DREAM
Danish Research Institute for
Economic Analysis and Modelling

MAKRO

MAKRO: Modeling Choices

Martin Bonde, João Ejarque, Grane Høegh, Anders Kronborg,
and Peter Stephensen

Economic memo
18 June 2021

www.dreamgruppen.dk

Contents

1. Model overview and approach

MAKRO is a large, empirically based macroeconomic model of the Danish economy, the purpose of which is to serve as a tool for medium and long-term projections, short and long run policy impact assessment, and long run fiscal policy sustainability measurement. At a later stage, the model should be able to incorporate short-term economic forecasts into its projections. The model's description of the structural development in the economy is an integrated part of the description of adjustments to shocks in the economy.

The first working version of MAKRO is a beta version where the bulk of theoretical modeling and empirical foundation are in place. Subsequently, there will be a period in which the Ministry of Finance in collaboration with the MAKRO group will start implementing the model and prepare the model for full use. During this implementation period, users will have the opportunity to build up practical experience using the model

During this period, changes and further improvements of the model will be made to the initial beta version. These adjustments will be based on the experience already gained from developing the model as well as external input in connection with the publication of the model. The essential model framework however, is reflected in the initial beta version. Hence, the basic properties and how the model will perform when implemented is to a large extend reflected in the beta version.

The purpose of this paper is to provide an overview of the beta version of the model, as well as to describe and explain the background for the key modeling choices made in the various areas of the model. In this way, the paper aims to provide an overall, relatively easily accessible and non-technical introduction to MAKRO. A detailed technical description of the modeling of all agents and markets can be found in the technical documentation. The empirical strategy behind the model, the model's conformity with the empirical data and properties of central shocks are described separately in separate notes. Together, these notes form the core of the documentation, supplemented by working papers on various topics.

This document is structured as follows: We first offer a brief description of the purpose of MAKRO and of the basic modeling choices made, followed by an overview of the model structure. Subsequent sections discuss modeling choices within each of the model's main areas, which are households, firms, the labor market, the public sector, and the rest of the world.

1.1 The purpose of MAKRO

MAKRO will be used by the Ministry of Finance for the purposes of

1. business cycle assessments (primarily as a framework, cf. below).
2. medium and long run projections.
3. impact assessments of policy measures and exogenous shocks.

MAKRO will be used for the same overall tasks as the ADAM model is currently used for in the Ministry of Finance. It is therefore important that MAKRO maintains the key strengths of ADAM, such as the level of detail in the description of public finances and a comprehensive, high-quality database.

In addition, the very purpose of the development of MAKRO has been to update the model framework in use so that it incorporates and reflects recent empirical methods and results from the economic literature. This has required a new approach to the empirical foundation of the model as well as to the modeling of expectation formation and behavior. The benefits of these changes will primarily relate to points 2 and 3 in the above.

Central in the development of MAKRO is the behavioral properties pertaining to the short and medium term adjustment towards the economy's structural levels in the face of various types of shocks and policy interventions, for example an increase in the labor supply. In addition, the modeling of firms' investment decisions and households' consumption and savings decisions is based on recent economic research etc.

Against this background, a number of factors have been emphasized in the development of the model.

First, the model is based on a broad empirical approach. In macroeconometric models, the time series estimation of each single equation as an empirical basis. The empirical foundation of MAKRO has a broader scope, in the sense that different approaches and results complement each other to a larger extend. This includes the fact that the description of the short run adjustment to various types of shocks a directly based on empirical analyses of the relevant speed of adjustment.

Second, emphasis is placed on the fact that the model takes into account the effects of expectations. MAKRO is built to take into account that the consequences of a shock to the economy in the short term may depend on whether the shock is permanent or temporary. For example, an increase in the households' income in a given year will have different effects on the consumption, depending on whether the increase in income is a one off payment or is lasting. This requires that firms and households to some extend have forward-looking expectations.

Third, the modeling of behavior is as a starting point theoretically well founded, in the sense that firms and households are trying to achieve the best possible outcome given the framework conditions and any restrictions (eg credit constraints, incomplete information, etc.) that they face.

Fourth, an explicit formulation is given of consumption and savings decisions of the households over the entire life cycle. This is done among other things to take into account the effects of demography on consumption and savings.

Finally, it is important that the model includes measures of of cyclical gaps and structural levels of (among other) employment and output. This ensures that the model can describe the economic adjustment to the (potentially changed) structural levels after a given shock.

A special focus for the use of the model by the Ministry of Finance is the analysis of public finances, including the fiscal sustainability indicator. Given this key purpose, emphasis has been placed on a detailed description of factors, which are relevant in this regard. The includes a detailed description of the structural factors that are also important for the economy as a whole: the age structure of the population, labor market participation, the evolution of the level of education in the population, the forecast of oil and gas revenues from the North Sea, etc. The population data from the Ministry of Finance and the Pension Model from DREAM are used to project some of these series.[1]

The sustainability indicator, which reflects whether the projected government revenues are sufficient to cover the projected expenditures, can also (to a certain extend) be affected by temporary factors regarding the short and medium term adjustment to the structural levels of the economy. If the government needs extra borrowing for a temporary period, future interest expenses could affect the sustainability of fiscal policy. Such temporary conditions is part of MAKRO, along with more structural conditions.

MAKRO is a relatively large macroeconomic model. To avoid making the model unnecessarily complicated, from the beginning of the project it has been important to keep in mind what *is not* the purpose of the model. This pertains to, among other things, which elements of the projections and impact assessments that will (still) be done outside of the framework of the MAKRO model. Examples includes when other – and for the specific purpose more appropriate – models are used.

As a consequence hereof, the development of MAKRO reflects the fact that a number of factors has not been prioritized – and consciously so.

First, it is the aim of the model that it should fundamentally be able to do more or be used differently in connection with business cycle assessments than is the case with ADAM today. The development of MAKRO has not taken place with the aim that the business cycle projections must to a large extent be based on model-generated short-term projections. MAKRO will thus primarily constitute a consistent framework for preparing the business cycle projections. The actual estimate of the behavior in the Danish economy for the projection years - both in detail and aggregated - will to a large extent continue to be made explicitly by the model users on the basis of a large number of indicators and estimates made outside the model.

Second, it is not the aim of the model that it should be used for endogenous projections of the population and the structural employment. Projections of demography and structural employment used in the model-generated projection by MAKRO will still be done separately in an external model developed by the Ministry of Finance specifically for this purpose. Hence, these projections will – as is the case with ADAM today – constitute an exogenous input to MAKRO.

Finally, it is not the aim that MAKRO should be used for assessments of the effects on structural employment in face of specific policy interventions. This is similar to other Danish macroeconomic models. The reason for this is the fact that assessments of such structural effects requires that the nature and effects of such interventions are included. This, in turn, requires that information is incorporated in such a detailed level that it is not feasible to include directly in a macroeconomic model. Hence, structural effects of policy interventions on the

[1] A stylized and provisional model projection is part of the beta version of the model. The primary purpose for this is to serve as a foundation from which the marginal properties of the model in face of shocks can be assessed. This projection is not an actual forecast of the Danish economy under the current economic policy and does not include, among other things, the effects of the corona-crisis.

employment will still be assessed outside of the model and provided as exogenous input through the mentioned external model.

Overall, the transition to MAKRO does not represent a dramatic change in the use of macroeconomic models or in the resulting projections and impact assessments made by the Ministry of Finance. Rather, it is a natural methodological development in the way these tasks are performed.

Despite the improvements which are sought to be achieved, MAKRO is not a flawless model which can unanimously be said to be correct – such a model does not exist. With MAKRO – as is the case with all models – the model user has the final responsibility for the analysis, including the assumptions which the results are based on. In addition, it will be necessary (as with other large-scale models) to, continually develop the model, reconsider its properties, etc.

1.2 Model Structure

As mentioned in the introduction, the goal is for MAKRO to have both good short-term and long-term properties. This goal is achieved by formulating MAKRO as a long-term structural model to which short-term real and nominal frictions are added.

As MAKRO is a comprehensive model with a lot of institutional detail, it has been chosen to disregard explicit modeling of uncertainty (stochastics), as is otherwise known from DSGE models. However, as uncertainty about the future may be an important factor behind the behavior of households and firms, the effect of uncertainty is added via specific elements such as risk premiums in firms and an element of precautionary savings in households, cf. further below and in the note *The Empirical Foundation of MAKRO*.

The long-term structural characteristics of MAKRO are based on (many) representative agents (the most important are households by age and firms by sector) with micro-founded behavior and an element of forward-looking expectations. Similarly, short-term frictions is, as far as possible, micro-founded and based on the forward-looking expectations of agents. Considerations of the overall model type, including the balance between consideration of empirical data and theoretical rigor, are described in *The Empirical Foundation for MACRO*.

Expectations

By forward-looking expectations we mean that firms and households include information about future changes in their framework conditions and the economy more generally in their formation of expectations. These can be changes in factors such as the tax system, the retirement age, fiscal policy in general, the level of education, demographics, etc. Knowledge of the future is, among other things, crucial for the model to provide an idea of the difference in the effects of temporary and permanent shocks to the economy.

Forward-looking expectations are in contrast to so-called static or adaptive expectations, where the agents only form their expectations for the future on the basis of the hitherto observed development in framework conditions and the economy in general (backward-looking expectations). Empirically, there are a number of signs of the relevance of forward-looking in the formation of expectations, including that households react in advance to known income changes, that firms' employment and investment decisions depend on expectations of future framework conditions and that asset prices react to news of future changes in the effective return.[2,3]

In MAKRO, the starting point for the modeling of firms' and consumers' forward-looking expectations is that these are model-consistent (or rational), such that the agents' expectations are in accordance with the model's predictions, and that no systematic expectations errors are committed in relation to this. This type of forward-looking expectations is widespread in modern macroeconomic models. However, there are a number of reasons why fully model-consistent expectations are not realistic in its purest form. The agents' expectation formation may, for example, be subject to different types of frictions in relation to the acquisition of precise information about current or future economic conditions, or the agents may be limited in their ability to form model-consistent expectations on the basis of this information. Models with full model consistent expectation formation therefore often have challenges in matching empirical results regarding the economy's adaptation to shocks.

Therefore, the modeling of the behavior in MACRO contains elements that (explicitly or implicitly) can contribute to the agents' behavior reflecting less than full model-consistent expectation formation. A proportion of households make their consumption decision solely on the basis of current conditions and do not form forward-looking expectations (the so-called H2Ms, who simply use the entire current income, cf. below). Furthermore, the proportion of households that form forward-looking expectations does not fully respond to the model's expected house price changes when they have to distribute their total consumption on resp. housing and other consumption.[4] Finally, in MAKRO there is a *financial accelerator*, which means that the firms' level of investment is more closely related to the current economic activity than it would otherwise be - roughly equivalent to the effect of a partially static or adaptive expectation formation. These conditions are described in more detail in the sections on the individual areas of the model below. The quantitative significance of these elements is determined as part of the matching of the model to empirical results for the economy's overall adaptation to shocks, cf. also *The Empirical Foundation of MAKRO*. Towards full commissioning in the Ministry of Finance (and subsequently), work can continue on the formation of expectations in MAKRO, including how less than fully rational or model-consistent expectations are incorporated or taken into account.

