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MEDSEA-FIN
A DSGE model of the Maltese economy with housing and financial frictions

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Abstract

We extend the Central Bank of Malta's core DSGE model – MEDSEA – with housing and financial frictions to capture the important theoretical links betweeen house prices, credit and consumption. The model features a rich set of features that are inherent to small open economies in a monetary union. We add a borrowing constraint on a subset of households that is contigent on the value of housing wealth and a maximum loan-to-value (LTV) ratio. We also impose capital requirements on the financial intermediary through a minimum capital-to-assets ratio (CAR) constraint. These two requirements form the basis of a typical macroprudential regime in a developed economy. We show how the macroprudential authority can dampen the rise in credit and consumption during a credit boom by using these two policy tools to 'lean against the wind'. MEDSEA-FIN is therefore tailored to study macro-financial issues related to housing and credit, and the adequate policy responses.

JEL Classification: C54, E44, E58, E60

Keywords: borrowing constraints, loan-to-value ratio, capital-to-assets ratio, macroprudential policy

Contents

1 Introduction

Financial frictions, a term summarizing 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). The reason is that over the 20 years that preceeded the crisis, macro-financial linkages seemingly did not have important business cycle implications. This belief was driven by the fact that during this period, the world financial and banking systems did not experience any major financial shocks. Moreover, modellers and policymakers alike implicitly assumed that monetary policy on its own was able to offset the business cycle implications of any financial shock that could hit the economy. As a result, quantitative models used in policy institutions typically did not include any meaningful role for finance shocks (see Smets and Wouters (2003, 2007), Gomes et al. (2012) and Christoffel et al. (2008)). 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 US and UK. Mortgage lending rose significantly in the run-up to the crisis, credit standards were relaxed and lenders were willing to extend risky 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).

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 through a collateral channel. When borrowing constraints are binding, 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 loan-to-value (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.[1]

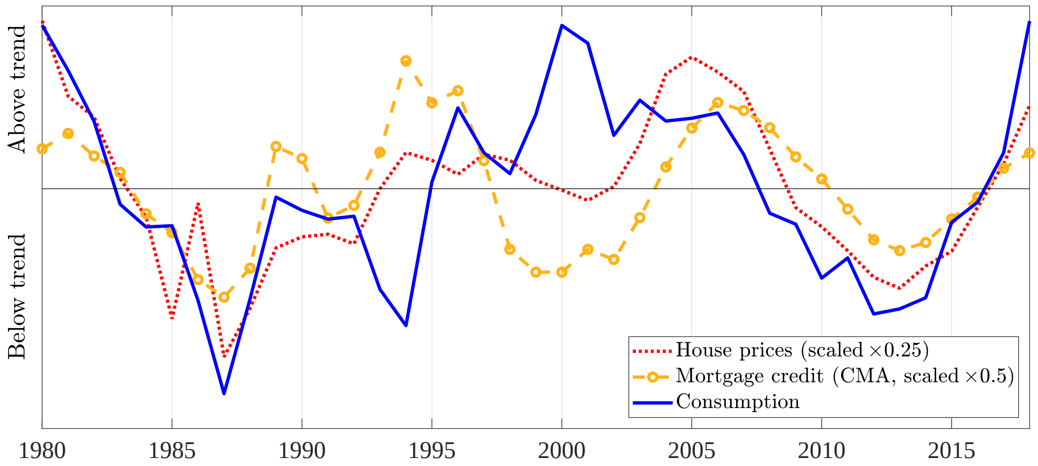
1.1 House prices and consumption in Malta

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 US. Figure 1 shows that there is also a broadly positive relationship between house prices, mortgage credit and consumption in Malta.[2] 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

[1] See Gatt (2019b) and the references cited therein for selected country case studies of borrower-based macroprudential policy implementation and its relative success.

[2] The rise in consumption in the early 2000s is likely due to the splicing of consumption data from two different statistical methodologies.

Figure 1: House prices, credit and consumption



Notes: Cyclical data are residuals from a regression of the log of the dependant variable on a constant and a quadratic trend, estimated from 1980 to 2018. House price data is based on the Central Bank of Malta's advertised property price index. Mortgage credit is regressed in logs on a quadratic trend with a slope dummy starting from 2001, and an intercept dummy for the year 2000. It is then smoothened using a 3-year centered moving average. The cyclical components of house prices and credit are scaled by a quater and a half respectively to improve readability. Data sources: Central Bank of Malta and National Statistics Office.

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). 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.

1.2 A model for macroprudential policy analysis

We extend the Central Bank of Malta's core DSGE model – MEDSEA (Rapa, 2016) – with housing as a durable good, impatient househoulds who face a borrowing limit, a real estate construction sector and a representative bank that acts as a financial intermediary between depositors and borrowers. In MEDSEA-FIN households borrow against the value of the housing they would like to purchase, and a macroprudential policy determines the limits that can be borrowed, namely the loan-to-value (LTV) ratio. The authority also regulates the capital buffer of the bank, requiring it to hold a minimum capital-to-assets ratio (CAR). In this paper we document the resulting properties of MEDSEA-FIN.[3] In the presence of borrowing constraints, it predicts a financial amplification channel through movements in house prices following a housing demand shock. Besides stimulating the real estate market, the shock transmits to the rest of the economy through the labour market, which is re-specified with imperfect movement across the multiple sectors present in MEDSEA-FIN. We show that, by using the LTV and CAR as policy tools, the macroprudential authority can dampen the rise in credit and consumption following a shock that raises house

[3]A preliminary version of the model is discussed in Gatt and Rapa (2019). That version lacks the real estate sector and does not impose any regulatory limits on the financial intermediary. It also has a different labour market setup.

prices.[4] This makes the model suited for the analysis of macroprudential policies in Malta within a general equilibrium framework.

Our model is close to others used in policymaking institutions for the analysis of credit market frictions, such as those described in Gerali et al. (2010); Rubio and Comunale (2018); Lozej et al. (2018); Funke et al. (2018) and Sangaré (2019). It embeds a rich production environment with local producers, importers, and exporters; features that are particular to small open economy models (Lane, 2001; Clancy and Merola, 2016). The rest of the paper is structured as follows. In the next section we discuss the model at some length, and in section 3 we discuss the calibration strategy of the model. Section 4 shows the properties of the model through a stochastic simulation of a rise in house prices driven by a housing demand shock, and section 5 concludes.

2 The model

In this section, we describe the main building blocks of the model. MEDSEA-FIN features households with different balance sheet compositions, 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. We distinguish between three main production sectors indexed by m, producing intermediate non-tradable goods (NT), goods used in the final export product (XD) and housing construction (H). A macroprudential authority exerts some influence on the economy by using policy tools.

2.1 Households

There are two infinitely-lived household types, patient and impatient, defined on a continuum $j \in \{[0, \varpi), [\varpi, 1]\}$ respectively, with $\varpi \in (0, 1)$. Both household types derive utility from consuming the final good C and housing services H, and disutility from working N. Impatient households derive their name from the fact that they discount the future more heavily. As a result, they are net borrowers in equilibrium, while patient households are net savers (Kiyotaki and Moore, 1997). We denote patient households by s and impatient households by b, and the subjective discount factor for household type i by β_i, $i \in \{s, b\}$. By assumption, $\beta_s > \beta_b$. Households are also heterogeneous with respect to the labour service that they provide, but are able to perfectly insure against idiosyncratic earnings risk using state-contingent securities, as in Christiano et al. (2005). Therefore all households within each type behave in the same way, and the dynamics will follow those of representative saver and borrower-type households.[5] The level of housing services that each household receives is proportional to the stock of housing that it holds. The nature of housing is that it yields a service but it is also a store of value. The latter function is especially important for borrowers, as will be discussed further below.

[4] We emphasise here that the macroprudential response that we model is not meant to capture specific policy implementation strategies of the Central Bank of Malta.

[5] This feature, together with the presence of nominal frictions described further below, classifies our model as a 'Two-Agent New Keynesian' (TANK) model (Bilbiie, 2008; Campbell and Mankiw, 1989; Debortoli and Galí, 2017; Galí et al., 2007).

