



BANK ĊENTRALI TA' MALTA
EUROSISTEMA
CENTRAL BANK OF MALTA

MEDSEA-FIN: A DSGE MODEL WITH FINANCIAL FRICTIONS FOR MALTA

Article published in the Research Bulletin 2019, pp. 13-20



MEDSEA-FIN: A DSGE MODEL WITH FINANCIAL FRICTIONS FOR MALTA¹

William Gatt Fenech and Noel Rapa



The events that led to the great financial crisis have led economists in academia and central banks to take into account the role of financial frictions in the amplification of economic shocks. In this article we describe efforts to extend MEDSEA, the Bank's dynamic stochastic general equilibrium model, with housing and credit frictions. Households have access to collateralised borrowing, which is subject to a maximum loan-to-value (LTV) constraint. As a result, shocks that impact house prices generate amplification through the changing value of the collateral, raising or lowering the borrowing limit. We show how a counter-cyclical LTV rule dampens economic responses to a positive house price shock, highlighting the potential for macroprudential policy to limit a rise in systemic risk. Although the model captures the key collateral channel which matters for macroprudential policy, we plan to add more features in the near future to bring it closer to the data and extend the number of policy questions that the model can answer.

Introduction and motivation

Financial frictions, a term summarising some form of impediment to the flow of credit, were not considered to play an important role in advanced economies prior to the great financial crisis (Christiano et al., 2018). As a result, quantitative models used in policy institutions typically did not include any meaningful role for finance. Recent history has taught us that when financial frictions do matter, they can matter a lot. The origins of the financial crisis that started in late 2008 can be traced back to the housing market in the United States and the United Kingdom. Mortgage lending rose significantly in the run-up to the crisis, credit was extended to risky households, with lenders willing to extend such credit as long as property prices kept rising. In this way, there was a strong reinforcing effect where rising demand due to looser credit raised house prices, improving collateral values and leading to more borrowing, which sustained the rise in house prices. This phenomenon is typically referred to as the collateral channel (Kiyotaki and Moore, 1997; Iacoviello, 2005).

“Since borrowing constraints are binding in these models, borrower-based macroprudential policies that tighten borrowing limits during an upswing can be effective in controlling excessive leverage”

A model with a housing market and credit-constrained households captures this phenomenon by predicting a wealth effect arising from higher house prices to higher consumption (Iacoviello, 2005). Since borrowing constraints are binding in these models, borrower-based macroprudential policies that tighten borrowing limits during an upswing can be effective in controlling excessive leverage (Rubio and Carrasco-Gallego, 2014). Indeed, Crowe et al. (2013) find a positive empirical relationship between the maximum LTV ratio in an economy and the extent of house price appreciation. Although not necessarily causal, it illustrates an important link between these two variables. Alam et al. (2019) recently provide empirical evidence in favour of a causal relationship from a reduction in LTV limits to lower credit growth, especially when maximum LTV regulation is introduced in an environment of a generally loose LTV cap.²

¹ We would like to thank Alexander Demarco, Brian Micallef and Margarita Rubio for helpful comments and suggestions. We thank colleagues from the Financial Stability Department for fruitful discussions on leverage ratios. We thank Reuben Ellul and John Farrugia for assistance with house price data and fiscal aggregates respectively. Luca Brugnolini contributed to this project while at the Central Bank of Malta.

² See Gatt (2019a) and the references cited within for country case studies of borrower-based macroprudential policy implementation and its relative success.

Iacoviello (2005) shows that a model with collateral effects is able to match the empirical evidence of positive co-movement between house prices and private consumption in the United States. Chart 1 shows that there is also a strong positive relationship between these two variables in Malta. While this relationship is not necessarily causal, it is suggestive evidence of a link between house prices and household demand. We interpret this link through the lens of the model we describe below.

Household-level data reveal that a significant proportion of house purchases in Malta are highly leveraged. Indeed, about half of all mortgages are at an LTV at origination of between 70-90% and a debt-servicing to income ratio of 20-35% (Spiteri, 2019).³

These figures imply that bank finance, and hence borrowing constraints, matter for this subset of households. Therefore, a counter-cyclical macroprudential policy framework can in principle be effective in controlling an excessive rise in leverage.