---

[2] There are a large number of Danish and foreign studies that indicate that forward-looking expectations are relevant. For Denmark, these include changes in interest expenses (Druedahl et al, 2021) and capitalization effects of housing taxation (Høj & Schou, 2018). On American data, studies find, among other things, that announced tax changes affect investments etc. (Mertens & Ravn, 2012) and stock prices (Lang & Shackelford, 2000) after they are adopted, but before they are implemented.

[3] It is noted that the formation of expectations in isolation will typically play a greater role for the short- and medium-term effects of shocks (including first-year effects) than for the long-term effects. But even in a situation where overall (ie, including effects of differences in modeling, estimation, and calibration that go beyond expectations), comparable first-year and long-term effects of a given shock across different macroeconomic models are achieved, it can be of great importance for the models' predictions about the intermediate course (the adjustment of the economy), whether - and to what extent and in what way - the expectations are modeled as forward-looking.

[4] This “limited rationality” can be understood both in the way that they systematically underestimate future house price changes or that for other reasons they do not let expectations of house price changes be fully reflected in their behavior.

Households, Firms, Government, and the Rest of the World

Households

There are two types of households in the model. Those that have free access to capital markets and those that are financially constrained. The financially constrained are denominated "hand-to-mouth" (H2M).

Unconstrained households choose optimally their savings (or alternatively their overall current consumption), the amount of housing to own, and their labor market search effort. All of these are dynamic forward-looking decisions. They also make a number of static consumption composition decisions.

The financially constrained are restricted to have zero non-housing financial assets. This is an extreme form of modeling the costs of saving and of borrowing, brought to mainstream macroeconomics by Campbell and Mankiw (1989). We further simplify the modeling of H2M agents by imposing an exogenous rule linking housing and non-durable consumption. They retain one forward-looking decision, which is the labor market decision. The labor market decision is formulated such that both unconstrained and H2M agents have the same search effort and employment levels. H2M agents perform an important function in the model as they raise the aggregate marginal propensity to consume out of an income shock due to the fact that they cannot save.

All of these choices are age dependent. The key modeling choice on the household side is to have a detailed characterization of the life cycle. Each cohort is therefore a separate agent, and cohorts live to age 100. The different living cohorts are part of an overlapping generations (OLG) structure.

Firms

There are nine production sectors in the model, one of them being the public sector. These nine sectors are obtained from the data by aggregating finer industrial classifications in the national accounts. The limited number of sectors is a consequence of the fact that it is not computationally feasible to model a complete disaggregation of production. Nevertheless, the disaggregation we use provides the model with rich sectoral dynamics and is important to replicate the differential sectoral impact of shocks and policy in the economy.

Firms in each sector produce goods and services by combining inputs of physical capital, labor, and intermediate inputs (materials) with a production technology (the production function) which is a constant elasticity of substitution (CES) structure with constant returns to scale. Due to constant returns to scale, long-run output prices are cost-determined and output quantities are demand determined.

Firms make positive profits due to imperfect competition in the product market, which allows them to set prices higher than the marginal unit costs of production. Price setting is modeled such that prices react slowly to shocks, implying markups vary over the business cycle.

Firms are able to choose the optimal degree of utilization of production inputs. This means that, in the short term, output can move beyond what would otherwise be possible given the quantity of inputs. This mechanism is essential to be able to reproduce the pro-cyclical nature of labor productivity found in the data.

Investment accumulates the capital stocks of equipment (machinery) and structures (buildings) through the standard perpetual inventory accumulation equation. The choice of optimal investment is a forward-looking one, and trades off the cost of investment today against the future marginal product of capital gains generated by the marginal unit of investment, which depreciates slowly over time. Any elements such as interest rates (opportunity costs), taxes, depreciation, and future (expected) resale prices of the capital good, impact the investment decision. Installation costs induce gradual adjustment of the capital stock and time to build of one period ensures the decision is forward-looking even in the absence of adjustment costs.

Firms are described as joint stock companies that maximize their value. Outstanding shares are owned by households, pension companies, companies and the rest of the world. The price of domestic shares depends on the companies 'future earnings and the investors' return requirements.

Labor market

Employment and wages are determined in a search and matching labor market where firms post vacancies and unemployed workers look for jobs. The two sides meet and employment results from the matching technology, which captures the labor market imperfection responsible for involuntary unemployment. This technology ensures that it is not possible for everyone to find employment or for every vacancy to be filled.

The matching friction differs from the search friction. The latter determines that if a worker fails to find a job he has to wait one period (a “time to build” type of assumption) before searching again. The two frictions are necessary to generate unemployment.

Wages are determined by bargaining between representatives of employers and employees. Only a fraction of contracts are negotiated in any given year. This gives rise to inertia in the average wage faced by households and firms. The sluggish wage formation is crucial for the model to be able to describe temporary deviations in actual employment around the structural level when the economy is hit by various shocks. It is because prices cannot adjust completely that quantities deviate from their long run levels. This is essential to reproduce the movement of employment and unemployment over the business cycle.

Government and the rest of the world

The public sector is mainly an accounting system rather than a behavioral model, where different items are indexed to objects such as population, employment, or gross domestic product. The fundamental characteristic of this part of the model is the level of detail with which both revenues and expenditures are described.

The rest of the world enters MAKRO through three objects. The interest rate, the prices of foreign goods, and the demand for Danish exports. The demand for exports is based on the theoretical Armington specification, expanded to ensure we are able to characterize the data. It is essential that we do so because exports represent a large fraction of aggregate demand directed at domestic production. The interest rate is determined in the world market.

2. Households

Private consumption accounts for circa half of GDP and is the largest single item in aggregate demand. Households therefore play a central role in the economy and it is fundamental to model their decisions carefully. The theoretical foundation we use is the life cycle model embedded in an overlapping generations structure. The description of the households starts from the perspective of the OLG structure of the model, which implies that consumption and savings for each cohort it seen in a life cycle perspective.

This section provides a brief description of more recent developments in the understanding of private consumption (section 2.1). To the extent that some degree of consensus can be said to have been achieved, some of the central *stylized facts* within the empirical and theoretical research are highlighted. This is to a large extent concerned with frictions which implies that the chosen level of consumption deviates from what is implied by the simple life cycle model. The section subsequently gives a non-technical description of how consumers are specifically modeled in MAKRO (section 2.2). In general terms, this pertains to the overlapping generations, the utility function of consumers, their budget constraint, and the way in which different sources of data. The modeling of housing consumption is described in a separate section (section 2.3).

2.1 Understanding Consumption

The central features of the data we work with are, first, that average household income displays the usual hump shaped pattern with a flat top between ages 40 to 60, rising in the early part of the life cycle and falling after retirement.

Second, the average household has little net non-housing financial wealth until around age 40, after which wealth accumulates significantly until the end of life without really decreasing. The old do not eat enough. Significant wealth is left as bequests after death, and this amount is hard to replicate, even with generous bequest motives and a strong intertemporal preference for the future (for saving). On the other hand, if households derive utility directly from wealth, this accumulation of wealth late in life becomes easier to replicate. At the opposite end of the life cycle, average wealth is never significantly negative for the average young cohort.

The last key life cycle data pattern is that of housing. Average owned housing starts at zero, peaks around age 60 and then drops to a lower value of around 40% of peak at the end of life, implying significant housing wealth is also left as bequests.

These patterns refer to the average values of these variables taken over all households of a given age. They hide, as all averages do, a significant amount of heterogeneity, particularly in income and non-housing wealth, that MAKRO cannot handle. The presence of more than 80 different cohorts alive at any given moment, plus the separation of financially constrained (H2M) from unconstrained households already provides a significant amount of heterogeneity for the model to work with.

In addition to matching these life cycle patterns, there are marginal features of the data which the literature has looked into, and which the model should match.

Private consumption generally responds *more* to known and to temporary income changes than the simple life cycle model predicts. This is true empirically both in aggregate data and in microeconomic studies. The data then indicates that it is not only lifetime income that drives private consumption (the permanent income hypothesis), but that the timing of income also plays a significant role. This marginal prediction can be linked to the absence of significant debt at young ages through limited access to credit. Credit constraints would both limit the amount of debt for the young, and induce their consumption to react more to income shocks.

In MAKRO our H2M agents are the simplified way in which we introduce credit constrained agents in the model. We can induce similar behavior for the financially unconstrained households through the shape of the utility function. This is akin to the idea of precautionary savings. Precautionary savings are the result of uncertainty, but the mechanism works through the utility function. With enough concavity – think log utility – even the remote possibility of permanent zero income with associated zero consumption implies the agent will never borrow. In the absence of uninsurable random income, one can parameterize the utility function to achieve a similar result.

On the other hand, consumption responds *less* to permanent income shocks than the simple life cycle model predicts. It reacts sluggishly rather than jumping immediately to the new life cycle optimum as one would expect of a permanent shock. It is not because permanent income is not volatile that consumption is smooth. In fact, permanent income is volatile. Something else, such as habits in the utility function, induces it to adjust slowly to changes in permanent income.

These extensions to the canonical life cycle model are well established and were achieved decades ago. Sumaries of consumption research can be read in Angus Deaton's book and in the article by Browning and Crossley on the life cycle model. The title above "Understanding Consumption" is stolen from Deaton's book.

2.2 Households

In the previous paragraphs we have hinted at the different extensions to the canonical life cycle model that allow the theory, and the MAKRO model, to match the data. We now go into additional detail, and supplement the description, particularly with more housing-related content.

MAKRO provides both a description of aggregate consumption and wealth, and of the life cycle profiles of the same objects. As there is no data at the individual level for private consumption, this variable is imputed through the age specific budget constraints using register data for income and wealth, and it is done so that after aggregating over age total consumption and wealth match the national accounts data. The construction of the imputed consumption profiles is described in Hoeck & Bonde (2021). With this data we can estimate the key parameters in household preferences. An early fundamental reference in estimation of the life cycle model is Gourinchas and Parker (2003). Their exercise is to use the rich life cycle data to estimate two *constants*: the intertemporal utility discount rate, and the curvature of the utility function. Estimating two constants is a minimaly intrusive exercise. If the discount rate and the curvature of utility were, for example, allowed to vary with age, one could fit their entire life cycle exactly, rendering their model irrelevant. MAKRO has heavy requirements to fit data, yet our estimation approach follows the minimalist philosophy of those authors.

Overlapping Generations

The overlapping generations (OLG) structure allows the life cycle to enter the model. Macro models with infinitely lived agents (Ramsey models) are equivalent to models where each agent lives for one period but cares in a very specific way about the utility of the cohort alive the following period. These cohorts do not need to overlap because they do not have a life cycle. Once the life cycle became the main tool of consumption analysis, the OLG structure became essential.

