was natural to delegate development of a new DSGE model to the NIER given its long history of model development (including relatively microfounded models like KIMOD). In Norway, Statistics Norway has significant experience with LMM models that are closely tied to the national accounts and it seems sensible to continue relying on them for the development and maintenance of this type of model. On the other hand, to the author's knowledge there are few institutions (with the notable exception of Norges Bank) that possess the expertise necessary to develop a DSGE-type model. If the Norwegian Ministry of Finance were to develop such a model the best option might therefore be to develop the model in-house, drawing extensively on the expertise in Statistics Norway, Norges Bank, and other institutions with relevant experience including the IMF.

5 Bibliography

Bergvall, A. T. Forsfält, G. Hjelm, J. Nilsson, and J. Vartiainen (2007), "KIMOD 1.0 – Documentation of NIER's Dynamic Macroeconomic General Equilibrium Model of the Swedish Economy", NIER Working Paper No. 100, January 2007.

Bjørnland, H. C., K. Gerdrup, A. S. Jore, C. Smith, and L. A. Thorsrud (2011), "Does forecast combination improve Norges Bank inflation forecasts?" *Oxford Bulletin of Economics and Statistics*, Vol 73(4).

Blanchard, O. (2016), "Do DSGE Models Have a Future", Peterson Institute for International Economics Policy Brief 16-11.

Boug, P., Å Cappelen, and A.R. Swensen (2016), "Inflation Dynamics in a Small Open Economy", forthcoming in the *Scandinavian Journal of Economics*.

Boug, P., Å Cappelen, and A.R. Swensen (2010), "The New Keynesian Phillips Curve Revisited", *Journal of Economic Dynamics and Control*, Vol. 34, pp. 858-874.

Boug, P., Å Cappelen, and A.R. Swensen (2006), "Expectations and Regime Robustness in Price Formation: Evidence from Vector Autoregressive Models and Recursive Methods", *Empirical Economics*, Vol. 31, pp. 821-845.

Boug, P. (1999), "The Demand for Labour and the Lucas Critique: Evidence from Norwegian Manufacturing, Statistics Norway Discussion Paper No. 256.

Boug, P. and Y. Dyvi (2008), "MODAG – En Makroøkonomisk Modell for Norsk Økonomi", Statistics Norway Social and Economic Studies No. 111.

Bårdsen, G., Ø. Eitrheim, E. S. Jansen, and R. Nymoen (2005), *The Econometrics of Macroeconomic Modelling*, Oxford University Press.

Brayton, F., T. Laubach, and D. Reifschneider (2014), "The FRB/US Model: A Tool for Macroeconomic Analysis", The Federal Reserve Board FEDS Notes, April 2014.

Burgess, S., E. Fernandez-Corugedo, C. Groth, R. Harrison, F. Monti, K. Theodoridis, and M. Waldron (2013), "The Bank of England's Forecasting Platform: COMPASS, MAPS, EASE and the Suite of Models", Bank of England Working Paper No. 471.

Chang, Y., Sun-Bin K., and F. Schorfheide (2011), "Labor-Market Heterogeneity, Aggregation, and the Policy-(In)variance of DSGE Model Parameters", RCER Working Papers 566, University of Rochester - Center for Economic Research (RCER).

CPB Netherlands Bureau for Economic Policy Analysis (2016), "CPB – Suite of Models", Memo to the Advisory Panel on Macroeconomic Models and Methods at the Norwegian Ministry of Finance, October 11, 2016.

Coenen, G., R. Straub, and M. Trabandt (2012), "Fiscal Policy and the Great Recession in the Euro Area", European Central Bank Working Paper No. 1429, March 2012.

Danmarks Statistik (2012), "ADAM – En Model av Dansk Økonomi", TemaPubl 2012:1, March 2012.

DeSeres, A., B. Robidoux, and B.S. Wong (1998), “The Canadian Economic and Fiscal Model 1996 Version: Dynamic Forecasting and Simulation Properties”, Canadian Department of Finance 98-06.

Dyvi, Y., S. I. Hove, M. E. Lund, P. Sletten, and S. A. H. Wingaard (2015), “Modelapparat for Kort- og Mellomlangsiktige Analyser”, Report to the Rådgivende Utvalg for Modell- og Metodespørsmål at the Norwegian Ministry of Finance, December 2015.

Edge R., M. Kiley, and J.P. Laforte (2010), “A Comparison of Forecast Performance Between Federal Reserve Staff Forecasts”, *Journal of Applied Econometrics*, Vol. 25, pp. 720-754.

Finansministeriet (2012), “Regneprincipper og Modelanvendelse i Finansministeriet”, Notat, November 2012.

Gervais, O. and M. Gosselin (2014), “Analyzing and Forecasting the Canadian Economy through the LENS Model”, Bank of Canada Technical Report No. 102.

Geweke, J (1985), “Macroeconometric Modeling and the Theory of the Representative Agent”, *The American Economic Review,* Vol. 75, No. 2, pp. 206-210.

Hjelm, G. (2015a), “Appropriate Macroeconomic Model Support for the Ministry of Finance and the NIER: A Pilot Study”, Presentation to the Rådgivende Utvalg for Modell- og Metodespørsmål at the Norwegian Ministry of Finance, September 2015.