“To capture these interactions we extend MEDSEA, a dynamic stochastic general equilibrium model of the Maltese economy with housing and borrowing constraints”

To capture these interactions we extend MEDSEA, a dynamic stochastic general equilibrium model of the Maltese economy with housing and borrowing constraints. MEDSEA features a rich production sector that reflects the small and open nature of the Maltese economy (Rapa, 2016). In this extension, households are only allowed to borrow up to a fraction m of their housing asset, which is henceforth referred to as an LTV constraint. The latter is allowed to vary over time to capture the ability of the macroprudential authority to change it counter-cyclically from time to time to control excessive risk-taking and a rise in economy-wide leverage.

Bird’s eye view of the model

This section provides a sketch of the model, focusing on households and the macroprudential authority. A bird’s eye view of the model is presented in Chart 2.

The household sector

There are two infinitely-lived household types, patient and impatient, making up a share $\bar{\omega}$ and $(1 - \bar{\omega})$ respectively of the total population.⁴ Both types derive utility from consuming a final good C_t , leisure, defined as the fraction of time not spent working, $1 - N_t$, and housing H_t . The latter is multiplied by a time-varying utility weight ε_t^H , which captures housing preference shifters, as in Iacoviello and Neri (2010).

Patient households (savers) can save through various assets. These include liquid assets, made up of local deposits $D_{s,t}$ and foreign bonds $B_{s,t}^*$, as well as illiquid assets in the form of housing $H_{s,t}$ and capital $K_{s,t}$. It is assumed that patient households own all firms such that their total income is made up of labour income, return on local deposits and foreign bonds, rental income on capital and firm profits.

³ There was no major difference between the leverage of first-time and second-time buyers in 2018. Around 70% of all first-time buyers and around 60% of all second-time buyers had an LTV ratio between 70-100%.

⁴ The two types of households are termed patient and impatient respectively because they discount the future at different rates. In equilibrium, patient households will accumulate resources and are therefore termed savers, while impatient households consume more than their labour income and therefore borrow to fund this gap. We use the subscripts s and b to denote savers and borrowers respectively.