2.1.1 Patient households — Savers

Saver households maximise lifetime utility subject to a budget constraint. They can save through various assets; financial assets in the form of domestic bank deposits $D_{s,j,t}$ and foreign bonds $B^*_{s,j,t}$ (both priced in terms of P^C_t), and durable assets in the form of housing $H_{s,j,t}$ and capital $K^m_{s,j,t}$, where m indexes the different sectors of production. Gross returns on deposits and foreign bonds are predetermined and are given by R_{t-1} and R^*_{t-1} respectively, while the net nominal return on capital is R^{Km}_t. Saver-type households own all firms and receive profits as dividends. Their problem is to maximise lifetime utility:

$$\max \ \mathbb{E}_t \Bigg\{ \sum_{t=0}^{\infty} \beta_s^t \varepsilon_t^\beta \Bigg((1-\chi)^\sigma \frac{(C_{s,j,t} - \Gamma_{s,t-1})^{1-\sigma}}{1-\sigma} + \varepsilon^H_t \log\left(H_{s,j,t}\right) - \frac{\varepsilon^N_t}{1+\varphi} \left[\left(N^{NT}_{s,j,t}\right)^{1+\varsigma} + \left(N^{XD}_{s,j,t}\right)^{1+\varsigma} + \left(N^{H}_{s,j,t}\right)^{1+\varsigma} \right]^{\frac{1+\varphi}{1+\varsigma}} \Bigg) \Bigg\} \tag{1}$$

where $\Gamma_{s,t-1} = \chi C_{s,t-1}$ denote habits external to the household with parameter $\chi \in (0,1)$, and the exponents σ and φ are the intertemporal elasticity of substitution and inverse of the labour Frisch elasticity respectively.[6] We follow Horvath (2000) and Iacoviello and Neri (2010) in specifying the disutility of labour so as to allow imperfect mobility of workers between three production sectors, with elasticity of substitution $-1/\varsigma$. The terms ε^β_t, ε^H_t and ε^N are aggregate intertemporal, housing and labour supply preference shocks respectively as in Iacoviello and Neri (2010), defined as stationary AR(1) processes in logs around steady-state values of $\overline{\varepsilon}^\beta$, $\overline{\varepsilon}^H$ and $\overline{\varepsilon}^N$, subject to uncorrelated i.i.d shocks:

$$\log(\varepsilon^i_t) = (1-\rho_{\varepsilon^i}) \log(\overline{\varepsilon}^i) + \rho_{\varepsilon^i} \log(\varepsilon^i_{t-1}) + \nu^i_t \tag{2}$$

for $i \in \{\beta, H, N\}$, with $\rho_{\varepsilon^i} \in (0,1)$ and $\nu^i_t \sim \mathcal{N}(0, \sigma_i^2)$. The budget constraint that they face is:

$$\begin{aligned} & C_{s,j,t} + p^H_t (H_{s,j,t} - (1-\delta_H) H_{s,j,t-1}) + D_{s,j,t} + B^*_{s,j,t} + p^I_t \left(I^{NT}_{s,j,t} + I^H_{s,j,t} + \frac{\delta K^{XD}_t}{\varpi} \right) \\ &= \sum_{m=\{NT,XD,H\}} w^m_{s,j,t} N^m_{s,j,t} \left(1 - AC^{W^m}_{s,j,t} \right) + r^{KNT}_t K^{NT}_{s,j,t-1} + r^{KH}_t K^H_{s,j,t-1} + \frac{R_{t-1} D_{s,j,t-1}}{\Pi^C_t} \\ &\quad - \frac{T_{s,j,t}}{P^C_t} + \frac{R^*_{t-1} \zeta(\phi_{t-1}, \varepsilon^R_{t-1}) B^*_{s,j,t-1}}{\Pi^C_t} + DIV_{s,j,t} + \frac{\pi_{B,t}}{\varpi} - AC_{s,j,t} \end{aligned} \tag{3}$$

where $p^H_t = P^H_t / P^C_t$ is the real house price, $I^m_{s,j,t}$ is capital investment in sector $m \in \{NT, XD, H\}$ with relative cost $p^I_t = P^I_t / P^C_t$, $w^m_{s,j,t} = W^m_{s,j,t} / P^C_t$ is the real hourly wage rate in sector m, $AC^W_{s,j,t}$ denote wage adjustment costs, defined further below, and $r^{Km}_t = R^{Km}_t / P^C_t$ is the real return on capital rented to firms in sector m. $\Pi^C_t \equiv P^C_t / P^C_{t-1}$ denotes the gross inflation rate, $T_{s,j,t}$ is nominal lump-sum taxes. The parameter δ_H captures housing maintenance costs. Saver households own and invest in capital used in the production on the intermediate non-tradable good $K^{NT}_{s,j,t}$ and in the construction sector $K^H_{s,j,t}$. We assume that they also maintain capital used

[6] The functional form on the first argument in the utility function ensures that the steady state shadow price on the budget constraint is equal to the marginal utility of consumption.

in the production of the exported good K_t^{XD}, which is the result of exogenous FDI decisions, by paying in each period the depreciation associated with this capital. Following Schmitt-Grohé and Uribe (2003) we introduce a risk premium term for foreign bonds $\xi(\phi_t, \varepsilon_t^R)$ to stationarize net foreign assets. The premium is composed of two time-varying elements; a debt premium ϕ_t and a risk premium shock ε_t^R, and are defined further below. The term $DIV_{s,j,t}$ denotes real dividends received from firm ownership, and the term $\pi_{B,t}/\varpi$ is the share of bank profits rebated to savers, explained further below. $AC_{s,j,t}$ are adjustment costs incurred from investment and price setting, also defined further below. Following Iacoviello (2005), savings decisions are taken in real terms at time t, but deposits and bonds are not indexed and pay back a nominal amount in period $t+1$. Therefore, an increase in goods prices lowers the return on saving via these assets, all else equal.

Capital owned by savers accumulates as the sum of capital from the previous period (less depreciation) and net investment

$$K_{s,j,t}^{NT} = (1-\delta_{KNT})K_{s,j,t-1}^{NT} + I_{s,j,t}^{NT}\left[1 - \frac{\xi_{INT}}{2}\left(\frac{I_{s,j,t}^{NT}}{I_{s,j,t-1}^{NT}} - 1\right)^2\right] \tag{4}$$

$$K_{s,j,t}^{H} = (1-\delta_{KH})K_{s,j,t-1}^{H} + I_{s,j,t}^{H}\left[1 - \frac{\xi_{IH}}{2}\left(\frac{I_{s,j,t}^{H}}{I_{s,j,t-1}^{H}} - 1\right)^2\right] \tag{5}$$

in which the term in square brackets denotes quadratic investment adjustment costs, governed by the parameters $\xi_{INT}, \xi_{IH} > 0$.[7] The saver-type household chooses $C_{s,j,t}, H_{s,j,t}, D_{s,j,t}, B_{s,j,t}^*, I_{s,j,t}^{NT}$, $I_{s,j,t}^{H}, K_{s,j,t-1}^{NT}$ and $K_{s,j,t-1}^{H}$ to maximise lifetime utility subject to the budget constraint and the law of motion for capital. It also chooses the real wage $w_{s,j}$ at which it supplies labour, explained further in section 2.2. Due to the existence of state-contingent securities, all households behave symmetrically in equilibrium, so we drop the subscript j in what follows. The first-order conditions are:

$$\lambda_{s,t} = \varepsilon_t^\beta \left(\frac{(1-\chi)}{(C_{s,t} - \Gamma_{s,t-1})}\right)^\sigma \tag{6}$$

$$\frac{\varepsilon_t^\beta \varepsilon_t^H}{H_{s,t}} = p_t^H \lambda_{s,t} - \beta_s(1-\delta_H)\mathbb{E}_t\{p_{t+1}^H \lambda_{s,t+1}\} \tag{7}$$

$$\lambda_{s,t} = \beta_s \mathbb{E}_t \left\{\frac{R_t \lambda_{s,t+1}}{\Pi_{t+1}^C}\right\} \tag{8}$$

$$\lambda_{s,t} = \beta_s \mathbb{E}_t \left\{\frac{R_t^* \xi(\phi_t, \varepsilon_t^R)\lambda_{s,t+1}}{\Pi_{t+1}^C}\right\} \tag{9}$$

$$\begin{aligned} p_t^{INT} &= p_t^{KNT}\left(1 - \frac{\xi_{INT}}{2}\left(\frac{I_{s,t}^{NT}}{I_{s,t-1}^{NT}} - 1\right)^2 - \xi_{INT}\left(\frac{I_{s,t}^{NT}}{I_{s,t-1}^{NT}} - 1\right)\frac{I_{s,t}^{NT}}{I_{s,t-1}^{NT}}\right) \\ &\quad + \beta_s \mathbb{E}_t\left\{\frac{\lambda_{s,t+1}}{\lambda_{s,t}} p_{t+1}^{KNT}\left(\xi_{INT}\left(\frac{I_{s,t+1}^{NT}}{I_{s,t}^{NT}} - 1\right)\left(\frac{I_{s,t+1}^{NT}}{I_{s,t}^{NT}}\right)^2\right)\right\} \end{aligned} \tag{10}$$

