MEDSEA-FIN: SOME RESULTS FROM AN ESTIMATED DSGE MODEL

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MEDSEA-FIN: SOME RESULTS FROM AN ESTIMATED DSGE MODEL

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This article documents the estimation of MEDSEA-FIN, a medium scale Dynamic Stochastic General Equilibrium (DSGE) model with household heterogeneity, housing and borrowing constraints. The model is estimated using Bayesian methods on Maltese data, and delivers reasonable identification of the structural parameters and shock variances. The article shows the dynamic responses of several macroeconomic variables to a monetary policy shock and uses the estimated model to decompose observed house price movements into the underlying structural drivers. The model delivers results that are in line with expectations and other findings in the literature.

Introduction

The Central Bank of Malta has a suite of structural, semi-structural and reduced form models that it uses for policy analysis and forecasting. DSGE models nowadays play a central role in the analysis of policy due to their theoretical underpinnings and microfounded structure which allows for structural analysis (Christiano et al., 2018; Gürkaynak and Tille, 2017). Consequently, they form part of the Bank’s policy toolkit. MEDSEA-FIN is a DSGE model developed at the Central Bank of Malta for policy analysis, with the primary aim to capture linkages between the real estate sector, banks, and the Maltese macroeconomy (Gatt et al., 2020). This model is thus well suited to study the role of macroprudential policy tools, particularly limits on loan-to-value and bank capital ratios.

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MEDSEA-FIN has a rich structure, featuring credit-constrained households, multiple savings instruments including deposits, foreign bonds, capital and housing, a segmented labour market, a domestic non-tradable goods sector, an export sector, a construction sector, banks and a macroprudential authority. This makes the model highly policy relevant, ideal for the study of issues related to the real estate sector, household leverage and the conduct of macroprudential policies. Hence, it is imperative that the behaviour of the model is disciplined by the data. This article estimates MEDSEA-FIN using Bayesian methods, thus making it the first medium-scale DSGE model to be estimated using a rich set of observables for the Maltese economy.

The rest of the article is organized as follows. The first part documents the estimation of a subset of the model’s parameters and the implied behaviour of the model to a monetary policy shock. The estimated model is then used to describe the structural forces that were behind the observed dynamics of house prices in Malta over the past 20 years.

MEDSEA-FIN: a bird’s eye view

MEDSEA-FIN is a multi-sector, medium-scale open-economy DSGE model featuring nominal, real and financial frictions. It is based on the Two-Agent New Keynesian (TANK) model framework (Bilbiie, 2008; Campbell and Mankiw, 1989; Deborgoli and Gali, 2017; Gali et al., 2007) that imposes limited household heterogeneity, distinguishing between patient and unconstrained households (savers), and impatient and constrained households (borrowers). The presence of limited enforcement on debt repayment means that borrowers face a collateral constraint that is binding, with a borrowing limit that fluctuates with house prices over the business cycle. The limited household heterogeneity is sufficient to capture first order effects, such as amplification due to financial frictions and stabilization from macroprudential policy. Households supply a differentiated labour service and therefore exercise some degree of monopoly power over the real wage rate for labour hours worked in each production sector.

1 The author would like to thank Alexander Demarco, Aaron G. Grech, Wendy Zammit and Brian Micallef for helpful comments and suggestions. Any remaining errors are the author’s own. The views expressed in this paper are the author’s own and do not necessarily reflect the views of the Central Bank of Malta.
The model features a real estate sector, a banking sector, and a rich production environment with local intermediate and final goods producers, importers and exporters, and an exogenous sector representing the rest of the world. It distinguishes between three main production sectors, producing intermediate non-tradable goods, intermediate export goods and domestic housing construction. All production sectors use labour and capital as factors of production. Capital used in the domestic non-traded and housing sectors is accumulated through investment by saver households, while capital used to produce the export good is determined exogenously, to reflect the reality that in very small and open economies investment in the tradeable sector is largely determined by foreign direct investment. Importers are local agents representing foreign producers and distribute imports to final goods producers. The latter use a mix of this imported good and the non-tradable good to produce final consumption and investment goods. Exporters combine imports and the domestically produced export good to produce the final export good. The presence of nominal and real rigidities means than some prices, wages, hours, and volumes cannot freely adjust in the wake of shocks.