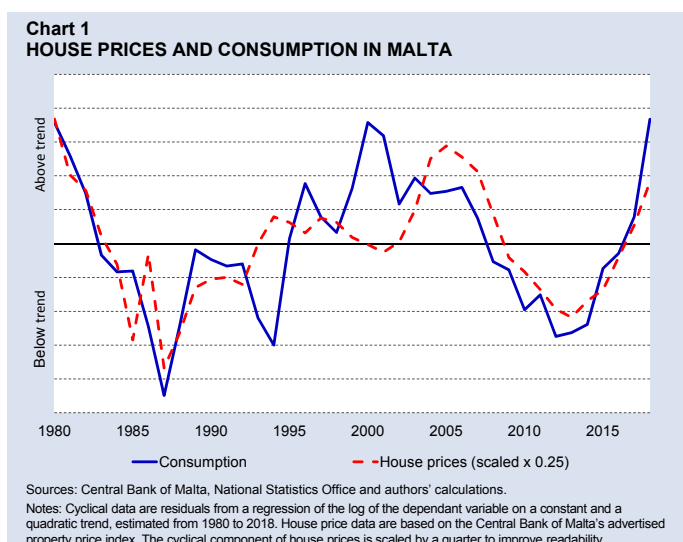
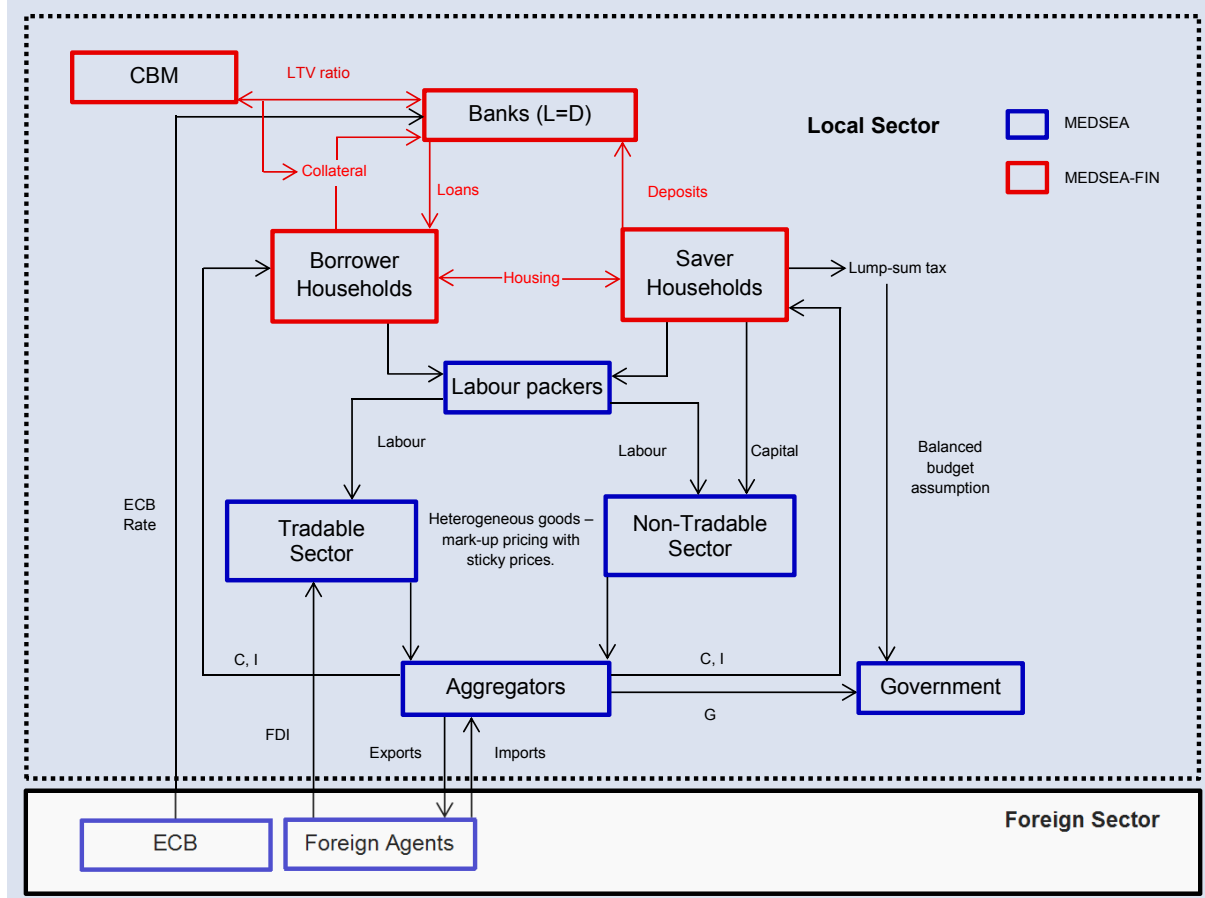


Chart 2
MEDSEA-FIN – A BIRD’S EYE VIEW



For simplicity we assume that impatient households (borrowers) do not participate in the international capital market and can borrow from domestic sources at a given interest rate. We further assume that this household type does not accumulate private capital and can only store wealth in the form of housing $H_{b,t}$. Following Iacoviello (2005) and Kiyotaki and Moore (1997), we assume that when borrowing, impatient households face a collateral constraint defined as a fraction of their expected housing wealth. Thus the maximum amount impatient households can borrow is bound by:

$$R_t L_{b,t} \leq m_t E_t \{ p_{t+1}^H H_{b,t} \pi_{t+1}^C \} \quad (1)$$

such that the total amount to be repaid at a given period including interest rates, $R_t L_{b,t}$, is less than a fraction m_t of the expected value of the total housing wealth of borrowers $E_t \{ p_{t+1}^H H_{b,t} \pi_{t+1}^C \}$. Moreover, the assumption that impatient households discount the future more heavily than patient ones guarantees an equilibrium in which impatient households are borrowing-constrained.⁵ Since housing is a durable good, it is demanded by both household types because it yields utility from housing services but also because it is a store of value. Additionally, impatient households also want to hold housing because a house price appreciation relaxes their borrowing limit.

Labour market

Households supply a continuum of labour types. For simplicity we assume that they delegate their wage setting problem to h labour packers⁶, each of which represents one type h of worker, in line with Galí et al. (2007). Each

⁵ In this version of the model we assume that banks are not bound by capital requirements and can therefore channel all deposits to borrower households as loans.