[7]This follows Christiano et al. (2005) who add nominal and real rigidities to a canonical New Keynesian model to bring the dynamics closer to those implied by a VAR. Adjustment costs affect only the dynamics of the model following a shock.

$$p_t^{KNT} = \beta_s \mathbb{E}_t \left\{ \frac{\lambda_{s,t+1}}{\lambda_{s,t}} \Big((1-\delta_{KNT}) p_{t+1}^{KN} + r_{t+1}^{KNT} \Big) \right\} \tag{11}$$

$$\begin{aligned} p_t^{IH} &= p_t^{KH} \left(1 - \frac{\xi_{IH}}{2} \left(\frac{I_{s,t}^H}{I_{s,t-1}^H} - 1 \right)^2 - \xi_{IH} \left(\frac{I_{s,t}^H}{I_{s,t-1}^H} - 1 \right) \frac{I_{s,t}^H}{I_{s,t-1}^H} \right) \\ &\quad + \beta_s \mathbb{E}_t \left\{ \frac{\lambda_{s,t+1}}{\lambda_{s,t}} p_{t+1}^{KH} \left(\xi_{IH} \left(\frac{I_{s,t+1}^H}{I_{s,t}^H} - 1 \right) \left(\frac{I_{s,t+1}^H}{I_{s,t}^H} \right)^2 \right) \right\} \end{aligned} \tag{12}$$

$$p_t^{KH} = \beta_s \mathbb{E}_t \left\{ \frac{\lambda_{s,t+1}}{\lambda_{s,t}} \Big((1-\delta_{KH}) p_{t+1}^{KH} + r_{t+1}^{KH} \Big) \right\} \tag{13}$$

Equation (6) is the definition of the shadow price on the borrowing constraint in real terms, equation (7) defines the housing demand equation, equations (8)–(9) are the Euler equations over domestic bank deposits and foreign bonds respectively. Equations (10) and (12) are the FOCs for investment in the different sectors and equations (11) and (13) are the Euler equations for capital in each sector. In each case, the price of capital $p_t^{Km'}$ for $m' = \{NT, H\} \subset m$ is the Lagrange multiplier on the capital accumulation function normalized by the marginal utility of consumption, which is the implicit price of capital in consumption utility units. The housing demand equation (7) not only equates marginal utilities of housing and consumption within a period, but also reflects the value of holding housing as an asset into the next period, implied by its future resale value in consumption units, $\mathbb{E}_t \left\{ p_{t+1}^H \lambda_{s,t+1} \right\}$, discounted to present value. Combining equations (8) and (9), we get a no-arbitrage condition between domestic deposits and foreign bonds $R_t = R_t^* \xi(\phi_t, \varepsilon_t^R)$, which, when linearized, can be interpreted as the Uncovered Interest rate Parity Condition (UIPC).

2.1.2 Impatient households — Borrowers

Borrower-type households solve a similar problem as saver-type households, conditional on having a lower discount factor β_b. To keep the model tractable, we assume they do not directly participate in the international capital market, and therefore only borrow from domestic sources at the given interest rate $R_t^L = (1 + r_t^L)$. When borrowing, they face a collateral constraint, as in Kiyotaki and Moore (1997) and Iacoviello (2005). In addition, borrower-type households do not accumulate capital, so their only store of value lies in housing.[8] The objective of impatient household j is to maximize lifetime utility:

$$\begin{aligned} \max\ \mathbb{E}_t \Bigg\{ \sum_{t=0}^{\infty} \beta_b^t \varepsilon_t^\beta \Bigg(& (1-\chi)^\sigma \frac{(C_{b,j,t} - \Gamma_{b,t-1})^{1-\sigma}}{1-\sigma} + \varepsilon_t^H \log(H_{b,j,t}) \\ & - \frac{\varepsilon_t^N}{1+\varphi} \left[\left(N_{b,j,t}^{NT}\right)^{1+\varsigma} + \left(N_{b,j,t}^{XD}\right)^{1+\varsigma} + \left(N_{b,j,t}^{H}\right)^{1+\varsigma} \right]^{\frac{1+\varphi}{1+\varsigma}} \Bigg) \Bigg\} \end{aligned} \tag{14}$$

[8] This assumption does not necessarily reflect our beliefs on 'borrower' households in Malta, but is a modelling device used to simplify the transition from a single representative household with capital as the only durable asset in MEDSEA, to the more general case presented in this model with two household types and housing as an additional durable good.

where the same definitions as for patient households apply. The preference shocks ε_t^β, ε_t^H and ε_t^N are common also to borrowers. Their budget constraint, in real terms, reads

$$\begin{aligned} C_{b,j,t} + p_t^H(H_{b,j,t} - (1-\delta_H)H_{b,j,t-1}) + \frac{R_{t-1}^L L_{b,j,t-1}}{\Pi_t^C} \\ = \sum_{m=\{NT,XD,H\}} w_{b,j,t}^m N_{b,j,t}^m \left(1 - AC_{b,j,t}^{W^m}\right) + L_{b,j,t} - \frac{T_{b,j,t}}{P_t^C} + \frac{\pi_{B,t}}{1-\varpi} \end{aligned} \tag{15}$$

Borrower households' expenditure includes payments on loans $L_{b,j,t}$ at the gross interest rate R_t^L.[9] Since saving and borrowing are specified in real terms, and are not indexed to inflation, then an increase in prices between periods $t-1$ and t reduces the real burden of debt for borrowers, while savers incur a loss through a lower return on liquid savings. The total amount of resources available to borrower households is composed of labour income across all production sectors and funds borrowed from the bank, less lump-sum taxes due to government. Like savers, they also receive a share of bank profits.

Borrowers secure one-period loans by using housing as collateral. They face an aggregate regulatory maximum LTV ratio $\mathsf{m}_t \in (0,1)$, which limits the size of the loan to a fraction of the value of the house to be purchased. The LTV ratio is time-varying, reflecting changes in regulation driven by macroprudential policy considerations. The collateral constraint they face is given by:

$$R_t^L L_{b,j,t} \leq \mathsf{m}_t \mathbb{E}_t \left\{ p_{t+1}^H H_{b,j,t} \Pi_{t+1}^C \right\} \tag{16}$$

where the term on the right hand side represents a proportion of the expected nominal value of housing wealth in the next period, which is when the loan is due. Note that the borrowing limit is endogenous; all else equal, an increase in nominal housing wealth increases the maximum amount that can be borrowed. This increase in credit finances consumption and house purchases and can stimulate the economy and push up house prices, leading to further increases in housing wealth, setting off a financial accelerator which amplifies the effects of shocks.[10] Therefore the inclusion of borrower households and a collateral constraint allows us to obtain business cycle amplification due to changes in net worth (Kiyotaki and Moore, 1997; Bernanke et al., 1999). This is the first important addition to MEDSEA that we introduce in this paper.