Each age group is representative of one cohort.[5] The model uses the demographic projections made in collaboration between DREAM and Statistics Denmark. In the model, the representative households enter the labor market aged 15, start making optimal consumption decisions aged 18, and die the year they turn 100 years old.[6]

This long and encompassing life cycle is ideally suited for policy analysis. The modern emphasis of macroeconomics recognizes that in order to understand the aggregate effects of policy these effects must be, as much as possible, aggregated from the respective impact on individual and heterogeneous agents. In particular, the detailed fiscal policy analysis demanded of MAKRO requires it. The Ministry of Finance therefore makes separate forecasts of population, education levels, structural employment, and population distribution by socioeconomic groups and by age. Finally, a separate model generates a cohort-based forecast of pension contributions and payments as well as of the assets of pension funds.

This does not imply other models are useless. DSGE models with a higher level of aggregation are widely used by central banks (see Smets et al, 2010). It is, however, increasingly accepted that the life cycle is crucial to understand the aggregate marginal propensity to consume, and the marginal propensity to consume is a key factor policy makers take into account.

Non-durable consumption is of course not the only important object in household behavior. Age is fundamental to understand the accumulation of housing and non-housing wealth, and of pension assets, as well as bequests (Davies & Shorrocks, 1999). And it is important to look at the life cycle to understand the aggregate marginal propensity to consume. Looking at studies on Danish data, age is key for the marginal propensity to consume out of increased income (Kreiner et al, 2019), out of housing wealth (Hviid & Kuchler, 2017), just as it is important for the probability of moving between unemployment and employment (Kronborg & Stephensen, 2019, Ejarque, 2021).

Non-forward-looking households (hand-to-mouth)

A fraction of consumers neither borrow nor save and their status never changes over the life cycle. Campbell & Mankiw (1989) show that including these agents helps to explain what Flavin (1981) called the "excessive sensitivity" of consumption to temporary income shocks, and this modeling strategy is used by the European Commission, the International Monetary Fund, Quest III (Ratto et al, 2008) and GIMF (Kumhof et al, 2010), respectively, where their share is anywhere between 25 and 50%. The mechanism is simple. If we force a fraction of the population to have a marginal propensity to consume (MPC) equal to 1, they will compensate for the low MPC of unconstrained and intertemporal smoothing households and raise the resulting average.

In MAKRO these households own housing. And their financially constrained status does not preclude them from making optimal forward-looking decisions regarding how much to invest in owned housing. This is how the problem of the “wealthy hand-to-mouth” is treated in the macroeconomic literature (Kaplan, Giovanni, and Weidner (2014)). However, as mentioned, we simplify this part of the model and impose an ad-hoc rule linking their owned

[5] All men and women of a given age, plus the children of these women.

[6] For each cohort there are two representative households. One constrained, and one unconstrained.

housing stock and their non-durable consumption. This static rule replaces the forward-looking first order condition and induces housing expenditure and non-durable consumption to move slightly more in tandem for these agents. Crawley & Kuchler (2018) show how Danish households, which are characterized by having a high marginal propensity to consume, owns either relativel few assets or own a relatively large amount of housing assets but few liquid assets.

Housing wealth is net of mortgage debt, which we also have in MAKRO. Mortgage debt is the largest single debt item in the economy, and it is of course connected to the largest asset owned by most households. And our H2M agents also have mortgage debt.

Allowing the model to contain a representative household that consumes closer to their current income than the forward-looking (intertemporally optimizing) households contributes to a higher marginal propensity to consume in MAKRO, which is supported by the empirical evidence. Campbell & Mankiw (1990) estimate the proportion of H2Ms to be around 50% for the United States on aggregate time series data. U.S. micro-data studies looking at temporary tax rebates during the 2001 crises (Shapiro & Slemrod, 2003 and Johnson, Parker & Souleles, 2006) and 2008 (Sahm, Shapiro & Slemrod, 2010 and Parker et al, 2013) find a marginal propensity to consume of 20 to 40% within a few weeks. Similar results are found in a number of recent Danish studies, e.g. Jørgensen & Kuchler (2017), Crawley & Kuchler (2018) and Kreiner et al (2019), which indicate that the marginal propensity to consume out of one-off or temporary income can be as high as 50 to 60%. The latter, which is based on questionnaires, however, finds a pronounced heterogeneity, so that the average propensity to consume of 60% primarily reflects an average of persons who consume either all or none of the SP amount paid, which supports the chosen modeling in MAKRO. Yde (2018) finds on detailed register data a propensity to consume of around 42% for the tax-free repayment of early retirement contributions for persons who opted out of the early retirement scheme in 2012. Finally, Chetty et al (2014) look at Danish micro-data and find that the marginal propensity to consume is significantly higher from disposable income than from higher income in form of pension contributions. In the Danish macroeconomic models ADAM and SMEC, the short-term elasticity of consumption via income is estimated to be around 0.4-0.5 (Borge & Knudsen, 2019 and Grinderslev & Smidt, 2007).

As mentioned, the use of H2M households in the model is a reduced form for other mechanisms. In the case of MAKRO it is certainly a substitute for the missing explicit model of consumer finance (Zeldes, 1989).[7] Kaplan & Violante (2014) note that households with little liquid wealth and significant housing react strongly to income shocks. The reason is that housing is an illiquid asset, and small temporary income shocks do not change housing decisions, implying the extra income is mostly consumed. Two factors are involved. First, savings must be expensive (must yield a low return), and borrowing must be costly (so that there is no debt or otherwise the extra income would be used to reduce that debt). And second, trading housing must imply transactions costs. MAKRO is missing a key element of this mechanism as housing is a liquid asset (without transaction costs), but this is partially tackled by the habit objects.

As mentioned, hand-to-mouth consumers is included in the model to reflect the empirical literature, e.g. short run effects of income shocks. The specific choice of modeling can further be seen as a reduced form way of describing a range of different mechanism. This includes income heterogeneity and liquidity constraints (Zeldes, 1989), illiquid assets and transaction

[7] See Gabaix (2020) for a model of bounded rationality.

costs (Kaplan & Violante, 2014), imperfect information (Cao & L'Hullier, 2018) or limited rationality and myopia (Gabaix, 2020). If one or more of these mechanisms are explicitely implemented for forward-looking households in a later version of MAKRO, one would expect the share of hand-to-mouth consumer necessary to replicate the empirical literature to fall. Finally, it should be noted that the direct utility of wealth of forward-looking households contribute to a higher MPC, hence lowering the necessary share of hand-to-mouth consumers.

Hand-to-mouth consumers have the same behavior regarding labor marked decisions as forward-looking households.

Forward-looking households

The majority of households in MAKRO are forward-looking optimizing agents. They choose the optimal level of consumption and savings, the optimal level of housing investment, and optimal search effort understanding their intertemporal trade-offs. Giving up one unit of consumption today implies the immediate loss of utility, and this loss is exactly compensated by the future consumption gain allowed by the return on saving the amount not consumed. This reasoning applies to all intertemporal choices.

The utility function contains the total private consumption, separated into housing and non-housing consumption (hereafter other consumption) and they can substitute between these types of consumption (housing consumption is described in the following section). The period utility function of total consumption is given by a so-called CRRA utility function, in which a parameter is determines the intertemporal elasticity of substitution. Finally, the utility of future consumption is subject to a subjective discount factor. This specification of the utility function is standard in comparable macroeconomic literature, both in its general form (e.g. the GIMF model of the IMF, see Kumhof et al, 2010) and in the special case of log-utility (e.g. the DSGE model of the Danish central bank, see Pedersen, 2016).

Further, the utility function of the forward-looking households contains habit formation in consumption, a bequest motive (utility of bequest), and a term which implies that they get direct utility of wealth. This affects the consumption and savings decisions of the forward-looking households and are described separately below.

The households get utility from leisure, meaning they get disutility from supplying their labor through job search.[8] This disutility is assumed to be additively seperable with consumption, both on the intensive (hours worked) and the extensive (participation) margin. This simplifies the properties of the model and the interpretation hereof, since it implies that the labor supply, employment and wages, etc. only affects the consumption throught the budget constraint (i.e. not through potential effects from the marginal utility of leisure on the marginal utility of consumption). This assumption is also fairly common in the DSGE literature and – implicitely – in larger macroeconomic models.[9]

Habits

Households in MAKRO get utility of the total consumption, seen relatively to a reference level. This is typically referred to as habit consumption and has become standard in almost

[8] The utility of consumers are modeled consistently with the search and matching labor marked, cf. section 4.

[9] In SEM models, the level of consumption if typically determined by income and wealth, both in the short and long run, i.e. independent of the amount of leisure.

all models which, like MAKRO, have intertemporally optimizing agents and are used to describe consumption at business cycle frequencies (an example is the Quest III model).

Habit formation can be specified in several ways. Central is that it breaks the time separability otherwise found in the utility function. Technically, habits increase the concavity of utility in the relevant point of consumption. As a result, the forward-looking households prefer a more smooth consumption path and react more sluggishly to shocks. For the hand-to-mouth consumers, habit formations only affects the distribution between housing and other consumption.

Specifically, habit formation is introduced additively and through an external reference point, the so-called "catching up with the Joneses" effect (introduced by Abel, 1990).[10] Because a single household cannot impact the average, this habit is exogenous to the household, while by symmetry it is, in equilibrium, identical to lagged individual household consumption. An example of this can be found in the Quest III model. One's own consumption is an externality on other households and vice versa unlike habits derived from one's own consumption. The difference does not seem to matter. Dennis, 2009 shows that the two specifications are equivalent up to a first-order approximation and Havranek et al, 2017, find no difference in the size of the estimates in studies that look at internal and external reference consumption.

In the current version of MAKRO there is a habit in both non-durable consumption and in housing, and at the housing habit is much stronger than the non-durable consumption habit. Guerrieri & Iacoviello (2017) find that habit formation on housing consumption is stronger than on other consumption. For Danish data, housing consumption develops more sluggishly than total consumption.

The inertia that is empirically found in the demand for housing is certainly due in a large degree to transaction costs in the housing market. For computational reasons we have not introduced these costs for individual households. Habits in housing utility compensate for this incomplete modeling. Flavin & Nakagawa (2008) note exactly that habit consumption can produce effects similar to those of a fixed-cost relocation model.

Since their introduction into the macroeconomics mainstream, habits have been pervasive in macroeconomic studies and in work on consumption in particular. In a meta-study summarizing around 600 estimates, Havranek et al (2017) find an average habit coefficient of 0.4 for non-durable consumption. In both Pedersen & Ravn (2013) and Pedersen (2016), which are estimated DSGE models for the Danish economy, there is a significant degree of habit formation.