⁶ Labour packers are a modelling device that is commonly used in literature to simplify the labour market of general equilibrium models. They act as aggregators and combine the labour hours supplied by patient and impatient households. The single wage that clears the labour market will therefore reflect the marginal disutility of labour effort of both types of households. This assumption ensures more tractable developments in the real wage and hours worked.

packer in turn represents $\bar{\omega}$ patient and $(1 - \bar{\omega})$ impatient households. In each period, it sets the wage of its workers by trading off the utility value of labour income with the disutility of total work effort, taking as given the demand for each labour type. This therefore assumes labour packers allocate labour demand uniformly across households, irrespective of their type, such that each household in the economy works the same number of hours, and earns the same wage. We then introduce nominal rigidities in the labour market by assuming that real wages respond sluggishly, in line with Hall (2005).

Macroprudential authority

The financial authority operates macroprudential policy with the objective of ensuring financial stability. Its main tool is the LTV ratio m_t that affects the borrowing limit faced by impatient households through their collateral constraint. Although there are many indicators which can be used to signal a rise in systemic risk, we use the deviation of the household credit-to-GDP ratio from its value in the steady state, which is typically referred to as the credit gap. The authority therefore revises the LTV ratio counter-cyclically to the credit gap, tightening borrowing limits during a credit boom and relaxing them during a bust. The linearised macroprudential policy rule is given by

$$m_t = \rho_m m_{t-1} + (1 - \rho_m) [\bar{m} - \tau L_t^{gap}] \quad (2)$$

where L_t^{gap} is the credit gap, defined as the log deviation of the credit-to-GDP ratio from its steady state level. The parameter τ controls the strength of the revisions in the LTV ratio following a change in the leverage ratio, while ρ_m controls how smooth these revisions are.

Rest of the model

The production sector is identical to that found in Rapa (2016). The model contains three intermediate good firms, those producing tradable and non-tradeable output, and those responsible for importing goods and services. The economy produces four final goods: private consumption, government consumption, private investment and exports. Each of these goods is made up of a varying proportion of domestic and imported output. This setup allows us to exactly pin down the different import intensities of aggregate demand components. The fiscal authority is assumed to follow a balanced budget in each period, where government expenditure, which is made up of non-tradeable production and imports, is financed by a lump-sum tax levied on saver households.

Calibration

The model is calibrated on a quarterly frequency and replicates key Maltese Great Ratios, as in the core version of the model (Rapa, 2016). The addition of impatient households, housing and the collateral constraint introduce new parameters which we briefly discuss next. The discount factor for impatient households β_b is calibrated at 0.975 as in Iacoviello (2005) (compared with 0.9926 for patient households). This value ensures that the borrowing constraint is binding in the steady state and for small shocks which move the economy off but close to the steady state. The share of patient households in the economy $\bar{\omega}$ is set to 0.57, such that their consumption share out of aggregate consumption is 0.75.⁷ The steady-state weight on housing in the utility function ε^H is set to 0.21, which implies an aggregate housing wealth-to-GDP ratio of 4, as in the data.⁸ We set the maximum LTV ratio \bar{m} at 0.9, which is the typical maximum leverage limit observed on mortgages in Malta.⁹ These two parameters imply an aggregate ratio of loans to GDP at 38.5% in the model, in line with the mortgage credit-to-GDP ratio registered over the period 2004-2018. Other parameters are calibrated at values that are standard in the literature.

We set the LTV sensitivity parameter τ in the macroprudential policy rule (2) to an arbitrary small number to assess the role of LTV tightening on the economy. We set the persistence parameter ρ_m to 0.95, to reflect the fact that the

⁷ Iacoviello and Neri (2010) and Gerali et al. (2010) calibrate the income share of patient households at 0.8. Since we assume a labour market with a common wage rate and hours worked, we calibrate the consumption share instead. The parameter $\bar{\omega}$ then implies significant economic size for saver households, as in the literature.