Although borrower households, like savers, are heterogeneous in their labour services, they mitigate sources of idiosyncratic disturbances through the use of state-contingent securities, as do savers. Therefore allocations $C_{b,j}$, $H_{b,j}$ and $L_{b,j}$ are symmetric across all impatient households,

[9] Most studies in literature use one-period debt instruments, mainly for simplicity. However, in our model this assumption is attractive as it introduces more realism. Since in Malta the majority of loan contracts feature variable interest rates, our choice of a one-period debt instrument can be thought of as a long term loan that is rolled over every period, in effect capturing the new interest rate in the same way an adjustable-rate mortgage does.

[10] The same applies in the downward phase; negative shocks to housing wealth will tighten borrowing limits and reduce consumption, dampening demand and house prices, which further reduce the borrowing limit, and so on.

and we drop the subscript j to simplify the notation. The first order conditions are:

$$\lambda_{b,t} = \varepsilon_t^{\beta}\left(\frac{(1-\chi)}{(C_{b,t}-\Gamma_{b,t-1})}\right)^{\sigma} \tag{17}$$

$$\frac{\varepsilon_t^{\beta}\varepsilon_t^{H}}{H_{b,t}} = p_t^H\lambda_{b,t} - \beta_b(1-\delta_H)\mathbb{E}_t\{p_{t+1}^H\lambda_{b,t+1}\} - \lambda_t^L \mathsf{m}_t\mathbb{E}_t\{p_{t+1}^H\Pi_{t+1}^C\} \tag{18}$$

$$\lambda_{b,t} = \beta_b\mathbb{E}_t\left\{\frac{R_t^L\lambda_{b,t+1}}{\Pi_{t+1}^C}\right\} + \lambda_t^L R_t^L \tag{19}$$

The first equation is the shadow price of the budget constraint expressed in consumption units, the second is the housing demand equation, and the third is the Euler equation for loans. The variable $\lambda_t^L > 0$ is the Lagrange multiplier associated with the borrowing constraint. A comparison of Euler equations for housing demand, deposits and loans across savers and borrowers shows the extent to which borrowers' consumption and investment decisions are affected by the collateral constraint. In this regard note that, in addition to the re-sale value of housing, borrowers also take into account the fact that holding more housing will, all else equal, relax their borrowing constraint in the current period by the expected nominal value of housing in the next period, multiplied by the LTV ratio. However, this also impacts their consumption smoothing due to the fact that higher borrowing implies a higher repayment in the next period, at the gross lending rate R_t^L in equation (19).[11] As for savers, we document the corresponding wage setting behaviour for borrower households below.

2.2 The labour market

2.2.1 Labour packers and wage setting

Following Erceg et al. (2000) we assume that household j of each type $i \in \{s,b\}$ working in sector $m \in \{NT, XD, H\}$ is able to supply a differentiated labour service. This implies that it can exercise some degree of monopoly power over the real wage rate $w_{i,j,t}^m$ at which it provides hours to a labour packer. To keep the structure tractable, we follow Iacoviello and Neri (2010) and model a labour packer for each household type i working in sector m.[12] We assume labour packers aggregate individual household j's labour hours in sector m using CES technology with elasticity of substitution $\mu_W > 1$ to produce aggregate labour from savers $N_{s,t}^m$ and borrowers $N_{b,t}^m$:

$$N_{i,t}^m = \left(\int N_{i,j,t}^{\frac{\mu_W-1}{\mu_W}}\, dj\right)^{\frac{\mu_W}{\mu_W-1}} \tag{20}$$

We also assume that μ_W is a parameter common to all labour packers, both at the household level and also at the overall sector level. The packers choose labour hours from each household j, $N_{i,j,t}^m$, taking the sectoral wage rate $w_{i,j,t}^m$ as given, to maximise

$$\max_{N_{i,j,t}} \quad w_{i,t}^m N_{i,t}^m - \int w_{i,j,t}^m N_{i,j,t}^m\, dj \tag{21}$$

[11]An increase in λ_t^L reflects a tightening of the borrowing constraint, which causes the shadow price λ_t^b to rise, implying lower consumption. In our simulations this constraint is binding throughout.

[12]That is, there are $i \times m = 6$ labour packers at the household-sector level in total.

subject to their labour aggregation technology (20). This yields optimal downward-sloping demand schedules:

$$N_{i,j,t}^{m} = \left(\frac{w_{i,j,t}^{m}}{w_{i,t}^{m}}\right)^{-\mu_W} N_{i,t}^{m} \tag{22}$$

We next describe wage setting by individual household j of type i. An individual household takes the wage in that sector $w_{i,t}^{m}$ and total demand $N_{i,t}^{m}$ as given. Any changes to the individual wage $w_{i,j,t}^{m}$ are subject to Rotemberg adjustment costs $w_{i,j,t}^{m} N_{s,j,t}^{m} AC_{i,j,t}^{W^m}$, where $AC_{i,j,t}^{W^m}$ is defined as

$$AC_{i,j,t}^{W^m} = \frac{\xi_W^m}{2}\left(\frac{\Pi_{i,j,t}^{W^m}}{(\Pi_{t-1}^{W_i^m})^{\iota^{W^m}}(\overline{\Pi})^{1-\iota^{W^m}}} - 1\right)^2 \tag{23}$$

and where $\Pi_{s,j,t}^{W}$ is each j household's gross nominal wage inflation, $\Pi_{i,t}^{W^m}$ is gross nominal wage inflation, $\overline{\Pi}$ is gross steady state overall inflation and ξ_W^m is the adjustment cost parameter. We assume that wages are indexed to a weighted average of lagged wage inflation and steady-state CPI inflation with weights ι^W and $1-\iota^W$ respectively, as in Gerali et al. (2010). Household j chooses the real wage $w_{i,j,t}$ to maximise utility, subject to its budget constraint (3) or (15), labour demand (22) and adjustment costs (23).[13] The first order condition, given symmetry $w_{i,j,t}^{m} = w_{i,t}^{m}$, yields a wage setting function for household type i in sector m:

$$\begin{aligned} w_{i,t}^{m}\left((\mu_W - 1) + \xi_W^m \Phi_{i,t}^{m}\left(\Phi_{i,t}^{m} - 1\right) - \xi_W^m \beta_i \mathbb{E}_t \frac{\lambda_{i,t+1}}{\lambda_{i,t}} \frac{N_{i,t+1}^{m}}{N_{i,t}^{m}} \Pi_{i,t+1}^{W^m} \Phi_{i,t+1}^{m}\left(\Phi_{i,t+1}^{m} - 1\right)\right) \\ = \frac{\mu_W \varepsilon_t^{\beta} \varepsilon_t^{N}}{\lambda_{i,t}} (N_{i,t}^{m})^{\varsigma}\left[\left(N_{i,t}^{NT}\right)^{1+\varsigma} + \left(N_{i,t}^{XD}\right)^{1+\varsigma} + \left(N_{i,t}^{H}\right)^{1+\varsigma}\right]^{\frac{\varphi-\varsigma}{1+\varsigma}}. \end{aligned} \tag{24}$$

where $\Phi_{i,t}^{m} = \Pi_t^{W_i^m} / \left((\Pi_{t-1}^{W_i^m})^{\iota^W}(\overline{\Pi})^{1-\iota^W}\right)$ and $\lambda_{i,t}$ is the Lagrange multiplier associated with the budget constraint of household type i.