Bequests

Regarding the utility from bequests, this way of modeling how you care for your descendants is called the "warm glow" motive (Andreoni, 1989, 1990). This framework can solve the problem that older people consume too little at the end of life, compared to what can be explained in a simple life cycle model without altruistic preferences (Kaplan et al, 2020). The

[10] We use the cohort's own consumption at the previous age level (in the previous year) as a reference for habit consumption rather than consumption for the same age group in the previous year. This is done to help the model calibration, especially for young age groups, where the age profile for consumption is both relatively steep and noisier. For the aggregate consumption, however, this hardly has significance. The degree of habit formation is assumed to be the same for households, across ages.

alternative to the warm glow motif (or "heritage-in-utility function") is a purer form of altruism, where the utility function of a cohort depends directly on the utility function of future generations. The warm glow bequest function implies that there is no Ricardian equivalence in MACRO.

Having utility from from bequests is useful not just in order to match observed life cycle profiles. In models with financially constrained households, the timing of bequests matters. The importance of intergenerational transfers of assets and their influence on individuals' wealth over life has been known at least since Kotlikoff & Summers (1981) or Modigliani (1988). In a recent study on Danish data, Boserup et al (2016) find that received inheritance accounts for more than a quarter of the total wealth of people aged 45-50 years. In other words, a good estimate of the size and timing of the inheritance is necessary to have realistic age profiles.

Inheritance data are not directly available, but by linking register data containing wealth information at the individual level with the population register containing family relationships, we estimate bequests by linking wealth changes to observed deaths using a difference-in-difference estimator as in Boserup et al (2016). Bequests received are included as a lump-sum income in the budget constraint of the recipient.

Direct utility from wealth

The forward-looking households are assumed to get (direct) utility from their current wealth, i.e. on top of the expected utility from future consumption (and bequests) that this wealth can be used for. Introducing wealth in utility can be seen as a way of approximating savings behavior which reflects a precautionary savings motive. This is the idea of precautionary savings when income is stochastic and uninsurable (Carroll & Kimball (2008)). This can explain why young people do not take on a large amount of debt (although some of the explanation for that lies on the supply side of credit if would like to borrow but no one will lend them what they want).

Both the utility function of bequests and that of wealth have their respective "habit" additive objects. This ensures that their wealth is above a certain level. In the absence of an explicit model of household credit, this habit-like interior parameter inside utility acts as a credit constraint or a substitute for the precautionary savings motive.

The notion that households benefit from wealth, for example via social status, has a long history in economic theory (Adam Smith, David Ricardo, J.S. Mill, Alfred Marshall, Thorstein Veblen, J.M. Keynes, Irving Fisher, Gary Becker). Within the last 10 years, it has become more common in New Keynesian models to assume that households have government bonds in the utility function as a measure of preference for safety.[11] Direct utility of wealth has another notable percursor, namely the "money-in-the-utility-function" model of Sidrauski (1967).

[11] Poterba & Rotemberg, 1987; Krishnamurthy & Vissing-Jorgensen (KVJ), 2012, Fisher, 2015 and Auclert et al, 2018. KVJ and Fisher have an additive utility of wealth term that contains only low risk liquid assets (bonds) with a random utility coefficient. This random term is observationally equivalent to a risk premium shock. See also Del Negro et al. (2017) and Michaillat & Saez (2019a; 2019b).

Wealth portfolio

Unconstrained households have four different assets and liabilities: Bank deposits and bank loans, bonds, and domestic and foreign equities. Mortgage debt is treated separately. Bank loans are partially related to housing. Each financial variable has its specific return and this return is not age dependent (rates on bank loans could be but we do not consider it).

Total financial assets and liabilities of the households in MAKRO are consistent with national accounts data taken from the ADAM database. In addition, the age profiles of the different portfolio objects are important in the model because they induce differences in the marginal rate of return on savings over the life cycle, and because they are related to the housing decision through non-mortgage bank debt.

The link between aggregate and age specific variables requires the use of data from several databases.[12] Data for the age distribution of households' wealth is taken from the Wealth Statistics from Statistics Denmark, while the relevant age-specific income items, including returns across asset classes, are taken from the Lovmodel's database.

Since there is no uncertainty in the model, the composition of the portfolio of households is not the result of an optimal decision within the model. However, we use the life cycle to obtain a partially endogenous portfolio composition. In order to do so, we estimate an empirical relationship between the holdings of each portfolio component (for example bonds), and three explanatory variables: age, total non-housing net financial wealth, and housing wealth. The last two variables are endogenous in MAKRO and age is policy invariant. Therefore we obtain exogenous rules linking portfolio composition to the endogenous decisions of the households in the model. This allows for a detailed characterization of household portfolios over the entire life cycle. Furthermore, to the extent that the data is the result of optimal portfolio choices, the empirically estimated relationships contain that optimality up to a regression residual. Therefore MAKRO, without uncertainty, contains an optimal household portfolio which adjusts to economic conditions.

Pensions

Pension contributions and pension income are exogenous to the household and treated as lump sum payments in the model. Because they are tied to wages, the contributed amounts are endogenous, and because pension fund returns depend on endogenous returns on corporate stocks, the pension income is also endogenous. Households know they will pay these contributions and know the income they will receive later, so these lump sum amounts have an income effect on household decisions. Under Ricardian equivalence that effect would be minimal, but because the model has features of credit constraints, even for unconstrained households, there is likely to be some non Ricardian effect, although possibly negligible.

Pension-related variables are constructed to match data. Households pay a constant share of their wage income into several pension funds. The pension funds are actuarially fair, so that they do not make a profit and pay out the full value of the pension savings each year. All pension funds have the same exogenous portfolio composition of domestic equities, foreign equities, bonds and bank deposits. Contributions and disbursements are taken from DREAM's more detailed pension model. Age-distributed data for pension assets as well as inflows and outflows are also based on DREAM's pension model, which is consistent with the aggregate figures from the national financial accounts.

---

[12] Due to immigration and emigration, there is not full agreement between the periodic survival rates and the population accounts. It is then necessary to make some model assumptions about the financial wealth of migrants. This is done to ensure consistent aggregation and has a limited impact on the overall characteristics of the model.

The composition of non-durable consumption

The quantity of non-durable consumption which is the subject of the intertemporal savings choice is a CES-tree composite of five sub-components: tourism, services, goods, energy and cars. As there is no data available for the age distribution of private consumption divided into its sub-components, this division is the same for all households of all ages, which allows all households to face the same consumption prices. This then maps into the organization of production and the input-output structure of the economy.

The CES-tree is a nested structure, where each good joins the trunk through the levels of the tree. This allows for different substitution elasticities throughout the tree and helps characterize the demand for the different goods. The share parameters (not the elasticities) at the different levels in the tree allow for the calibration of structural shifts in consumer demand given prices, such as a gradual shift of consumption towards services and tourism. The decomposition of total consumption allows MAKRO to provide a detailed description of private consumption.[13]

2.3 Housing

After the 2008 crisis, housing and housing finance took center place in macroeconomics.[14] Housing is the single biggest household asset and mortgage debt is the largest household debt item. Housing is also a durable good, a store of value and a direct store of utility, with particular financing properties, and with its own interest rate dependence properties (Mankiw, 1982, 1985).

The relevant measure of housing cost is the user cost, obtained from the optimality conditions of unconstrained agents. Whereas for non-durable goods the user cost is the price of the good, in the case of housing the user cost contains opportunity costs, financing costs, depreciation and maintenance costs, taxes, capital gains, and land revenues, as well as a term that proxies for transaction costs which are not explicitly modeled. This is equivalent to the user costs of capital or labor faced by firms, also derived from their intertemporal optimality conditions. One of the characteristics that sets MAKRO apart from its Danish predecessors is the detailed modeling of housing, and of mortgage finance.

Mortgages are the largest household debt item, and they have different financial terms than bank debt. The model does not have an endogenous mortgage choice, as adding this margin of adjustment proved computationally taxing. Instead, we use the observed levels of mortgage debt relative to house values as an exogenous measure of the fraction of the house that is mortgage financed over the life cycle. This fraction is then further modelled to depend on house prices, although it remains exogenous to the household. This construction allows us to isolate mortgage finance and its impact on the user cost, and to generate realistic mortgage debt magnitudes when we forecast the model. Through the modelling of the mortgage ratio, we obtain some empirical properties concerning the reaction of mortgage ratios to the movement in house prices. The household only has an extensive margin choice, which is how much housing to buy, but through that choice we can obtain a more accurate user cost measure and have a start-up model of housing finance that can be improved.

It is in the derivation of the user cost of housing that MAKRO contains its most significant deviation from the perfect foresight baseline. In the household's budget constraint we have

[13] Baqaee and Farhi (2018). NBER Working Paper 24684.

[14] Early work by Davis and Heathcote (2005). Garriga, Noeth, and Schlagenhauf (2017) and references therein.

only observed prices since the budget constraint is an accounting identity. In the intertemporal first order condition we deviate from assuming that agents know next period's exact house and land prices, and instead impose that these agents understand in which direction the price will move but have only a conservative expectation of the magnitude of the price movement. This is needed is because capital realized gains on housing make the user cost too low such that the model cannot match the data. This is a well known problem (Khan & Reza, 2017), and other authors use a similar approach (Gelain et al (2013), Kravik and Mimir (2019)).

Owned housing is (currently) the only good in the model that includes land. And land, as a quasi-fixed factor, is an important determinant of house prices (Davis and Heathcote (2007)). Land is owned exclusively by households, and is embodied in the house they buy. In order to add land to the model we introduce an intermediary between households and the construction sector. This intermediary buys materials from the construction sector, and land released by housing depreciation as well as land released by the state, packages them together and sells the resulting housing good to households.[15] When households buy their homes they understand there is a residual value of land they will receive when their house depreciates and the fraction of land attached to that depreciated housing is sold. In this way, land appears explicitly in the user cost of housing.

The intermediary plays an additional role in the model. It helps match the data. The flow of construction input used in packing new houses is used as an investment quantity that accumulates an auxiliary stock of buildings. This auxiliary stock measure adds to another quantity that stands for the stock of buildings in rental housing, and which are exogenous in the model. In the data this aggregate stock is then assigned a rental value. As the rental market is a regulated market, the rental value from the national accounts does not reflect the real user cost of owner-occupied housing. Rents are then exogenous in MAKRO, and this auxiliary stock purged of land helps match this nominal variable in the data.

The housing market has significant inertia on both the supply and demand sides. The inertia on the demand side comes from habit formation. On the supply side, it comes from imposing quadratic adjustment costs on the intermediary, and by the fact that only a limited amount land is available each period.

[15] Th is intermediary has a production function. The elasticity between construction and land is from Epple et al, 2010 and Ahfeldt & McMillen, 2014, who look at other countries.

3. Firms

There are eight private sectors and one public sector in MAKRO representing aggregation from a disaggregated industry classification in the national accounts. Firms in the private sectors are optimizing agents. Each sector has two markets with independent agents. A producer's market where optimal inputs are chosen and the marginal production cost is determined, and a distribution market where prices are set as a markup over the marginal production cost. Separating price setting from optimal input choice makes the problem tractable.