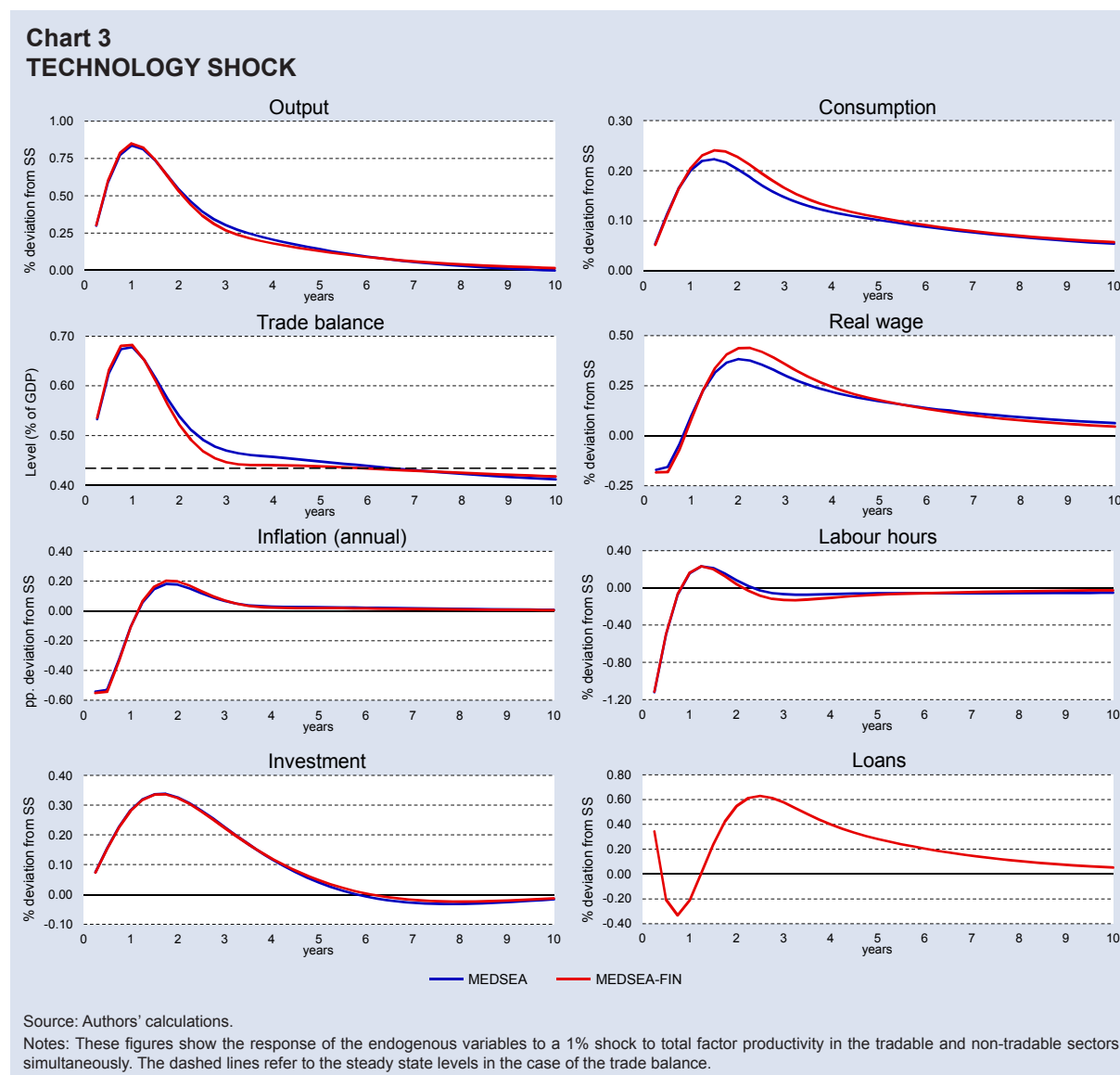
⁸ This ratio is based on mean and median hedonic prices from Ellul et al. (2019) and estimates of housing stock are taken from Gatt (2019b). Hedonic house price data are only available from 2010 onwards.

⁹ See Spiteri (2019). This is a value which is also commonly used in the literature.

borrowing limit is not revised frequently in most countries with an active LTV policy.¹⁰ We solve the model with a first-order perturbation around the stochastic steady state using Dynare.¹¹

Properties of the model

We first analyse the dynamics of the model by simulating a technology shock that is common to the production of tradable and non-tradable goods. We compare the reaction of the economy in MEDSEA-FIN to that in MEDSEA, which abstracts from financial frictions. We show the respective impulse response functions in Chart 3.¹² Note that we switch off the macroprudential policy rule, such that the LTV in MEDSEA-FIN is constant throughout the adjustment path.¹³



¹⁰ These values do not necessarily characterise the LTV macroprudential policy implementation of the Central Bank of Malta.