2.2.2 Aggregate labour supply

At a national level, a labour agency combines the aggregated labour hours from each household type working in sector m, $N_{s,t}^{m}$ and $N_{b,t}^{m}$ into a homogeneous labour service N_t^m which it sells to firms in sector m at a common wage rate w_t^m using the following technology

$$N_t^m = \left(\varpi^{\frac{1}{\mu_W}}\left(N_{s,t}^{m}\right)^{\frac{\mu_W - 1}{\mu_W}} + (1-\varpi)^{\frac{1}{\mu_W}}\left(N_{b,t}^{m}\right)^{\frac{\mu_W - 1}{\mu_W}}\right)^{\frac{\mu_W}{\mu_W - 1}} \tag{25}$$

For simplicity, we assume that there is the same degree of substitutability between labour from saver and borrower households as within the continuum of each household type. The labour agency therefore seeks to maximise sectoral labour income:

$$\max_{N_{s,t}^{m}, N_{b,t}^{m}} \; w_t^m N_t^m - w_{s,t}^{m} N_{s,t}^{m} - w_{b,t}^{m} N_{b,t}^{m} \tag{26}$$

[13]Implicit in this optimization, which we include here for the sake of brevity, is the optimal allocation of total labour hours of a household of type i across hours in all sectors.

subject to (25). Optimal demand for labour hours from each household type is:

$$N_{s,t}^m = \varpi \left(\frac{w_{s,t}^m}{w_t^m} \right)^{-\mu_W} N_t^m \tag{27}$$

$$N_{b,t}^m = (1-\varpi) \left(\frac{w_{b,t}^m}{w_t^m} \right)^{-\mu_W} N_t^m \tag{28}$$

By plugging (27) and (28) into (25), we obtain the sectoral real wage w_t^m as a CES composite of household type wages:

$$w_t^m = \left(\varpi \left(w_{s,t}^m \right)^{1-\mu_W} + (1-\varpi) \left(w_{b,t}^m \right)^{1-\mu_W} \right)^{\frac{1}{1-\mu_W}} \tag{29}$$

2.3 The real estate sector

In our second contribution, we add a construction sector to MEDSEA similar to Davis and Heathcote (2005) and Iacoviello and Neri (2010). We model a representatitve construction firm which produces new housing units using labour and sector-specific capital. The firm is perfectly competitive, taking both factor input prices and house prices as given. Its production technology is given by

$$Y_t^H = \left(\alpha_H^{\frac{1}{\mu_H}} (N_t^H)^{\frac{\mu_H - 1}{\mu_H}} + (1-\alpha_H)^{\frac{1}{\mu_H}} (A_t^H K_{t-1}^H)^{\frac{\mu_H - 1}{\mu_H}} \right)^{\frac{\mu_H}{\mu_H - 1}} \tag{30}$$

where Y_t^H are units of housing produced, N_t^H and K_{t-1}^H are sector-specific labour and capital respectively, and A_t^H is capital-augmenting technology. The latter follows a stochastic process in logs around the steady state level $\overline{A}^H$: $\log(A_t^H) = \rho_{A^H} \log(A_{t-1}^H) + (1-\rho_{A^H}) \log(\overline{A}^H) + \nu_t^H$. The technology parameters α_H and μ_H denote the quasi-share of labour in production and the elasticity of subtitution between labour and capital, respectively. We depart fom Cobb-Douglas technology used by Iacoviello and Neri (2010) so that we can control the marginal rate of technical substitution between labour and capital in this sector.

The firm takes wages W_t^H and the rental rate of capital R_t^{KH} as given, and chooses N_t^H and K_{t-1}^H to maximise profit

$$\pi_t^H = P_t^H Y_t^H - W_t^H N_t^H - R_t^{KH} K_{t-1}^H \tag{31}$$

subject to the production technology (30). The first order conditions are:

$$N_t^H = \alpha_H \left(\frac{P_t^H}{W_t^H} \right)^{\mu_H} Y_t^H \tag{32}$$

$$K_{t-1}^H = (1-\alpha_H) \left(\frac{P_t^H}{R_t^{KH}} \right)^{\mu_H} A_t^{H(\mu_H - 1)} Y_t^H \tag{33}$$

which yield labour and capital demand respectively. These define the aggregate house price as a composite of the wage rate and capital rental rate:

$$P_t^H = \left(\alpha_H \big(W_t^H\big)^{1-\mu_H} + (1-\alpha_H) \big(R_t^{KH}\big)^{1-\mu_H} A_t^{H\,\frac{(\mu_H - 1)^2}{\mu_H}} \right)^{\frac{1}{1-\mu_H}}. \tag{34}$$

The aggregate housing stock $\widetilde{H}_t$ therefore evolves according to the law of motion:

$$\widetilde{H}_t = (1-\delta_H)\widetilde{H}_{t-1} + Y_t^H \tag{35}$$

where the depreciation rate δ_H captures wear and tear of the existing housing stock. As discussed above, these maintenance costs are borne by households.

2.4 Banks

The third contribution of this paper is to add a financial intermediary between savers and borrowers which operates subject to a financial friction. We specify the financial sector as in Iacoviello (2015). A representative bank takes deposits D_t from savers and issues loans L_t to borrowers, and operates subject to a regulatory constraint on the its capital-to-assets ratio (CAR) c_B:

$$K_{B,t} \geq \mathsf{c}_{B,t} L_t. \tag{36}$$

for $\mathsf{c}_{B,t} \in (0,1)$. This constraint proxies macroprudential requirements such as the Countercyclical Capital Buffer, and we allow this ratio to be time-varying and counter-cyclical as in Angelini et al. (2014) and Lozej et al. (2018).

The bank is perfectly competitive and takes the interest rates on deposits R and loans R^L as given.[14] It chooses the amount of loans to issue to maximise its profit in every period $\pi_{B,t}$, which it distributes fully to households. It incurs quadratic portfolio adjustment costs on its loans and deposits given by $\frac{\xi_B^L}{2}\frac{(L_t-L_{t-1})^2}{L}$ and $\frac{\xi_B^D}{2}\frac{(D_t-D_{t-1})^2}{D}$ respectively. Although households own shares in the bank, they delegate the operation to a banker which discounts future profit streams at the rate β_B, where $\beta_b < \beta_B < \beta_s$. This ensures that in equilibrium funds flow from savers to the bank, and from the bank to borrowers. The bank's problem is:

$$\max_{L_t, D_t} \; \mathbb{E}_t \sum_{t=0}^{\infty} \beta_B^t \pi_{b,t} \tag{37}$$

subject to its flow-of-funds constraint

$$D_t + \frac{R_{t-1}^L L_{t-1}}{\Pi_t^C} = L_t + \frac{R_{t-1} D_{t-1}}{\Pi_t^C} + \pi_{B,t} - \frac{\xi_B^L}{2}\frac{(L_t - L_{t-1})^2}{L} - \frac{\xi_B^D}{2}\frac{(D_t - D_{t-1})^2}{D} \tag{38}$$

and the leverage constraint

$$D_t \leq (1-\mathsf{c}_{B,t})L_t \tag{39}$$

which we obtain by plugging in the CAR requirement (36) in the bank balance sheet $L_t = D_t + K_{B,t}$. Denoting the Lagrange multiplier on the leverage constraint (39) by λ_t^B, the first

[14]We assume a perfectly competitive bank for simplicity and following Iacoviello (2015).

order conditions are:

$$\beta_B R_t^L + (1 - \mathsf{c}_{B,t})\lambda_t^B + \beta_B \mathbb{E}_t \left\{ \xi_B^L \frac{(L_{t+1} - L_t)}{L} \right\} = 1 + \xi_B^L \frac{(L_t - L_{t-1})}{L} \tag{40}$$

$$1 + \beta_B \mathbb{E}_t \left\{ \xi_B^D \frac{(D_{t+1} - D_t)}{D} \right\} = \beta_B R_t + \lambda_t^B + \xi_B^D \frac{(D_t - D_{t-1})}{D}. \tag{41}$$

These show that, at an optimum, the discounted return on issuing a loan at the margin must equate the associated cost. Absent adjustment costs, an increase in loans relaxes the leverage constraint by $(1 - \mathsf{c}_{B,t})\%$ but reduces the amount of profits that can be distributed today to households. By issuing more deposits, the bank tightens its leverage constraint one-for-one, but this allows it to pay dividends to households today. Since the banker internalizes the adjustment costs, these decisions also take into account the fact that adjusting in the present period is costly but generates some cost-savings with respect to adjustments forgone in the next period. Combining these two equations, and abstracting from adjustment costs for simplicity, we get:

$$R_t^L = R_t + \frac{\mathsf{c}_{B,t}\lambda_t^B}{\beta_B} \tag{42}$$

which shows that there will be a spread between the lending and deposit rates as long as there is a positive regulatory CAR ratio which is binding.[15]

2.5 Production: non-durable consumption and investment goods

The production sector is virtually the same as in MEDSEA, and is tailored to small open economies following Lane (2001) and Clancy and Merola (2016), but also includes some features unique to the Maltese economy. Firms fall into two broad categories; manufacturers and final sellers. In particular, there are three main sectors for manufacturers: intermediate local goods, imports, and exports. The first use local resources and sell on the local wholesale market. The second, importers, purchase goods from abroad and resell them domestically, while the third combine locally-produced and imported goods to create a new intermediate product which is subsequently sold in the foreign market. Furthermore, the model includes two final sellers. The first combines local and imported goods to sell final consumption and investment goods C and I respectively on the local market. The second re-brands export goods into a final export good Y^X which it sells on the foreign market. All firms are owned by saver households, and rebate all profits and operating costs to them. Therefore, future income streams are discounted by their corresponding stochastic discount factor (SDF) $\Lambda_{t,t+k} = \beta_s^k \frac{\lambda_{s,t+k}}{\lambda_{s,t}}$, derived from the saver households' problem.