3.1 Production

Output is produced with four inputs. Intermediate inputs (materials, R) sourced from all sectors, two types of capital goods, buildings (structures, B) and machinery (equipment, K), and labor (L). The production function is a nested CES production function. The nest structure matches machinery capital and labor at the bottom in a KL aggregate. This KL object is then matched with building capital in a KLB aggregate. The KLB object is then matched at the top with materials (R) to form the upper KLBR aggregate which is the final output. At each stage in the CES production tree different prices are formed, consistent with a zero profit condition such that the upper KLBR price is the marginal cost of one unit of output. The different substitution elasticities in the production function are estimated from the data.

The sector-specific intermediate input of materials is assembled with purchases from the nine sectors, and can be sourced from domestic as well as foreign suppliers. This is done through two layers of zero profit CES aggregation, the bottom one being the allocation from domestic versus foreign suppliers within a sector. The upper CES aggregator which assembles purchases from the nine different sectors is a zero elasticity (Leontief) aggregator. The lower aggregator has a positive elasticity. This construction allows the model to match the input-output structure of the economy, and is similar to that of the Danish models DREAM and ADAM.

The capital stocks inside the firm accumulate through a standard perpetual inventory law of motion. The investment flows adding to the undepreciated stock are constructed in a similar way to that of the input of materials. They also use two layers of zero profit CES aggregation.

The relevant price of capital is the user cost, derived from the optimality conditions in the problem of the producing firm. It contains the opportunity cost of capital (given by the required rate of return inside the discount factor), the depreciation and marginal adjustment costs, and the capital losses or gains attached to the undepreciated stock. The problem of the firm contains also an embryonic model of firm finance, with costly external finance modeled after Gomes (2003), and with exogenous debt finance[16]. Both affect the user cost of capital. Costly external finance adds a Keynesian multiplier type of effect to the response to

[16] This type of constraint made popular by Gomes (2001) is now widespread in the literature on firm finance (Quadrini, 2011, Drechsel, 2020). The fact that external finance is more expensive than internal finance also satisfies a pecking order where retained earnings are preferred (Donaldson, 1961 and Myers & Majluf, 1984). This is not the collateral effect of Bernanke and Gerter (1989), although that mechanism can be added.

shocks as an increase in profitability relaxes the current constraint, which allows for extra investment that in turn will help relax the constraint in the future.

The required return reflects the earnings investors expect to have when they hold company stock. This contains a risk premium since equity is a residual claimant, subordinate to debt. The corporate capital structure therefore affects the size of the risk premium. The fact that the model has no random variables and profit streams are deterministic does not mean the risk premium should be zero since the model must reproduce the average return, and not an exact stochastic return.[17] MAKRO follows DREAM and ADAM and assumes that firms hold corporate debt in proportion to the capital stock. Gustafsson and Knudsen (2014) from ADAM examine the empirical corporate capital structure.

The model has a standard one period time to build in the capital stock. Current output is a function of one period lagged capital stock(s). However, variable capacity utilization means that companies can use their input with varying intensity if the need arises, and thus affect the output obtained in the short run from the rigid stock. Capacity utilization is a standard modeling tool that allows for procyclical productivity. As an example, the DSGE model of Pedersen (2016) used by the Danish central bank also has it. Capacity utilization is present, and modeled in the same way, on labor and on both capital stocks.

Firms incur quadratic capital installation costs, formulated in terms of changes in the level of investment rather than in the levels of the stock. This makes it easier to match the impulse responses from the VAR models and is common practice in the literature (Christiano et al, 2005).

3.2 Price-setting

In each sector there is a retailer market where firms buy goods from producers and sell them to consumers. In this retail market there are many firms in monopolistic competition where every firm faces an iso-elastic demand curve with the same elasticity (Dixit & Stiglitz, 1977). Each firm will in equilibrium be identical to all others in the market. When setting prices they incur costs of changing prices as in Rotemberg (1982). The resulting sectoral price will contain the standard constant markup over unit costs expanded with an endogenous term reflecting the costs of changing prices. In the long run the markup is reduced to the constant part.

In the data, inflation displays a hump-shaped response to shocks. This pattern cannot be obtained when using the exact adjustment cost function from Rotemberg (1982). Instead we model costs of changing the inflation rate rather than the price level (Kravik and Mimir (2019)). This can no longer be interpreted as a proxy for "menu costs", but can be interpreted as costs of acquiring and processing information about other price developments in the economy.

3.3 Value of the firm

The value of the firm contains two different objects. The present value of all future cash flows generated by the firm, and value associated with liquid financial assets. These assets exclude the corporate debt mentioned above. They are a separate entity and enter the value of the firm because of the way the data is constructed, particularly in the service sector. This

[17] Evidence from ECB (2018) shows that, despite the low interest rate environment, firms maintain a high rate of return. We follow Autrup & Hensch (2020) and assume that the risk premium ensures a total return of circa 7%.

sector includes financial services and therefore investment houses that trade on financial assets are in the data. The way to separate these firms from our production units is to exogenize these financial assets, forecast their evolution independently, and include that exogenous forecast in the model so as to match the available data on the value of the firm, which is aggregated to our sectoral level. The value of Danish listed and unlisted shares is thus equal to the value of their financial assets plus the discounted value of their operating profit.

The value of the firm matters. For example, an announcement of lower corporate tax rates in the future will increase the share value of the firm at the time of the announcement. This is true in the model. This is an unexpected gain. Share prices will jump once, and then resume their normal course associated with the normal required return. They will not jump later when the tax rate changes. The increased wealth associated with higher share prices will affect household wealth and consumption through their portfolio. It will also affect pension wealth and thus future pension income, which also affects current consumption.

3.4 Input-Output structure and market clearing

By construction, the supply of each of the nine products/sectors can come from any of the nine domestic producers or from their nine foreign counterparts. However only three private sectors have foreign supply: energy, manufacturing, and services. It is assumed that imports of goods excl. energy are substitutes for goods from the domestic manufacturing industry, that energy import is a substitute for goods from the domestic energy industry, and service imports are a substitute for services from the private service industry.

Output from each sector is sold as intermediate inputs to firms in the nine sectors. It is also sold as investment goods to firms in each of the nine sectors. It is also sold as input to the six different final consumption goods and to the public consumption good, as well as to the different export goods. These flows are links in the input-output structure, and such a structure is also a core part of the ADAM, DREAM and SMEC models.

As noted above, in the description of intermediate inputs and of investment, each quantity inside the firm aggregates purchases from the nine sectors through two layers of zero profit CES problems, the bottom one being the allocation from domestic versus foreign suppliers within a supplying sector. These two layers can be viewed either as part of the technology of the firm, or as independent zero profit intermediation sectors. The same occurs in the relationship between the nine sector supply and the five non-housing decomposition of consumption goods. There one can view these intermediary steps as part of household preferences.

Each sector produces one homogeneous product, and sells at the same price to all buyers. The supply curve for the individual industry is upward sloping in the short term (due for example to installation costs on capital), while the demand curve is downward sloping. The price clears the market. In the long run the supply curve is flat, with the output price determined as an exogenous markup over unit costs. There are ten endogenous prices in the model. Eight product market clearing prices, plus the price of labor and the price of land. All other prices are derived from these.

4. The Labor Market

MAKRO uses a search and matching model of the labor market where wages are determined by a bargaining process that generates wage rigidity. The seminal contributions to search theory of Diamond (1971) and of Mortensen and Pissarides (1994) provide an explanation for the existence of involuntary unemployment. Merz (1995) and Andolfatto (1996) are the first to successfully include search and matching in a general equilibrium model. This is now the standard in macroeconomics where we single out Gali, Smets and Wouters (2012) as a key modern reference.

The purpose of labor market modeling is to obtain involuntary unemployment, and to explain fluctuations in employment and wages. In particular, the fact that employment moves more than wages over the cycle even though the labor supply is not elastic.

Fluctuations in employment are relative to its structural level. Employment and unemployment are measures of population. The projections of population and structural employment are constructed outside the model, and the benchmark exercise takes these structural processes as given when evaluating the short and medium run impact of shocks to the economy. Some experiments can require an update of these structural forecasts.

There are four key elements in the labor market.[18] Workers choose search effort. Firms post vacancies. A matching technology brings them together and determines employment. Unions bargain on behalf of workers and firms to determine the wage. This wage applies only to the fraction of contracts eligible for negociation in the current period. Other contracts retain their previously agreed wages.

4.1 Search and Matching

In a search model of the labor market workers search for jobs and employers post vacancies. In our model, workers have convex disutility from searching and firms have linear and convex costs of posting vacancies. These costs for the firm are measured in employment taken from the activity of production. Non-linear costs of posting vacancies have been shown to help with the employment response to shocks (Fujita and Ramey, 2007).

Workers and employers meet and the outcome of this meeting is determined by a matching function. This function is such that it is never possible for all unemployed workers to find jobs. This is the matching friction. As noted in the introduction, the search friction is contained in the fact that if a worker fails to find a job this period he or she has to wait until the following period to search again for a job. Both frictions are necessary to generate involuntary unemployment.

An increase in the labor supply is a good example of how a search labor market works. The initial effect of a higher labor supply is an increase in the number of jobseekers for a given number of vacancies. The key effect is that the job finding rate falls and the vacancy filling rate increases. There is a reduction in the costs of hiring for firms so that even if wages and prices do not change there is a small increase in employment. New employees move from being transfer recipients to being wage earners. There is an increase in aggregate demand

[18] Workers also choose how many hours to work, and firms take them as given (a simplifying assumption). Hours are a minor part of the labor market in MAKRO and we refer the reader to the technical documentation for details.

which increases firm profits and leads to further increases in employment. It is not possible to predict the movement of prices and wages, but adjustment continues until the structural unemployment rate is restored.

Employment relationships end with a certain probability, the job destruction rate. This probability is age-specific, measured from the data, and exogenous in the model. As the job destruction rate is less than 100%, taking a job if you are a worker or hiring someone if you are a firm, are dynamic forward-looking decisions. Workers know that their search effort will be rewarded with a job that will last a number of periods, and crucially, avoid the disutility of having to search for a job in those periods. Firms know that when they hire a worker, that worker will stay for several periods, and save on the costs of hiring during those periods. For firms, this dynamic aspect is relatively small, as the wage is still the overwhelming part of labor costs, but it is not insignificant.

Finally, we make the necessary assumptions to ensure that all households (unconstrained or H2M) make the same decisions in the labor market and have the same outcomes. A key assumption necessary to obtain this result is that there are no wealth effects in the labor supply. The marginal utility of consumption must not be present in the first order conditions. This is a common assumption in the literature (Galí, Smets and Wouters 2012).

4.2 Bargaining and wage rigidity

Wages are determined by bargaining between two large unions, one representing all workers, and the other representing all firms. Despite being monopoly unions we do not treat them as such, as the otherwise bargaining problem would be unnecessarily complex.[19]

Bargaining serves two purposes in the model. It determines wages, and it determines wage rigidity. It is possible to design the bargaining game such that it generates rigidity. The need for such a bargaining game arises due to the fact that the most widespread bargaining model, the Nash bargaining game, does not generate enough rigidity since it yields a proportional split of the surplus on the table. The reasons for this failure lie in the definition of the fundamental surplus and in the nature of the bargaining solution. The fundamental surplus is the difference between the output generated by the worker and the worker's outside option, and it is the quantity bargained over when deciding the wage.