“The model features a real estate sector, a banking sector, and a rich production environment”

Banks intermediate financial resources between savers and borrowers. Both households and banks are subject to regulatory restrictions that take the form of limits on household loan-to-value and bank capital-to-asset ratios, respectively. A macroprudential authority, driven by financial stability objectives, uses these limits as policy tools and changes them over the financial cycle to exert some influence on the economy. The authority systematically tightens (loosens) these requirements when the credit-to-GDP ratio is above (below) trend. Since these macroprudential policy tools were only recently implemented, the loan-to-value and bank capital ratio rules were switched off throughout the estimation. The government consumes a fixed amount of the non-tradable good in every period. It balances the budget in each period by levying non-distortionary lump sum taxes on households. Finally, the foreign (euro area) economy is modelled as a stylised 3-equation system that has a demand equation, a supply equation, and a Taylor rule that characterises euro area monetary policy and closes the model.

The model economy is perturbed by several structural shocks that can be broadly grouped into domestic demand and supply, foreign demand and supply, financial and monetary policy shocks. Further details on the model and the results discussed below can be found in Gatt (2022).

Bayesian estimation

The estimation of MEDSEA-FIN relies on Bayesian methods as discussed in An and Schorfheide (2007) and Fernández-Villaverde (2010). The linear rational expectations solution of the model has a state space representation, which is composed of the transition equation (1) and the measurement equation (2):

\[ s_t = A_{st-1} + \nu_t, \quad \nu_t \sim N(0, Q) \]  \hspace{1cm} (1)
\[ y_t = B_{st} + \varrho, \quad \varrho_t \sim N(0, R) \]  \hspace{1cm} (2)

where \( s_t \) is the vector of the states of the model, \( y_t \) is the vector of observed variables, the elements of matrix \( A \) are functions of the structural parameters of the model and the elements of matrix \( B \) map the states of the model to the data. The vector \( \nu_t \) represents the structural shocks of the model with variance-covariance matrix \( Q \), while the vector \( \varrho_t \) represents measurement errors that capture both data measurement errors as well as the potentially imperfect mapping of model to actual variables due to statistical definitions. Both \( Q \) and \( R \) are assumed to be diagonal.

The objective of Bayesian estimation is to construct the posterior distribution of the parameters (and shock variances) \( \theta \) given the data sequence \( Y = \{y\}_T \), represented as \( p(\theta | Y) \). The log posterior is proportional to the log of the prior distribution of the parameters \( (\log p(\theta)) \) and the log likelihood formed by the model given the data \( (\log L(\theta | Y)) \):

\[ \log p(\theta | Y) \propto \log p(\theta) + \log L(\theta | Y). \]  \hspace{1cm} (3)

* Some of these shocks, such as labour supply, foreign risk premia and foreign direct investment shocks proved difficult to identify and estimate given the available data. These shocks were shut off during estimation.
Since the log posterior distribution does not admit a closed-form solution, Monte Carlo Markov Chain methods (the Metropolis-Hastings algorithm) are used to trace the posterior distribution.

Eleven macroeconomic variables — eight for Malta and three for the euro area — are used as observables over the period 2000Q1-2019Q4, which are real consumption per capita, real house prices, the HICP index, the services HICP index, credit to households per capita, investment in dwellings per capita, the import price deflator, real GDP per capita, euro area GDP, euro area HICP and the short-term shadow rate estimate of the ECB policy rate.\(^3\)\(^4\) The short-term shadow rate is a proxy for both conventional and unconventional monetary policy stances adopted by the ECB. The observables enter the model as demeaned annual growth rates, except for the interest rate, which is only demeaned. These data make up the vector of observed variables that are mapped to the model states, as shown in equation (2). The first four years of data are used to initialise the Kalman filter, so the posterior distributions are based on data spanning the period 2005Q1-2019Q4.