2.5.1 Local Producers

There is a continuum of intermediate good firms indexed by $l \in [0, 1]$, each producing the intermediate non-tradable good $Y_{l,t}^{NT}$. Each firm operates in the perfect compeition in in their input market renting capital $K_{l,t-1}^{NT}$ at the rental rate R_t^{KNT} and labour $N_{l,t}^{NT}$ at the wage rate W_t^{NT}.

[15] As in the case for the LTV constraint, in our calibration we ensure that the CAR is binding in the steady state and in any stochastic simulations that we show.

Firms therefore face a static problem in choosing $N_{l,t}^{NT}$ and $K_{l,t-1}^{NT}$ optimally by minimizing their cost function $\mathcal{C}_{l,t}^{NT}$

$$\min_{N_{l,t}^{NT},K_{l,t-1}^{NT}} \mathcal{C}_{l,t}^{NT} = W_t^{NT} N_{l,t}^{NT} + R_t^{KNT} K_{l,t-1}^{NT} \tag{43}$$

subject to Cobb-Douglas technology:

$$Y_{l,t}^{NT} = A_{l,t}^{NT} (K_{l,t-1}^{NT})^{1-\gamma_{NT}} (N_{l,t}^{NT})^{\gamma_{NT}} \tag{44}$$

where technology $A_{l,t}^{NT}$ follows a log stochastic process. After imposing symmetry, this gives rise to the following conditions:

$$W_t^{NT} N_t^{NT} = \gamma_{NT} MC_t^{NT} Y_t^{NT} \tag{45}$$

$$R_t^{KNT} K_{t-1}^{NT} = (1-\gamma_{NT}) MC_t^{NT} Y_t^{NT}. \tag{46}$$

In their second problem, firms choose their current price $P_{l,t}^{NT}$, by maximising the (real) value of their firm at time t ($\pi_{j,t}^{NT}$) subject to some Rotemberg costs and the demand function of good (l), derived from goods aggregators and analogous to that shown in Appendix A:

$$\max_{P_{l,t}^{NT}} \pi_{l,t}^{NT} = E_t \sum_{k=0}^{\infty} \Lambda_{t,t+k} \left[\left(P_{l,t+k}^{NT} - MC_{l,t+k}^{NT}\right) \frac{Y_{l,t+k}^{NT}}{P_{t+k}^{NT}} - AC_{l,t}^{NT} \right] \tag{47}$$

subject to a downward-sloping demand curve:

$$Y_{l,t}^{NT} = \left(\frac{P_{l,t}^{NT}}{P_t^{NT}} \right)^{-\mu_{NT}} Y_t^{NT} \tag{48}$$

with $AC_{l,t}^{NT}$ capturing adjustment costs modelled as:

$$AC_{l,t}^{NT} = \frac{\xi_{NT}}{2} \left(\Phi_{l,t}^{NT} - 1\right)^2 Y_t^{NT} \tag{49}$$

where $\Phi_{l,t}^{NT} = \Pi_{l,t}^{NT} / \left((\Pi_{t-1}^{NT})^{\iota^{NT}} (\overline{\Pi})^{1-\iota^{NT}} \right)$. Solving the above maximisation problem and imposing symmetry leads to the following Phillips Curve for the non-tradable sector.

$$P_t^{NT} \left((\mu_{NT} - 1) + \xi_{NT}(\Phi_t^{NT} - 1)\Phi_t^{NT} - \xi_{NT} \mathbb{E}_t \Lambda_{t,t+k} \frac{Y_{t+1}^{NT}}{Y_t^{NT}} (\Phi_{t+1}^{NT} - 1)\Phi_{t+1}^{NT} \right) = \mu_{NT} MC_t^{NT} \tag{50}$$

2.5.2 Importers

There is a continuum $n \in [0,1]$ of importing firms that buy a homogenous good $Y_{n,t}^M$ at the foreign price level P_t^* and re-brand it using a naming technology.[16] This assumption differentiates importers from local producers and exporters, as they do not hire labour and capital from households but only need to solve a dynamic problem to set the price of the imported goods $P_{n,t}^M$

[16] P_t^* is the foreign price of imported goods, which is assumed to follow a stochastic process in logs

$$\log(P_t^*) = \rho_{P^*} \log(P_{t-1}^*) + (1-\rho_{P^*}) \log(\overline{P}^*) + \nu_t^{P^*} \tag{51}$$

where $\rho_{P*} \in (0,1)$ is the autoregressive parameter, $\overline{P}^*$ is the steady state price level and $\nu_t^{P^*} \sim \mathcal{N}(0, \sigma_{P*}^2)$ is an i.i.d. shock.

given a downward-sloping demand function derived from aggregators as in Appendix A, and the marginal cost of goods purchased from abroad.

The dynamic problem faced by importers is analogous to that shown in equations (47) and (48). We further assume that Malta's effective exchange rate S_t is fixed such that the importers' marginal costs are given by

$$MC_{n,t}^{M} = P_t^{*} S_t \tag{52}$$

where MC_t^M is the marginal cost for each unit of imported good, and $S_t = 1$. The first-order condition related to $P_{n,t}^M$ after imposing symmetry is:

$$P_t^M \left((\mu_M - 1) + \xi_M (\Phi_t^M - 1)\Phi_t^M - \xi_M \mathbb{E}_t \Lambda_{t,t+k} \frac{Y_{t+1}^M}{Y_t^M} (\Phi_{t+1}^M - 1)\Phi_{t+1}^M \right) = \mu_M MC_t^M. \tag{53}$$

The imported good is then used in the production of the domestic consumption and investment goods and in the export good.

2.5.3 Export goods producer

The wholesale production process of export goods involves two manufacturing stages, with the latter setting the wholesale price on the export goods. The retail stage, discussed in more detail below, involves a packer which re-brands and distributes the good to the foreign market.

The first manufacturing stage involves a continuum of firms which are perfectly-competitive both in the input and output markets. They produce an intermediate export good Y_t^{XD} using Cobb-Douglas technology with labour N_t^{XD} and capital K_{t-1}^{XD}, with share parameters γ_{XD} and $1 - \gamma_{XD}$ respectively. Production is also subject to an aggregate technology shock A_t^{XD} which follows an AR(1) process.[17] Capital is exogenous and follows a stochastic process around a fixed level.[18] As discussed in Clancy and Merola (2016), this assumption reflects the fact that in very small and open economies, investment decisions in the tradable sector are typically heavily influenced by foreign direct investment. As a result, these firms face a single static problem of choosing the quantity of labor to minimize cost subject to their technology, and optimal labour demand, given symmetry across the producers, is given by

$$N_t^{XD} = \frac{\gamma_{XD} MC_t^{XD} Y_t^{XD}}{W_t^{XD}} \tag{54}$$

where $MC_t^{XD} = P_t^{XD}$ is the Lagrangian multiplier associated with the resource constraint.

[17] This is given by

$$\log(A_t^{XD}) = \rho_{AXD} \log(A_{t-1}^{XD}) + \nu_t^{A^{XD}}$$

where $\rho_{A^{XD}} \in (0,1)$ is the autoregressive parameter and $\nu_t^{A^{XD}} \sim \mathcal{N}(0, \sigma^2_{A^{XD}})$ is an i.i.d. shock.