Suppose the outside option is zero. The Nash wage becomes a fraction of the match surplus and therefore moves exactly like the match surplus. This implies the fraction of the surplus allocated to both workers and firms also moves like the total surplus, which means wages and employment move the same way, and therefore employment does not move enough while wages move too much (Shimer (2005), Blanchard and Gali (2008)).

Hall (2005) pointed out that any wage that lies inside the surplus, even a constant, is an acceptable solution to the bargaining problem. Hagedorn and Manowski (2007) noted that a realistically larger (than zero) outside option for the worker would shrink this surplus and therefore make small changes in the output generated by the worker imply big changes for the match surplus. These bigger changes in the match surplus can then generate more vacancies being posted if this outside option is exogenous to the output generated in the firm.[20] In MAKRO we have such a lower bound which is common in the literature (Mortensen

[19] For monopoly unions see Krusell and Rudanko (2016).

[20] With wage $w = b + \mu (y-b)$ and profit $y-w = (1-\mu) (y-b)$, an increase in y with a constant b will increase the payoff of the firm by more than the payoff of the worker, and more so if (y-b) is small to start with.

& Pissarides 1994, Ljungquist & Sargent 2017) which helps to ensure an empirically sufficient inertia in wage formation. But this is not enough.

There is, however, another way to generate wage rigidity. That is the case if the rigidity is placed elsewhere, in a Calvo-type framework where only a fraction of contracts can be negociated in a given period. In MAKRO we use this staggered contract negotiation taken from Galí and Gertler (1999).

The Calvo-type assumption results in rigid behavior of the average salary in the economy. In order for the average salary to be the one that determines the behavior of firms and workers it is necessary to define how contracts allocated. We assume they are allocated randomly, both to workers who have kept their jobs and to newly employed workers, and that this allocation is not known when making decisions to post vacancies or to search for a job.

5. The Public Sector

The public sector in MAKRO is modeled in detail. It is primarily a very large accounting system with relatively few and simple assumptions. The starting point is the actual and structural government balance.

5.1 Determination of the actual budget balance

The actual government balance is the government operating income minus operating expenses plus net interest income. Operating income consists primarily of revenue from income taxes, corporate taxes, pension return tax and other miscellaneous taxes. Operating expenses primarily consist of public consumption and income transfers. Public consumption consists of public employment, purchases of goods, and public investment expenditure. Net interest income depends on the public sector's assets and liabilities as well as the location and return on these.

Income tax revenues contain bottom and top personal income taxes, municipal taxes, taxes on income from financial assets, corporate taxes, estate taxes and labor market contributions. The proceeds from these depend on applicable tax rates and tax bases. The tax base is calculated separately for each age, and depends primarily on household wages and capital income. In addition, there are housing taxes and excise duties, which primarily depend on the household consumption composition. Finally, the pension return tax depends on the return on household pension assets. The modeling of public revenues ensures that the bases are taxed correctly, but it is the modeling of household savings and consumption that is decisive for determining most of the bases - and thus also the revenues.

Value added taxes (moms) are determined in detail based on input-output production flows. This applies to product taxes which are flows from (nine types of) producers to private consumption (six types of goods), public consumption, Investments (three types of capital sourced from all nine production sectors) and exports (five export goods). Similarly, input taxes paid by firms (labor and two types of capital) are distributed among the nine industries. Again, the modeling of public revenues from taxes ensures that the various tax bases are taxed correctly, but it is the modeling of the demand from households, firms and the rest of the world that is decisive for determining the correct size of the tax bases. Similarly, the modeling of corporate profits is essential for the correct determination of corporation tax revenue.

The default is that public consumption is exogenous in the event of a shock to the model. In the basic run of the model, public consumption is determined exogenously within the medium-term planning horizon used by the ministries (currently 2025), according to which the nominal costs for both public employment and purchases of goods are assumed to follow the demographic trend and the evolution of wages. Public investment is exogenous in the face of shocks and, in the basic run, exogenously given within the planning horizon. According to the planning horizon, public investment is determined on the basis that the public capital system must follow a weighted average of public and private gross value added. These assumptions follow the practice of the Ministry of Finance's medium-term projections.

Income transfers are decomposed into 33 types and follow the number of people associated with each of the 33 recipient groups. These population groups are measured and predicted outside the model by the ministry of Finance using Population Accounts data and are related to the level of structural employment. Changes in structural employment affect this decomposition, which should be redone. In the event of a shock to MAKRO, these groups change endogenously due to changes in employment. In the model, the number of persons in a specific transfer group receives an average transfer, which follows the evolution of wages.

Net interest income consists of the return on public assets minus interest payments on public debt. Government assets follow GDP exogenously (as a starting point) and are divided into domestic equities, foreign equities, bonds and bank deposits, with exogenous portfolio weights. Government debt consists of bonds, and budget deficits increase it while surpluses reduce it. The return rates for the public sector portfolio are the normal rates for assets. The marginal interest rate of the public sector is thus the bond rate, forecasted exogenously by the Ministry of Finance.

5.2 Structural balance and sustainability.

The structural balance consists of the actual budget balance adjusted for cyclical factors and other temporary conditions.

The cyclical factor measures the gap between realized budget balance and the long run structural balance as a weighted average of the output and employment gaps, multiplied by a budget factor. This last factor is a measure of the cyclical sensitivity of public finances and is calculated by the Ministry of Finance.

The employment gap is calculated as the difference between actual and structural employment. Structural employment is calculated in the Ministry of Finance by means of a separate population account, where estimates of policy effects such as changes in retirement age are taken into account. The output gap is the difference between actual and structural gross value added. Structural gross value added is calculated using the *observed* capital stock and the measure of structural employment.

Corrections for other temporary conditions include fluctuations in a number of specific items, including the proceeds from pension return tax, oil and gas extraction in the North Sea, other corporation and registration taxes, capital gains taxes, net interest payments, other special budget items and a number of non-recurring items. These are in principle exogenously determined by the users, and are in the basic model run determined by the Ministry of Finance.

The structural balance is not included in the beta version of the model.

The sustainability indicator (HBI) adds the general government net wealth in a given year and the present value of future primary surpluses and deficits. In MAKRO, the public sector is set to comply with its intertemporal budget constraint via the imposition of a long-term adjustment to the normal fiscal policy. This amounts to a very soft forced adjustment using lump sum transfers, starting from 2030. The HBI indicator generated by the model is the standard one and excludes the lump sum transfers.

5.3 Determination of public production and employment

Public production can be described from a demand viewpoint. The primary demand is for public consumption. From an accounting and model perspective, the public sector produces the goods it consumes. There is also a small demand from private consumption of services produced by the public sector. These are direct non-tax payments from households to the state such as some day-care payments. And there is demand for public production coming from public investment. Part of the investment in the economy comes from public research. Public research is technically not part of public consumption as it contributes to accumulate the aggregate capital stock in the economy, but still has to come from public production. This item is determined as a share of GDP based on policy research objectives.

From the supply perspective the measure of public consumption is given by the inputs it uses (wage sum, etc). Indeed, the production of public services is calculated by the input method. This means that the value of production is given by the cost of its production inputs. The nominal value of public production is thus easy to obtain since wages and input prices, and employment and physical inputs are the same objects as in the private sector. However, whereas private sector output quantities are the result of production functions that combine inputs to produce output, in the public sector this technology is replaced with a theory of the price of public output. This "theory" is a chain price index. A zero profit condition then generates output quantities as a residual quantity. There is no production function (no idea of technology) for public output.

The costs of production are given by the input costs of materials, labor, and capital. In the case of capital the only cost allocated in the public sector is that of depreciation, per international public sector accounting standards. Investment in buildings (structures) and the resulting capital stock are exogenous in the planning horizon. This is followed by a capital weighted average of public and private GVA. Labor costs and intermediate input (materials) costs are given by exogenous fixed proportions of public production net of depreciation costs.

6. The Rest of the World

The rest of the world plays a major role in MAKRO in both capital and product markets.

In the capital market, the rest of the world is the marginal investor with a given exogenous return requirement. Due to a fixed exchange rate policy, the interest rate level in Denmark is also exogenous (however, with the possibility of shocks to the interest rate spread to Germany). Danish households and firms can borrow and save at this rate and, as Denmark is a small open economy, this borrowing and lending behavior cannot affect it.

In product markets foreign prices are exogenous. Danish imports of foreign goods and services and exports of domestic output follow an adapted version of the classic Armington model of foreign trade.

In the basic run of the model, export market growth, import prices, export-competing prices, future interest rates and risk premia, are forecasted using external work done in the Ministry of Finance based on other work from international organizations such as the IMF, EU or OECD.

6.1 Foreign Trade

Foreign trade is based on an Armington specification. Imports and exports are determined by CES demand functions, which depend on relative prices and total demand. Imports are derived endogenously from the optimal consumption decisions of households and optimal input choices of firms. These choices occur in a CES-tree organization of production and consumption. The demand for Danish exports is a function with similar characteristic with the difference that it is exogenous to the model as MAKRO does not solve the optimization choices of the rest of the world. This Armington-inspired approach is standard in small open economy macroeconomic models.

The model therefore contains a number of foreign variables which are determined exogenously. They can interact with each other, and this interaction is estimated in the SVAR models to which MAKRO is subsequently matched, and then incorporated in the model. It is generally up to the model user to take into account the interrelationships between foreign variables in the basic run and in the response to shocks. In the case of shocks to domestic variables (such as a government expenditure shock) the assumption of a small open economy means that the relationship between foreign variables is unaffected. In the event of a shock to a particular foreign variable, the model user must be aware that such a shock may impact on other foreign variables.

Arguably, the most important parameters in the entire model are the price elasticities of the demand functions for Danish exports as they provide additional concavity to help close the model in an otherwise largely linear mathematical environment. These are not the only elasticities affecting foreign trade, as there is also a large number of CES demand elasticities on the import demand side. The MAKRO group has estimated the relevant long-term import and export price elasticities (Kronborg et al (2020)). However, the observable response of quantities to price changes differs in the short and in the long term, and this difference requires an adaptation of the canonical Armington model. In the case of domestic imports of foreign goods we introduce minimal ad-hoc changes, whereas in the case of exports we have a more extensive theoretical addition to the model with a layer of foreign intermediaries which face imperfect competition and price rigidity.

As mentioned, the demand for Danish exports is exogenous to the model. And in fact, it is not exactly a demand function as it is not a partial equilibrium construction. Instead, the equation governing the demand for Danish exports is a reduced form for the equilibrium relationship in a multilateral trade model. And, as shown in Anderson and van Wincoop (2003), this object contains other terms than the demand side income and the appropriate price ratio which would be the only variables in a strict Armington demand equation. In particular, it contains the gross domestic product of the exporter and this feature has been empirically confirmed (Fernandez et al, 2018).