¹¹ Higher-order approximations produce very similar results. This means that we do not miss important non-linearities implied by financial frictions for the shocks that we study below.

¹² Note that some parameters, such as the intertemporal elasticity of substitution and elasticity of substitution between final export good varieties, are calibrated differently in the core version. We re-calibrate MEDSEA accordingly in the simulations that we report. In addition, we also re-model the labour market block in MEDSEA with the wage frictions as described above. This ensures that any differences in the reactions of the economy across models are due solely to the financial frictions present in MEDSEA-FIN.

¹³ The shock is unanticipated and no other shocks are expected to hit. Therefore, total factor productivity decays slowly back to its steady state value.

The shock produces very similar dynamics across the two versions of the model. The rise in total factor productivity temporarily increases the output production frontier and lowers marginal costs. This fall in marginal costs translates into lower overall prices which has a positive impact on the economy's competitiveness, leading to a more favourable trade balance. Positive wealth effects allow households to supply less labour hours. This effect is in the short-run outweighed by a reduction in labour demand brought about by an improvement in the productive efficiency of the factors of production leading to a marginal and short-lived fall in the wage rate. These positive wealth effects together with a steadily increasing wage rate drive up private consumption. Government expenditure on domestic non-tradable goods rises on account of the fall in price of such goods, with no changes in taxes, keeping the government budget in balance.

The main differences between the two versions of the model emerge after the first year following the shock. Consumption and the real wage rise and labour hours fall by more in the presence of constrained households although the effects are relatively small. This minor amplification occurs due to the collateral constraint, as the boost to economic activity also raises house prices. Borrower households use the increased value of their housing wealth to increase their borrowing, financing consumption. This pushes up demand for the consumption good, raising prices, including wages. The effect of the financial accelerator dies off by the fifth year following the shock, and the two economies follow close adjustment paths back to the steady state.

The effectiveness of LTV ratio tightening

To study the effectiveness of macroprudential policy in containing a rise in credit stemming from rising asset prices, we simulate a 1% rise in house prices through a temporary but persistent shock to housing preferences common across saver and borrower households.¹⁴ As discussed in Iacoviello and Neri (2010), this shock can account for shifts in tastes for housing relative to other goods as well as other factors that are not explicitly modelled, such as population changes. We simulate this shock with passive macroprudential policy in which the LTV ratio is fixed throughout, and again with the LTV responding endogenously as specified in the policy rule (2) above (see Chart 4). This simulation is meant to illustrate the theoretical channel through which a credit boom leads the macroprudential authority to tighten the borrowing limit by lowering the LTV ratio.

“This simulation is meant to illustrate the theoretical channel through which a credit boom leads the macroprudential authority to tighten the borrowing limit by lowering the LTV ratio”

First we look at the case with a fixed LTV ratio. The rise in house prices boosts the collateral value of impatient households, which allows them to borrow more. As a result credit rises and borrower households use these additional resources to finance higher consumption of the final good as well as the purchase of real estate. As discussed in the model description, housing serves the dual role of providing shelter services as well as a store of value. Borrowers are therefore willing to increase their holdings of housing as long as prices are higher than in the steady state, and as long as they are able to keep up with interest payments on additional credit that they take on. They also experience a wealth effect and supply less labour hours, which causes the equilibrium wage to rise.