A total of 39 parameters and shock variances (including measurement errors) are estimated. For the sake of brevity, this article does not show the prior and the resulting posterior distributions but discusses them briefly instead. The priors on most of these parameters follow the convention in the literature; the Beta distribution is used for parameters bound between 0 and 1, Gamma distributions for the adjustment cost parameters and Inverse Gamma distributions for shock variances. Most of the priors are neither loose nor overly tight and are centred around the calibrated values of the parameters documented in Gatt et al. (2020). A more conservative approach is adopted for parameters whose values were somewhat arbitrarily set in the calibrated version of the model, such as for the persistence of shocks, and centre the distribution around lower persistence. Since Maltese macroeconomic data tend to be particularly volatile and noisy, the mean of the prior on the measurement errors is calibrated such that these account for up to 10% of the variance of the observables, similar to the approaches of Adolfson et al. (2013) and Schmitt-Grohés and Uribe (2012). These priors are imposed relatively tightly.

“A total of 39 parameters and shock variances are estimated”

The data are generally informative on most parameters, in particular the persistence of shock processes, although some parameters remain unidentified and therefore at their prior distribution. The mean values of some parameters are in line with estimates from other studies; wage and price indexation are like those estimated in the ECB’s New Area Wide Model II (NAWM-II, Coenen et al., 2018), while the mean inertia in the stock of household loans is close to that estimated in Iacoviello (2015) and Guerrieri and Iacoviello (2017). All structural shocks are identified except for the markup shock in the non-tradable goods sector. The posterior distributions for the measurement errors are mostly reasonably close to their priors, such that the measurement errors do not explain a sizeable share of the fluctuations observed in the data.

The transmission of a monetary policy shock

The estimated model can be used to trace the expected reaction of the model variables to a temporary shock through impulse response functions (IRFs). Chart 1 shows the Bayesian IRFs to a euro area monetary policy shock. This shock is particularly relevant for the current environment given the monetary policy normalisation effort announced by the ECB. In the model, the shock raises the ECB policy rate by around 50 basis points on impact, which is high relative to a ‘typical’ response of around 30 basis points as documented in Coenen et al. (2018), but within the ballpark of recent monetary policy tightening decisions. As discussed above, the shadow rate used in the estimation captures both conventional and unconventional monetary stances adopted by the ECB over the past 15 years, so the impact on the shadow rate will be larger than what would prevail under typical conventional monetary tightening. The effects of the shock on euro area variables are as expected, with a persistent decline in both output and prices. The contraction in euro area output and inflation are similar to those in the NAWM-II, bottoming out at around 0.35% and 0.15 percentage point, respectively.

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\(^3\) The short-term shadow rate estimate is based on the methodology of Krippner (2013).

\(^4\) The estimation period does not cover the COVID-19 pandemic since this can lead to a significant effect on the results if the statistical properties of the structural shocks are not adjusted. See Cardani et al. (2022) for a discussion and application.
A monetary policy shock transmits to the Maltese economy through trade and financial channels. Demand for the export good falls, leading to a drop in nominal wages in that sector and hitting households' income. The drop in euro area inflation transmits via reduced import prices, which lowers inflation in the price of the final consumption good. At the same time, the rise in the nominal interest rate transmits to the local economy, and coupled with the decline in inflation, leads to a rise in (real) borrowing costs. The increase in the real deposit rate (not shown below) is even higher on impact than that estimated in Micallef et al. (2016), although their empirical estimates should be interpreted with caution as they represent unconditional interest rate changes, whereas here the shock is defined as an unexpected monetary tightening.

Chart 1
IRFs TO A MONETARY POLICY SHOCK

Source: Author's calculations.

Notes: The chart shows Bayesian dynamic responses of the variables to a monetary policy shock, generated using 5,000 draws from the posterior distributions of the estimated parameters. The solid line is the median response, while the shaded region represents the 90% credible interval. The responses are in percentage deviations from the steady state level for all variables except for inflation and interest rates, which are in percentage point deviations. Inflation and interest rates are in annual terms. The horizontal axis measures quarters after the impact of the shock.