[18] The exogenous process for K_t^{XD} is given by:

$$\log(K_t^{XD}) = (1 - \rho_{KXD}) \log\left(\overline{K}^{XD}\right) + \rho_{KXD} \log(K_{t-1}^{XD}) + \nu_t^{K^{XD}}$$

where $\overline{K}^{XD}$ the exogenous steady state level of capital in this sector.

2.5.4 Final sellers – local market

Final domestic sellers combine local produced and imported goods to create a final good sold on the local market. Goods are aggregated using CES technology to create consumption and investment bundles $\{Y_t^C, Y_t^I\}$. In equilibrium, these quantities are equal to $\{C_t, I_t\}$ respectively.[19] The problem of final sellers is

$$\max_{Y_t^{NT}, Y_t^M} \quad \pi_t^z \equiv P_t^z Y_t^z - P_t^{NT} Y_t^{z,NT} - P_t^M Y_t^{z,M}, \quad z = (C, I) \tag{55}$$

s.t.

$$Y_t^z = \left((1-\alpha_z)^{\frac{1}{\eta_z}} \left(Y_t^{z,NT} \right)^{\frac{\eta_z - 1}{\eta_z}} + \alpha_z^{\frac{1}{\eta_z}} \left(Y_t^{z,M} \right)^{\frac{\eta_z - 1}{\eta_z}} \right)^{\frac{\eta_z}{\eta_z - 1}}, \quad z = (C, I) \tag{56}$$

where $Y^{z,NT}$ and $Y^{z,M}$ are the intermediate local and imported goods respectively used in sector z. These yield the first-order conditions shown below, which in equilibrium characterise the share of local and imported goods in total consumption and investment.

$$Y_t^{z,NT} = (1-\alpha_z) \left(\frac{P_t^{NT}}{P_t^z} \right)^{-\eta_z} Y_t^z, \quad z = (C, I) \tag{57}$$

$$Y_t^{z,M} = \alpha_z \left(\frac{P_t^M}{P_t^z} \right)^{-\eta_z} Y_t^z, \quad z = (C, I) \tag{58}$$

which imply aggregate price indices for consumption and investment goods:

$$P_t^C = \left((1-\alpha_C) \left(P_t^{NT} \right)^{1-\eta_C} + \alpha_C \left(P_t^M \right)^{1-\eta_C} \right)^{\frac{1}{1-\eta_C}} \tag{59}$$

$$P_t^I = \left((1-\alpha_I) \left(P_t^{NT} \right)^{1-\eta_I} + \alpha_I \left(P_t^M \right)^{1-\eta_I} \right)^{\frac{1}{1-\eta_I}} \tag{60}$$

2.5.5 Final sellers – foreign market

The final export good from individual producers $Y_{j,t}^X$ is bundled into the final good Y_t^X using CES technology with elasticity μ^{XW}. The firm is assumed to operate in a perfectly competitive market on the input side, and in a monopolistically competive market on the output side. We therefore assume there is a continuum of firms indexed by $k \in [0, 1]$ that combine locally-produced tradable goods $Y_{k,t}^{XD}$ with a homogeneous import $Y_{k,t}^{XM}$ at P_t^M per unit, to produce their final wholesale good $Y_{k,t}^{XW}$. To reflect the fact that the import content of exports is usually considered to be irreplaceable by domestic sources, final export goods are produced using Leontief technology with complementarity parameter α_X

$$Y_{k,t}^X = \min \left\{ \frac{Y_{k,t}^{XD}}{1-\alpha_X}, \frac{Y_{k,t}^{MX}}{\alpha_X} \right\} \tag{61}$$

[19] See (78) and (79) further below.

This implies the following relationships

$$Y_t^{XD} = (1-\alpha_X)Y_t^X \tag{62}$$

$$Y_t^{MX} = \alpha_X Y_t^X \tag{63}$$

$$MC_t^X = (1-\alpha_X)MC_t^{XD} + \alpha_X P_t^M \tag{64}$$

where we drop the firm identifier k due to symmetry. In the output sector, wholesale export good producers exploit their price setting power by deciding what wholesale price $P_{k,t}^{XW}$ to charge for their output by maximising the real value of their firm at time t subject to the demand function for good k. Firms face quadratic adjustment costs whenever they choose to change prices, therefore their dynamic problem is the same as for local producers and importers, so we do not show it in the interest of space. The resulting price-setting behaviour, after imposing symmetry, gives rise to the following Phillips curve for the wholesale export price

$$P_t^{XW}\left((\mu_{XW}-1) + \xi_{XW}(\Phi_t^{XW}-1)\Phi_t^{XW} - \xi_{XW}\mathbb{E}_t\Lambda_{t,t+1}\frac{Y_{t+1}^X}{Y_t^X}(\Phi_{t+1}^{XW}-1)\Phi_{t+1}^{XW}\right)$$
$$= \mu_{XW} MC_t^X \tag{65}$$

where $\Phi_t^{XW} = \Pi_{j,t+k}^{XW}/(\Pi_{t-1}^X)^{\iota}\overline{\Pi}^{(1-\iota)}$.

As in MEDSEA, we follow Corsetti et al. (2008) and assume that a distribution service intensive in local non-tradables delivers the final export good to the foreign economy. Therefore, the final price P_t^X depends on the wholesale export price P_t^{XW} and a fixed basket $\theta \geq 0$ of locally produced goods:

$$P_t^X = P_t^{XW} + \theta P_t^{NT}. \tag{66}$$

2.6 Policy authorities

The model features stylized macroprudential, fiscal and monetary policy authorities. As the model describes a country in a monetary union, there is no Taylor rule, and monetary policy is limited to link the domestic interest rate to the foreign one.

2.6.1 Macroprudential policy authority

The financial authority operates macroprudential policy with the objective of ensuring financial stability. In our model financial stability is defined as the prevention of an excessive rise in credit following a shock that boosts housing wealth. Moreover, the imposition of a regulatory capital-to-assets ratio on banks ensures that these are able to withstand shocks by having a capital buffer. In this sense, policymakers in our model promote financial stability by using the two tools at their disposal to control both household and bank leverage. The first tool is the LTV ratio m_t that affects the borrowing limit faced by impatient households through their collateral constraint (16). This proxies borrower-based measures that limit household leverage. The second is the CAR, which requires banks to build a strong capital buffer to strenghten its resilience to shocks.

Although there are many indicators which can be used to signal a rise in systemic risk, in this paper we assume a suitable proxy is the deviation of nominal credit to GDP from its value in the steady state, which is typically referred to as the credit gap, as in Angelini et al. (2014).[20] The authority therefore revises the LTV ratio and CAR counter-cyclically to credit conditions; tightening borrowing limits during a credit boom, and relaxing them during a bust.[21] Therefore, the LTV is lowered, and the CAR is raised, when the credit gap is positive. The non-linear LTV and CAR rules are given by

$$\mathsf{m}_t = \mathsf{m}_{t-1}^{\rho_\mathsf{m}} \, \overline{\mathsf{m}}^{(1-\rho_\mathsf{m})} \left(\frac{P_t^C L_t}{Y_{t-1}^4} \Big/ \frac{\overline{P^C L}}{4Y} \right)^{-\tau_\mathsf{m}(1-\rho_\mathsf{m})} \tag{67}$$

$$\mathsf{c}_{B,t} = \mathsf{c}_{B,t}^{\rho_{\mathsf{c}_B}} \, \overline{\mathsf{c}}_B^{(1-\rho_{\mathsf{c}_B})} \left(\frac{P_t^C L_t}{Y_{t-1}^4} \Big/ \frac{\overline{P^C L}}{4Y} \right)^{\tau_{\mathsf{c}_B}(1-\rho_{\mathsf{c}_B})} \tag{68}$$

where $\overline{\mathsf{m}}$ and $\overline{\mathsf{c}}_B$ are the steady-state LTV ratio and CAR, and $Y_t^4 = \sum_{k=0}^{3} Y_{t-k}$ is the 4-period moving sum of nominal output.[22] These policy rules captures, through the inclusion of the first lag, the authority's preference to only partially adjust the regulatory limits rather than introducing full changes between any two periods. The parameters $\{\rho_\mathsf{m}, \rho_{\mathsf{c}_B}\} \in (0, 1)$ reflect how smooth these revisions are. The response parameters $\{\tau_\mathsf{m}, \tau_{\mathsf{c}_B}\} > 0$ reflect the strength of revisions to following a deviation from steady state economy-wide leverage.