Hjelm, G., H. Bornevall, P. Fromlet, J. Nilsson, P. Stockhammer, and M. Wiberg (2015b), “Appropriate Macroeconomic Model Support for the Ministry of Finance and the National Institute of economic Research: A Pilot Study”, NIER Working Paper No. 137, March 2015.

Johansen, S. (2002), “Discussion of E. S. Jansen: Statistical Issues in Macroeconomic Modelling”, *Scandinavian Journal of Statistics*, Vol. 29, pp. 213–216.

Kranendonk, H. and J. Verbruggen (2007), “SAFFIER: A Multi-Purpose Model of the Dutch Economy for Short-Term and Medium-Term Analysis”, CPB Document No. 144, April 2007.

Krogh, T.S. (2015), “Macro Frictions and Theoretical Identification of the New Keynesian Phillips curve”, *Journal of Macroeconomics,* Vol. 35, pp. 191-204.

Kuismanen, M., M. Obstaum, M. Sariola, and S. Pietiläinen (2013), “The KOOMA Model of the Finnish Ministry of Finance”, Unpublished Manuscript.

Kuismanen, M. (2016a), “Valtiovarainministeriön Makrotaloudellisten Analyysimallien Käyttö ja Julkisuus”, Presentation, October 2016.

Kuismanen, M. (2016b), “Model Development in the Finnish Ministry of Finance”, Presentation to the Rådgivende Utvalg for Modell- og Metodespørsmål at the Norwegian Ministry of Finance, April 2016.

Kumhof, M., D. Laxton, D. Muir, and S. Mursula (2010), “The Global Integrated Monetary and Fiscal Model (GIMF) – Theoretical Structure”, IMF Working Paper 10/34.

Lucas, R. (1976), “Econometric Policy Evaluation: A Critique”, *Carnegie-Rochester Conference Series on Public Policy*, Vol 1, pp. 19–46.

Maih, J. (2015), “Efficient Perturbation Methods for Solving Regime-Switching DSGE Models”, Norges Bank Working Paper 01/2015.

Nymoen, R., A.R. Swensen, and E. Tveter (2013), “Interpreting the Evidence for the New Keynesian Models of Inflation Dynamics”, *Journal of Macroeconomics*, Vol. 35, pp. 253-263.

Office for Budget Responsibility (2013), “The Macroeconomic Model”, Briefing Paper No. 5, October 2013.

Office for Budget Responsibility (2011), “Forecasting the Economy”, Briefing Paper No. 3, October 2011.

Office for Budget Responsibility (2011), “Forecasting the Public Finances”, Briefing Paper No. 1, January 2011.

Pedersen, J. (2012), “Finanspolitik i Makroøkonomiske Modeller”, Kvartalsoversigt, 3. Kvartal 2012, Del 2, Danmarks Nationalbank.

Pedersen, L. H. (2015), “Økonomiske Fremskrivninger og Finanspolitisk Planlægning”, Presentation to the Rådgivende Utvalg for Modell- og Metodespørsmål at the Norwegian Ministry of Finance, September 2015.

Peiris, S. J. and M. Saxegaard (2007), “An Estimated DSGE Model for Monetary Policy Analysis in Low-Income Countries”, IMF Working Paper No. 07/282.

Regjeringskansliet (2015), “Regjeringsbrev för Budgetåret 2016 Avseende Konjunkturinstitutet”, December 2018.

Robidoux, B. and B.S. Wong (1998), “The Canadian Economic and Fiscal Model 1996 Version: Model Structure”, Canadian Department of Finance 98-05.

Romer, Paul (2016), “The Trouble With Macroeconomics”, Commons Memorial Lecture of the Omicron Delta Epsilon Society, January 4, 2016.

Ryan, M. and K. L. Szeto (2009), “An Introduction to the New Zealand Treasury Model”, New Zealand Treasury Working Paper 09/02, September 2009.

Sims, C. A. (1980), “Macroeconomics and Reality”, *Econometrica*, Vol. 48, No. 1, pp. 1-48.

Van der Horst, A. (2016a), “To Explore and to Clarify”, Presentation to the Rådgivende Utvalg for Modell- og Metodespørsmål at the Norwegian Ministry of Finance, October 2016.

Van der Horst, A. (2016b), New Roads”, Presentation to the Rådgivende Utvalg for Modell- og Metodespørsmål at the Norwegian Ministry of Finance, October 2016.

Westerdahl, Y. H. (2015), Ny Makroekonomisk Modell för Finansdepartementet i Sverige", Presentation to the Rådgivende Utvalg for Modell- og Metodespørsmål at the Norwegian Ministry of Finance, September 2015.

Wolden Bache, Ida (2015), "Refleksjoner Rundt Valg av Modell(er) for Finansdepartementet", Presentation to the Rådgivende Utvalg for Modell- og Metodespørsmål at the Norwegian Ministry of Finance, September 2015.

Woodford, M. (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press.

Woodford, M. (2009), "Convergence in Macroeconomics: Elements of the New Synthesis", *American Economic Journal: Macroeconomics*, Vol. 1, No. 1, January 2009.

Wren-Lewis, S. (2017), "Blanchard joins calls for Structural Econometric Models to be brought in from the cold", blogpost available at https://mainlymacro.blogspot.no.