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5 The interest rate pass-through is higher on impact than that estimated in Micallef et al. (2016), although their empirical estimates should be interpreted with caution as they represent unconditional interest rate changes, whereas here the shock is defined as an unexpected monetary tightening.
larger, which stimulates a rise in deposits and lowers investment in capital and housing demand. Investment, house prices and household credit all fall, leading to a peak median contraction in real output of around 0.29% relative to its steady state value.

“A monetary policy shock transmits to the Maltese economy through trade and financial channels”

The profile for consumption in Malta is very similar to the corresponding estimates for the euro area reported in Coenen et al. (2018), with a peak drop of just above -0.4% in the first year of the shock. The easing of domestic price pressures leads to a gradual decline in the real effective exchange rate (REER), which boosts exports after the initial decline. This prop up real output in the medium term despite the monetary policy tightening in the euro area; a result consistent with Vector Autoregression (VAR) evidence documented in Gatt and Ruisi (2022), who find that a euro area monetary policy shock causes a drop in inflation but a rise in output.

A historical decomposition of house price movements

The estimated model can be used to provide an economic narrative on the drivers of house price movements over time around their long run average growth rate. Recall that the model economy can be perturbed away from its steady state equilibrium when it is hit by one or more of the exogenous structural shocks discussed above. Chart 2 shows that the key driver of house prices over the period 2001-2019 were housing preference shocks which shift the demand for housing, in line with a priori expectations and the findings in the literature (Iacoviello and Neri, 2010; Iacoviello, 2015).

The decomposition shows both the direct and general equilibrium effects of the shocks as they transmit through the entire economy. The increase and correction in house prices in the 2000s, the lower-than-average growth in 2012-2013, and the more recent increase in prices since 2015 are largely interpreted by the estimated model as being demand-driven. Housing supply (through shocks to construction productivity) played a much more limited role throughout the entire period, although they contributed marginally (negatively) during the boom that started in late 2015, with the increase in dwelling investment. Towards the end of 2019 the model interprets the lower-than-average house price growth as being driven by a contraction in housing demand, although other factors (including monetary policy shocks) pushed somewhat in the opposite direction.

This narrative on the drivers of house price growth is based on a theoretical model with tight cross-equation restriction, and therefore can be model-dependent. To assess the extent of model dependence of the results, the estimated time series of the housing preference shock referred to above were cross-checked with a similar estimate from the empirical model of Gatt and Ruisi (2020). The empirical model is a Structural Vector Autoregression (SVAR) estimated using Bayesian methods and, importantly, imposes far fewer restrictions in the identification of the structural shocks than in MEDSEA-FIN. Despite these differences, Chart 3 shows that the two methodologies deliver very similar time paths for the housing preference shock. Strictly speaking, in a Bayesian context, the output from both models is a distribution of the structural shock at each point in time.

6 The model is stationary around a level steady-state and therefore captures business cycles.

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Chart 3 shows the mean or median value of the shock for legibility. Therefore, the full degree of overlap of these two estimates is higher than what the chart conveys. This provides an important validation test for the results presented above based on MEDSEA-FIN.7

Conclusion
This article documents the Bayesian estimation of MEDSEA-FIN, an estimated medium-scale DSGE model for Malta, and shows some simulation results and structural output. The implied dynamic responses of Maltese macroeconomic variables to a monetary policy shock are reasonable and match findings from other studies. The historical decomposition showed that the housing preference (demand) shock was the key driver of the observed cycles in house prices. Overall, the estimation of this model makes its suitable to address policy-relevant questions.

Model development is a continuous process. Future development of the model is likely to include efforts to estimate the parameters using more recent data that covers also the COVID-19 pandemic, an enhanced structure for the foreign block, further development of the bank structure and the introduction of more macroprudential policy tools. Efforts are also underway to expand the energy block of the model to allow the Bank to address policy questions related to environmental targets and energy transition.

References


7 See Gatt (2022) for other similar validation exercises.