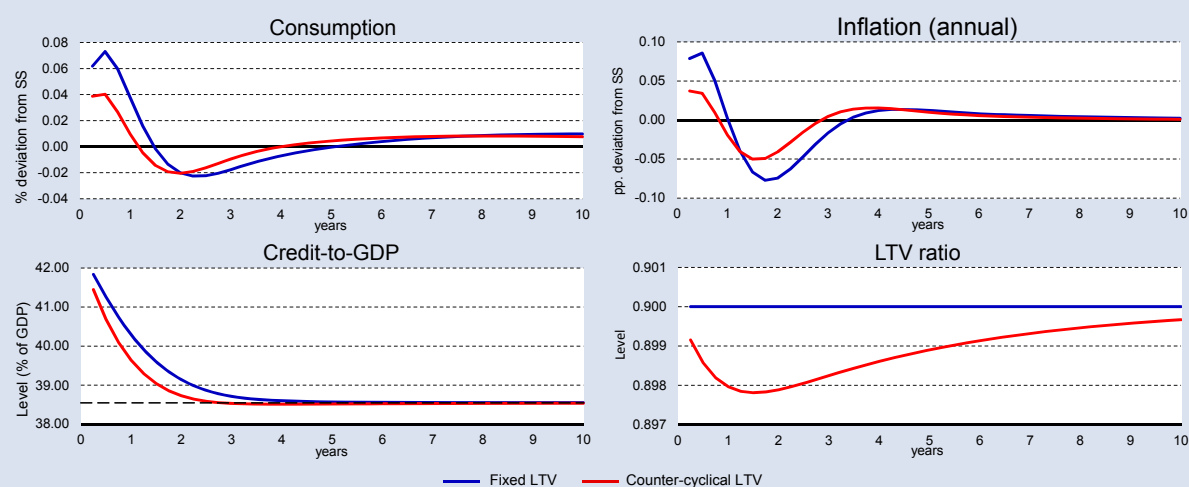
Although in our calibration around 60% of households are savers, the dynamics of aggregate consumption track closely the consumption behaviour of borrower households, since their reaction to the rising house prices is larger throughout. This can explain the observed correlation between house prices and consumption in Malta as shown in Chart 1 above. Aggregate consumption rises on impact and remains higher up to six quarters after the shock, falling below the steady state level thereafter. This reflects the deleveraging process by borrower households, as the initial inflationary effects of the shock start to fade and the real interest rate rises, increasing the debt burden. This causes aggregate credit to GDP to return to its steady state level. Lower consumption reduces demand for consumption goods, easing pressure on wages and prices. The shock takes more than ten years to die out of the system, highlighting the endogenous persistence present in the model. Despite the deleveraging process by borrowers, house prices remain above steady state levels throughout.

We now analyse the effect of moving the LTV ratio counter-cyclically with the credit-to-GDP gap, with an arbitrary calibration of the responses parameter in the policy rule.¹⁵ A positive credit-to-GDP gap lowers the LTV ratio, which

¹⁴ This shock is also unanticipated and in expectation the housing preference term reverts to its steady state level over many quarters.

¹⁵ We emphasize that the discussion that follows is neither a characterisation of borrower-based policy implementation of the Central Bank of Malta nor is it meant to be interpreted as the optimal macroprudential policy response to a housing demand shock. Rather, it is meant to showcase the potential impact on the economy under the scenario that we consider.

Chart 4
HOUSING PREFERENCE SHOCK: WITH AND WITHOUT ENDOGENOUS LTV REACTION



Source: Authors' calculations.

Notes: These figures show the response of the endogenous variables to a shock to housing preferences that generates a 1% rise in house prices. The dashed line in the bottom left panel refers to the steady state level of the credit-to-GDP ratio.

in turn tightens the borrowing constraint, limiting the rise in housing wealth that can be pledged as collateral against further borrowing. In the simulation the LTV ratio falls by about 0.1 percentage points on impact as a result of the rise in housing demand which pushes house prices up by 1%. This has a strong dampening effect on the total credit-to-GDP ratio, which leads to a smaller rise in aggregate consumption.

The response of the LTV ratio reflects the inertia built into the policy rule, adjusting slowly to the rise in credit and reaching the lowest value about a year and half following the onset of the shock.¹⁶ Note that the policy does not have any direct effects on house prices as it operates through the collateral constraint, lowering the borrowing potential of impatient households. House prices remain elevated in both scenarios as they are driven by the exogenous housing demand shock, which is invariant to the level of the LTV ratio, and is common to both borrower and saver households. To this end, LTV policy can reduce the build-up of systemic risk without intervening directly in the property market.¹⁷

Conclusion

The last financial crisis has been a stark reminder of the important role of financial frictions in developed economies. In the run-up to the crisis, mortgage lending rose significantly on the back of a sustained increase in house prices, which produced a reinforcing effect between the value of collateral and demand for mortgages. The presence of a collateral channel with binding borrowing constraints implies that a macroprudential authority is able to control excessive leverage by imposing countercyclical borrower-based measures.