Increased supply stemming from a growing workforce, an increase in trade openness, an increase in the number of exporting companies, and an increase in product variety, are linked with growing exports. Empirically, Bernard et al (2009) find that relative prices are the most important export determinant in the short term, while supply and scale effects are more important in the long term. Kronborg and Kastrup (2021) find evidence for a scale effect in Danish exports. The ADAM group has investigated the same issue and found that supply effects have a significant effect on Danish exports (Temere & Kristensen, 2016).

MAKRO therefore has a long-term supply effect that comes into force slowly with little impact on short-term properties. This supply effect allows exports to increase due to an expanding production capacity in Denmark without export prices having to fall relative to export-competing prices, so that no exchange rate effects occur if the Danish economy grows at a different rate than abroad.

6.2 Capital Market

MAKRO is linked to the national financial accounts available from ADAM's database. The various agents, households, firms, the public sector, pension funds, and foreign investors have portfolios of assets and liabilities of domestic equities, foreign equities, bonds (divided into mortgages and others) as well as bank deposits and gold. Aside from gold, the claims are a zero-sum game. Assets of one agent are liabilities of another.

For all assets and liabilities, the rest of the world is the marginal investor. Investors abroad have an exogenous required return on domestic equities, foreign equities, bonds and bank deposits. The driving interest rate in the model is the bond rate, on which the other returns are set. Foreign investors' risk premium on equities provide a spread to bond yields. The financial assets and portfolios of households and companies - including a description of mortgages, pension funds and the determination of the value of the firm - are given under the description of these agents.

In the determinist environment of MAKRO it is not possible to have endogenous optimal portfolio composition choices. These are therefore exogenous. However, in the case of the household portfolio we are able to use the variation in portfolio composition observed over the life cycle to capture some endogenous optimal adjustment, since portfolio composition varies with age itself but also with net non-housing financial assets and with the amount of owned housing, both of which are endogenous. The portfolios of firms and pension funds are simpler exogenous proportions of the total wealth contained in them.

7. Referencer

Abel, Andrew. (1990). Asset Prices Under Habit Formation And Catching Up With The Joneses. American Economic Review. 80. 38-42.

K. Abildgren, A. Kuchler, A. S. L. Rasmussen, and H. S. Sørensen. Consistency between household-level consumption data from registers and surveys. Danmarks Nationalbank working paper, 2018.

G. Ahlfeldt and D. McMillen. New estimates of the elasticity of substitution of land for capital. ERSA conference papers, 2014.

Beth Allen & James S. Jordan, 1998. "The existence of rational expectations equilibrium: a retrospective," Staff Report 252, Federal Reserve Bank of Minneapolis.

Anderson, J. E., 1979. "A Theoretical Foundation for the Gravity Equation," American Economic Review, 69(1), 106–116.

Anderson, J. E., and Eric van Wincoop. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle ." American Economic Review, 93 (1): 170-192.

D. Andolfatto, Business cycles and labor-market search. American Economic Review, 1996.

J. Andreoni. Giving with impure altruism: Applications to charity and Ricardian equivalence. Journal of Political Economy, 1989.

Andreoni, J. (1990). Impure Altruism and Donations to Public Goods: A Theory of Warm-Glow Giving. The Economic Journal, 100(401), 464-477.

P. S. Armington, 1969: "A Theory of Demand for Products Distinguished by Place of Production," International Monetary Fund Staff Papers, 16, 159–178.

Attanasio, O. Levell, P., Low, H., and Sanchez-Marcos, V. (2018). Aggregating Elasticities: Intensive and Extensive Margins of Women's Labour Supply. June 4, 2018.

A. Auclert, M. Rognlie, and L. Straub. The intertemporal keynesian cross. NBER working papers, 2018.

S. L. Autrup and J. L. Hensch. Do equity prices reflect the ultra-low interest rate environment? Danmarks Nationalbank Economic Memo, 2020.

J. Bang-Andersen, T. S. Hvolbøl, P. L. Kramp, and C. R. Thomsen. Forbrug, indkomst og formue. Danmarks Nationalbanks Kvartalsoversigt (2. kvt. 2013), 2013.

Becker, G. (1974). A Theory of Social Interactions. Journal of Political Economy, 82(6), 1063-1093.

Bernanke, Ben & Gertler, Mark, 1989. "Agency Costs, Net Worth, and Business Fluctuations," American Economic Review, American Economic Association, vol. 79(1), pages 14-31, March.

A. B. Bernard, J. B. Jensen, S. J. Redding and P. K. Schott. Trade, Product Turnover and Quality. American Economic Review, 2009.

Blanchard, O., and Jordi Gali, 2008. "Labor Markets and Monetary Policy: A New-Keynesian Model with Unemployment," NBER Working Papers 13897, National Bureau of Economic Research, Inc.

A. Borge and D. Knudsen. Reestimation af makroforbrugsrelationen til adam modelversion jun19. Danmark Statistik Modelgruppen Arbejdspapir, 2019.

S. Boserup, W. Kopczuk, and C. T. Kreiner. The role of bequests in shaping wealth inequality: Evidence from danish wealth records. American Economic Review, 2016.

Browning, Martin, and Thomas F. Crossley. 2001. "The Life-Cycle Model of Consumption and Saving." Journal of Economic Perspectives, 15 (3): 3-22.

Browning, M., & Ejrnæs, M. (2009). Consumption and Children. The Review of Economics and Statistics, 91(1), 93-111.

J. R. Campbell, J. D. M. Fisher, A. Justiniano, and L. Melosi. Forward guidance and macroeconomic outcomes since the financial crisis. NBER Macroeconomics Annual, 2017.

John Campbell & Angus Deaton, 1989. "Why is Consumption So Smooth?," Review of Economic Studies, Oxford University Press, vol. 56(3), pages 357-373.

J. Y. Campbell and N. G. Mankiw. Consumption, income and interest rates: Reinterpreting the time series evidence. NBER Macroeconomics Annual, 1989.

J. Y. Campbell and N. G. Mankiw. Permanent income, current income, and consumption. Journal of Business & Economic Statistics, 1990.

D. Cao and J. L'Hullier. Technological revolutions and the three great slumps: A medium-run analysis. Journal of Monetary Economics, 2018.

C. D. Carroll and M. S. Kimball. Precautionary saving and precautionary wealth. Palgrave Macmillan (eds) The New Palgrave Dictionary of Economics. Palgrave Macmillan, London, 2008.

C. D. Carroll, J. Slacalek, and M. Sommer. International evidence on sticky consumption growth. The Review of Economics and Statistics, 2011.

V. V. Chari, Patrick J. Kehoe and Ellen R. McGrattan (2007) Business Cylce Accounting**.** Econometrica Vol. 75, No. 3 (May, 2007), pp. 781-836 (56 pages)

R. Chetty, J. N. Friedmand, S. Leth-Petersen, T. H. Nielsen, and T. Olsen. Active vs. passive decisions and crowd-out in retirement savings accounts: Evidence from denmark. Quarterly Journal of Economics, 2014.

L. J. Christiano, M. Eichenbaum, and C. L. Evans. Nominal rigidities and the dynamic effects of a shock to monetary policy. Journal of Political Economy, 2005.

Christiano, L., Eichenbaum, M., and Trabant, M., (2016), Unemployment and Business Cycles, Econometrica, July 2016, 84(4), pp. 1523-1569,

Coles, M., and Petrongolo, B. (2008). A test between stock-flow matching and the random matching function approach. International Economic Review 49(4). pp 1113-1141.

Constantinides, G. (1990). Habit Formation: A Resolution of the Equity Premium Puzzle. Journal of Political Economy, 98(3), 519-543.

E. Crawley and A. Kuchler. Consumption heterogeneity: Micro drivers and macro implications. Danmarks Nationalbank arbejdspapir, 2018.

N. A. Dam, T. S. Hvolbøl, and P. B. Sørensen. Kan udsvingende i boligpriserne dæmpes? Danmarks Nationalbank, kvartalsoversigt 2011q1, 2011.

Danmarks Nationalbank. Mona - en kvartalsmodel af dansk økonomi. Danmarks Nationalbank, 2003.

Danmarks Statistik. Adam - en model af dansk økonomi. Danmarks Statistik, 2012.

Davis, Morris A. and Heathcote, Jonathan, (2005) Housing and the Business Cycle. International Economic Review, Vol. 46, No. 3, pp. 751-784, August 2005

Davis, Morris A. & Heathcote, Jonathan, 2007. "The price and quantity of residential land in the United States," Journal of Monetary Economics, Elsevier, vol. 54(8), pages 2595-2620, November.

J. B. Davies and A. F. Shorrocks. The distribution of wealth. Chapter in Handbook of Income Distribution, 1999.

M. Del Negro, D. Giannone, M. P. Giannoni, and A. Tambalotti. Safety, liquidity, and the natural rate of interest. Brookings Papers on Economic Activity, 2017.

R. Dennis. Consumption habits in a new keynesian business cycle model. Journal of Money, Credit and Banking, 2009.

P. Diamond. National debt in a neoclassical growth model. American Economic Review 55, 1126-1150, 1965.

P. Diamond. A model of price adjustment. Journal of Economic Theory, 1971.

A. K. Dixit and J. E. Stiglitz. Monopolistic competition and optimum product diversity. American Economic Review, 1977.

G. Donaldson. Corporate debt capacity: a study of corporate debt policy and the determination of corporate debt capacity. Harvard University Press, 1961.

Thomas Drechsel, 2020. "Earnings-Based Borrowing Constraints and Macroeconomic Fluctuations," University of Maryland.

J. Druedahl, E. B. Jensen and S. Leth-Petersen. The Intertemporal Marginal Propensity to Consume out of Future Persistent Cash-Flows: Evidence from Transaction Data. Arbejdspapir, 2021.

ECB. Measuring and interpreting the cost of equity in the euro area. Article in Economic Bulleting, issue 4, 2018.

Ejarque, J. (2021). Job destruction and job finding rates by age in Denmark. DREAM/MAKRO.

Ejarque, J. (2021). Forecasting the impact of pension age reform on job destruction rates by age in Denmark. DREAM/MAKRO.

D. Epple, B. Gordon, and H. Sieg. A new approach to estimating the production function for housing. American Economic Review, 2010.

J. Favilukis, S. C. Ludvigson, and S. van Nieuwerburgh. The macroeconomic effects of housing wealth, housing finance, and limited risk sharing in general equilibrium. Journal of Political Economy, 2017.

J. D. M. Fisher. On the structural interpretation of the smets-wouters risk premium shock. Journal of Money, Credit and Banking, 2015.

A. M. Fernandes, P. J. Klenow, S. Meleshchuk, M. D. Pierola and A. Rodriguez-Clare. The Intensive Margin in Trade. IMF Working Paper, 2018.

M. Flavin and S. Nakagawa. A model of housing in the presence of adjustment costs: A structural interpretation of habit persistence. American Economic Review, 2008.

M. A. Flavin. The adjustment of consumption to changing expectations about future income. Journal of Political Economy, 1981.

H. B. Fosse, R. H. Jacobsen, and J. M. Kuhn. Effekt på boligmarkedet af politiske, strukturelle reformer af dansk økonomi. CEBR Analyserapport, 2012.

Fujita, S., and Ramey, G. (2007). Job matching and propagation. Journal of Economic dynamics and control, vol. 31, no. 11, pp. 3671-3698.

Gabaix, Xavier. 2020. "A Behavioral New Keynesian Model." American Economic Review, 110 (8): 2271-2327.

Galí, J., and Gertler, M. (1999), Inflation Dynamics: A Structural Econometric Analysis. Journal of Monetary Economics Volume 44, Issue 2, October 1999, Pages 195-222.

J. Galí, J. D. Lopez-Salido, and J. Valles. Understanding the effects of government spending on consumption. Journal of the European Economic Association, 2007.

J. Galí, F. Smets, and R. Wouters. Unemployment in an estimated new Keynesian model. NBER Macroeconomics Annual, 2012.

Garriga, Carlos and Noeth, Bryan and Schlagenhauf, Don, (2017) Household Debt and the Great Recession (2017). St. Louis Fed Review, Vol. 99, Issue 2, pp. 183-205.

P. Gelain, K. J. Lansing, and C. Mendicino. House prices, credit growth, and excess volatility: Implications for monetary and macroprudential policy. International Journal of Central Banking, 2013.

J. F. Gomes. Financing investment. American Economic Review, 2001.

P. O. Gourinchas and J. Parker. Consumption over the life cycle. Econometrica, 2003.

D. Grinderslev and J. Smidt. Smec modelbeskrivelse og modelegenskaber, 2006. Det Økonomiske Råd Sekretariatet, 2007.

N. Gustafsson and D. Knudsen. Usercost med egenfinansiering. Danmark Statistik Modelgruppen Arbejdspapir, 2014.

Hall, Robert E, 1978. "Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence," Journal of Political Economy, University of Chicago Press, vol. 86(6), pages 971-987, December.

Hall, Robert, E. (2005). "Employment Fluctuations with Equilibrium Wage Stickiness." American Economic Review, 95 (1): 50-65.

Hall, Robert, E. (2012). The 2010 Nobel Prize in Economics: How the DMP Model Explains Current High Unemployment.

Hagedorn, Marcus, and Iourii Manovskii. 2008. "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited." American Economic Review, 98 (4): 1692-1706.

T. Havranek, M. Rusnak, and A. Sokolova. Habit formation in consumption: A metaanalysis. European Economic Review, 2017.

C. P. Hoeck and M. K. Bonde. The creation of lifecycle profiles for households in MAKRO. DREAM memo, 2021.

S. J. Hviid and A. Kuchler. Consumption and savings in a low interest-rate environment. Danmarks Nationalbank Working Paper, 2017.

A. K. Høj, M. R. Jørgensen and P. Schou. Lax tax changes and full capitalisation. Fiscal Studies, 2018.

M. Iacoviello and L. Guerrieri. Collateral constraints and macroeconomic asymmetries. Journal of Monetary Economics, 2017.

D. S. Johnson, J. A. Parker, and N. S. Souleles. Household expenditure and the income tax rebates of 2001. American Economic Review, 2006.

C. N. Jørgensen and A. Kuchler. Non-parametric estimation of marginal propensities to consume: The case of regression splines. Danmarks Nationalbank Working Papers, 2017.

G. Kaplan, K. Mitman and G. L. Violante. The housing boom and bust: model meets evidence. Journal of Political Economy, 2020.

G. Kaplan, G. L. Giovanni, and J. Weidner. The wealthy hand-to-mouth. NBER Working Paper, 2014.

G. Kaplan and G. L. Violante. A model of the consumption response to fiscal stimulus payments. Econometrica, 2014.

H. U. Khan and A. Reza. House prices and government spending shocks. Journal of Money, Credit and Banking, 2017.

N. Khorunzhina. Intratemporal nonseparability between housing and nondurable consumption: Evidence from reinvestment in housing stock. Journal of Monetary Economics, 2020.

G. M. Korniotis. Estimating panel models with internal and external habit formation. Journal of Business & Economic Statistics, 2010.

L. J. Kotlikoff and L. H. Summers. The role of intergenerational transfers in aggregate capital accumulation. Journal of Political Economy, 1981.

E. M. Kravik and Y. Mimir. Navigating with nemo. Norges Bank Staff Memo, 2019.

C. T. Kreiner, D. D. Lassen, and S. Leth-Petersen. Liquidity constraint tightness and consumer responses to fiscal stimulus policy. American Economic Journal: Economic Policy, 2019.

A. Krishnamurthy and A. Vissing-Jorgensen. The aggregate demand for treasury debt. Journal of Political Economy, 2012.

A. F. Kronborg and P. P. Stephensen. Decomposing the ins and outs of unemployment: Cyclical, structural, and demographic trends in the danish labor market. DREAM arbejdspapir, 2019.

A. F. Kronborg, C. S. Kastrup, and P. P. Stephensen. Estimating the constant elasticity of substitution when technical change is time-varying: a kalman filtering approach. Dream arbejdspapir, 2019.

A. F. Kronborg, K. A. Poulsen, and C. S. Kastrup. Estimering af ces udenrigshandelselasticiteter i makro. DREAM arbejdspapir, 2020.

A. F. Kronborg and C. S. Kastrup. Udbudseffekter i dansk eksport? DREAM arbejdspapir, 2021.

Krusell, Per & Rudanko, Leena. (2016). Unions in a Frictional Labor Market. Journal of Monetary Economics 80, pp 35-50.

M. Kumhof, D. Laxton, D. Muir, and S. Mursula. The global integrated monetary and fiscal model (gimf) - theoretical structure. IMF Working Paper, 2010.

M. H. Lang and D. Shackelford. Capitalization of capital gains taxes: evidence from stock price reactions to the 1997 rate reduction. Journal of Public Economics, 2000.

W. Li, H. Liu, F. Yang, and R. Yao. Housing over time and over the life cycle: A structural estimation. International Economic Review, 2016.

L. Ljungqvist and T. Sargent. The fundamental surplus. American Economic Review, 2017.

Maddock, R., & Carter, M. (1982). A Child's Guide to Rational Expectations. Journal of Economic Literature, 20(1), 39-51.

Mankiw, G. (1982), "Hall's Consumption Hypothesis and Durable Goods", Journal of Monetary Economics 10, 417-425.

N. Mankiw, (1985). Consumer Durables and the Real Interest Rate. *The Review of Economics and Statistics, 67*(3), 353-362.

K. Mertens and M. O. Ravn. Empirical evidence of the aggregate effects of anticipated and unanticipated us tax policy shocks. American Economic Journal: Economic Policy, 2012.

M. Merz. Search in the labor market and the real business cycle. Journal of Monetary Economics, 1995.

Mian, Atif T. and Sufi, Amir. "House Prices, Home Equity-Based Borrowing, and the US Household Leverage Crisis." American Economic Review, August 2011, 101(5), pp. 2132-156;

P. Michaillat and E. Saez. Resolving new keynesian anomalies with wealth in the utility function. Review of Economics and Statistics, 2019a.

P. Michaillat and E. Saez. An economical business-cycle model. Working paper, 2019b.

F. Modigliani. The role of intergenerational transfers and life cycle saving in the accumulation of wealth. Journal of Economic Perspectives, 1988.

D. T. Mortensen and C. Pissarides. Job creation and job destruction in the theory of unemployment. Review of Economic Studies, 1994.

S. C. Myers and N. S. Majluf. Corporate financing and investment decisions when firms have information that investors do not have. Journal of Financial Economics, 1984

J. A. Parker, N. S. Souleles, D. S. Johnson, and R. McClelland. Consumer spending and the economic stimulus payments of 2008. American Economic Review, 2013.

J. Pedersen. An estimated dsge-model for Denmark with housing, banking, and financial frictions. Danmarks Nationalbank Working Papers, 2016.

J. Pedersen and S. H. Ravn. What drives the business cycle in a small open economy? evidence from an estimated dsge model of the danish economy. Danmarks Nationalbank Working Papers, 2013.

M. Piazzesi, M. Schneider, and S. Tuzel. Housing, consumption and asset pricing. Journal of Financial Economics, 2007.

J. M. Poterba and J. J. Rotemberg. Money in the utility function: An empirical implementation. In New Approaches to Monetary Economics, 1987.

Quadrini, V. (2011). Financial Frictions in macroeconomic Fluctuations. Economic Quarterly, Volume 97, Number 3, Pages 209–254. Richmond FED.

M. Ratto, W. Roeger, and J. i.t. Veld. Quest iii: An estimated dsge mode of the euro area with fiscal and monetary policy. European Commission Economic Papers, 2008.

R. Rogerson. Indivisible Labor, Lotteries and Equilibrium. Journal of Monetary Economics 21, pp 3-16, 1988.

J. J. Rotemberg. Monopolistic price adjustment and aggregate output. Review of Economic Studies, 1982.

C. R. Sahm, M. D. Shapiro, and J. Slemrod. Household response to the 2008 tax rebate: Survey evidence and aggregate implications. Chapter in Tax Policy and the Economy, 2010.

Samuelson, Paul A. (1958). "An exact consumption-loan model of interest with or without the social contrivance of money". *Journal of Political Economy*. 66 (6): 467–482.

M. D. Shapiro and J. Slemrod. Comsumer response to tax rebates. American Economic Review, 2003.

Shimer, R. (2004). The consequences of rigid wages in search models. Journal of the European economic association 2. pp 469-479.

Shimer, R. (2005). The Cyclical Behavior of Equilibrium Unemployment and Vacancies. The American Economic Review, 2005, 95 (1), pp 24-49.

Shimer, R. (2006): "On-the-job search and strategic bargaining," European Economic Review, 50, 811–830.

Shimer, R. (2007). Mismatch. The American Economic Review, Vol. 97, No. 4, pp. 1074-1101.

Sidrauski, M. (1967) Rational Choice and Patterns of Growth in a Monetary Economy. The American Economic Review, 57, 534-544.

F. Smets, K. Christoffel, G. Coenen, R. Motto, and M. Rostagno. Dsge models and their use at the ecb. SERIEs paper, 2010.

N. L. Stokey. Moving costs, nondurable consumption, and portfolio choice. Journal of Economic Theory, 2009.

D. S. Temere and T. M. Kristensen. Supply factors in trade determination. Danmark Statistik Modelgruppen Arbejdspapir, 2016.

Yde, H. (2018). Do tax incentives for saving in pension accounts cause debt accumulation? Evidence from Danish register data. European Economic Review, 2018.

S. P. Zeldes. Optimal consumption with stochastic income: Deviations from certainty equivalence. The Quarterly Journal of Economics, 1989.