“The model predicts that counter-cyclical movements of the LTV ratio have considerable dampening effects on the total credit-to-GDP ratio, and consequently on consumption and other GDP components”

In this light we extend MEDSEA with borrowing constraints, where households are allowed to borrow a fraction, denoted by a maximum LTV ratio, of the value of their housing assets. Moreover, we allow the macroprudential authority to implement counter-cyclical policy by varying the maximum LTV ratio in response to an excessive rise in the economy-wide leverage. The introduction of a collateral channel can have minor amplification effects especially for shocks that emanate in the housing market. A boost in housing wealth induces borrowers to demand more housing, allowing them to increase their borrowing to finance consumption. The model predicts

¹⁶ Although in practice a macroprudential authority is likely to revise the LTV ratio in large, discrete steps, it is also likely to wait until it receives enough information from indicators correlated with systemic risk. The LTV rule in the model therefore represents a compromise between these two policy considerations while remaining stylised and tractable.

¹⁷ It is useful to reiterate that in our model the macroprudential authority uses the household credit gap as an indicator for systemic risk. In practice, the relevant authority is likely to analyse an array of indicators before setting policy.

that counter-cyclical movements of the LTV ratio have considerable dampening effects on the total credit-to-GDP ratio, and consequently on consumption and other GDP components.

While already useful for policy analysis purposes, the model together with the results described in this article need to be interpreted as a first step towards a model that can answer more policy-oriented questions. More importantly, in its current state, MEDSEA-FIN assumes a stylised banking system in which banks are not bound by capital requirements. In future versions of this model, this assumption can be dropped in favour of a more realistic banking setup in which banks are subject to a minimum regulatory capital requirement. Apart from bringing the model closer to the data, these intermediation frictions will also help expand the policy relevance of this model by introducing the possibility of using the capital requirement as an additional macroprudential policy tool.

References

Alam, Z., Atler, A., Eiseman, J., Gelos, G., Kang, H., Narita, M., Nier, E. and Wang, N. (2019), Digging deeper – evidence on the effects of macroprudential policies from a new database, International Monetary Fund, Working Paper WP/19/66.

Christiano, L. J., Eichenbaum, M. S. and Trabandt, M. (2018), On DSGE models, *Journal of Economic Perspectives*, 32(3), pp. 113-40.

Crowe, C., Dell’Ariccia, G., Igan, D. and Rabanal, P. (2013), How to deal with real estate booms: Lessons from country experiences, *Journal of Financial Stability*, 9(3), pp. 300-319.

Ellul, R., Darmanin, J. and Borg, I. (2019), Hedonic house price indices for Malta: A mortgage-based approach, Central Bank of Malta, Working Paper WP/02/2019.

Gatt, W. (2019a), ‘Panel B: Borrower-based measures – theory and practice’, in *Special Feature: Banks’ exposure to real estate market and the Central Bank of Malta’s macro-prudential policy response*, Central Bank of Malta, Financial Stability Report 2018, pp. 57-59.

Gatt, W. (2019b), The evolution of the housing stock in Malta, Central Bank of Malta, Quarterly Review 2019:1, pp. 45-50.

Galí, J., López-Salido, J.D. and Vallés, J. (2007), Understanding the effects of government spending on consumption, *Journal of the European Economic Association*, 5(1), pp. 227-270.

Hall, R. (2005), Employment fluctuations with equilibrium wage stickiness, *American Economic Review*, 95(1), pp. 50-65.

Iacoviello, M. (2005), House prices, borrowing constraints, and monetary policy in the business cycle, *American Economic Review*, 95(3), pp. 739-764.

Iacoviello, M. and Neri, S. (2010), Housing market spillovers: evidence from an estimated DSGE model, *American Economic Journal: Macroeconomics*, 2(2), pp. 125-64.

Kiyotaki, N. and Moore, J. (1997), Credit cycles, *Journal of Political Economy*, 105(2), pp. 211-248.

Rapa, N. (2016), MEDSEA: a small open economy DSGE model for Malta, Central Bank of Malta, Working Paper WP/05/2016.

Rubio, M. and Carrasco-Gallego, J. A. (2014), Macroprudential and monetary policies: Implications for financial stability and welfare, *Journal of Banking & Finance*, 49, pp. 326-336.

Spiteri, A. (2019), ‘Panel A: Trends in the real estate market and banks’ lending practices in Malta’, in *Special Feature: Banks’ exposure to real estate market and the Central Bank of Malta’s macro-prudential policy response*, Central Bank of Malta, Financial Stability Report 2018, pp. 50-56.