As a result, a rise (fall) in credit will stimulate a macroprudential response which tightens (eases) the LTV ratio and the CAR. The extent to which the authority uses one tool more forcefully than the other is determined by the parameters of these two policy rules. All else equal, a higher smoothening parameter and lower response parameters in one rule will induce more inertia in that tool relative to the other.

2.6.2 Fiscal and monetary authorities

The fiscal and monetary authorities are the same as in MEDSEA. Starting with the fiscal authority, government expenditure Y_t^G is based on the purchase of the domestic non-tradable good, and is financed by lump-sum taxes T_t levied on households. Therefore, government runs a balanced budget in every period:

$$T_t = P_t^{NT} Y_t^G \tag{69}$$

where government expenditure is a fraction of nominal steady-state output $\overline{Y}$

$$P_t^{NT} Y_t^G = g_t \overline{Y}. \tag{70}$$

[20] In practice policymakers use a array of indicators, over and above the credit gap, to guide their policy stance. In this model the credit gap is a sufficient indicator for financial stability concerns.

[21] The term 'counter-cyclical' may be confusing given that the CAR is increased when the credit gap increases. Our use of this term follows the literature and its use in practice and relates to a policy of 'leaning against the wind', that is, tightening credit conditions when credit rises, and vice-versa.

[22] See Angelini et al. (2014) for a similar time-varying capital requirement rule.

The time-varying fraction $g_t \in (0,1)$ follows a stochastic process in logs around the steady state government share of output $\overline{g}$:

$$\log(g_t) = (1-\rho_g)\log(\overline{g}) + \rho_g \log(g_{t-1}) + \nu_t^g \tag{71}$$

where $\rho_g \in (0,1)$ is the autoregressive parameter and $\nu_t^g \sim \mathcal{N}(0,\sigma_l^2)$ is an i.i.d. shock, interpreted as a government demand shock.

This specification assumes that government consumption is unresponsive to economic conditions along a transition path.[23] However, since government spending is also a function of P^{NT}, then a rise in this price affects the right-hand side of the budget constraint (69), raising nominal government expenditure on the non-tradable good. Since a balanced budget is enforced in every period, this induces a corresponding increase in lump-sum taxes.[24]

The monetary authority is modelled following Schmitt-Grohé and Uribe (2003) and sets the local interest rate on deposits R_t equal to the foreign rate R_t^* and a risk premium ϕ_t through the *Uncovered Interest rate Parity* (UIP) condition:

$$R_t = R_t^* \frac{\mathbb{E}_t S_{t+1}}{S_t} e^{\phi_t} \tag{72}$$

where the time-varying risk premium ϕ_t is stochastic and contingent on the gap between the foreign debt-to-GDP ratio $P^* S_t B_t^*/4Y_t$ and the steady-state level $\zeta = \overline{P^* S B^*}/\overline{4Y}$, as well as an i.i.d. shock $\epsilon_t^\phi \sim \mathcal{N}(0,\sigma_\phi^2)$, and the parameter ρ_ϕ determines the interest rate sensitivity:

$$\phi_t = \rho_\phi \left(\frac{P_t^* S_t B_t^*}{4Y_t} - \zeta \right) + \epsilon_t^\phi \tag{73}$$

Foreign debt evolves as

$$B_t^* = \frac{B_{t-1}^* R_{t-1}}{\Pi_t^*} - TB_t \tag{74}$$

where $\Pi_t^* \equiv P_t^*/P_{t-1}^*$ and the trade balance TB_t is equal to the difference between exports and imports in the country $TB_t \equiv P_t^X Y_t^X - P_t^M Y_t^M$.

2.7 Rest of the World

The rest of the world is stylized as a downward-sloping demand function as in equation (75). The equation depends on the export price, but also on the world demand and good price with elasticity of demand η_X.

$$Y_t^X = \left(\frac{P_t^X}{S_t P_t^*} \right)^{-\eta_X} Y_t^* \tag{75}$$

Where Y_t^* denotes the world demand modeled as an exogenous process. In particular, $\log Y_t^*$ is defined as an autoregressive process, as shown in equation (76).

$$\log\left(Y_t^*\right) = \rho_{Y^*} \log\left(Y_{t-1}^*\right) + \nu_t^{Y^*} \tag{76}$$

[23] Unless, of course, g_t is perturbed by the shock ν_t^g.

[24] See Rapa (2017) for a version of MEDSEA with fiscal rules that include an output stabilization objective.

where $\rho_{Y^*} \in (0,1)$ is the autoregressive parameter and $\nu_t^{Y^*} \sim \mathcal{N}(0, \sigma_{Y*}^2)$ is an i.i.d. process.

2.8 Market clearing and equilibrium

The market clearing conditions require that all goods produced are consumed, invested, used by the fiscal authority, exported or imported, yielding the nomimal GDP equation (77):

$$Y_t = P_t^C C_t + P_t^I I_t + P_t^{NT} Y_t^G + P_t^X Y_t^X - P_t^M Y_t^M. \tag{77}$$

As discussed above, local consumption and investment are equal to the supply bundles (Y^C, Y^I) made up of locally produced and imported goods:

$$Y_t^C = C_t \tag{78}$$

$$Y_t^I = I_t \tag{79}$$

Additionally, the total amount of local and imported products are equal to local and imported consumption and investment, plus public spending and imported goods used for export production respectively–equation (80) and (81):

$$Y_t^{NT} = Y_t^{C,NT} + Y_t^{I,NT} + Y_t^G \tag{80}$$

$$Y_t^M = Y_t^{C,M} + Y_t^{I,M} + Y_t^{MX}. \tag{81}$$

Housing supply is normalized to one

$$\int_0^{\varpi} H_{j,t}^s \, dj + \int_{\varpi}^1 H_{j,t}^b \, dj = \varpi H_{s,t} + (1-\varpi) H_{b,t} = \widetilde{H}_t \tag{82}$$

and total consumption is given by

$$C_t = \int_0^{\varpi} C_{s,j,t} \, dj + \int_{\varpi}^1 C_{b,j,t} \, dj = \varpi C_{s,t} + (1-\varpi) C_{b,t}. \tag{83}$$

Similarly, other market clearing conditions are given below:

$$D_t = \varpi D_{s,t} \tag{84}$$

$$L_t = (1-\varpi) L_{b,t} \tag{85}$$

$$B_t^* = \varpi B_{s,t}^* \tag{86}$$

$$I_t = \varpi (I_{s,t}^N + I_{s,t}^H) + \delta K_t^{XD} \tag{87}$$

$$K_t^{NT} = \varpi K_{s,t}^{NT`} \tag{88}$$

$$K_t^H = \varpi K_{s,t}^H \tag{89}$$

$$T_t = \varpi T_{s,t} + (1-\varpi) T_{b,t} \tag{90}$$

which aggregate across household types. Total investment I in equation (87) includes investment in K^{NT} and K^{H} as well as the maintenance on K^{XD}. We allow lump sum taxes to be allocated differently across the two household types as in Rapa (2017). The share of taxes accruing to borrowers is:

$$T_{b,t} = \upsilon_T T_t \tag{91}$$

where $0 \leq \upsilon_T \leq \frac{1}{(1-\varpi)}$, and the rest are levied on savers.[25] We measure total real output as the sum of demand for local production:

$$\widehat{Y}_t = Y_t^{NT} + Y_t^{XD} + Y_t^{H}. \tag{92}$$

Finally, we normalise the model on the foreign price, $P_t^* = 1$. Equilibrium is defined as a sequence of prices and choices which satisfy optimality conditions, budget constraints and aggregate market clearing.

3 Calibration

There are several parameters which are imported from MEDSEA for which we keep the same calibrated values, and therefore we do not discuss them further here.[26] Here we focus on the parameters that are new or that need to be re-calibrated following the changes to the model. We split this set in two subsets. One subset is used to pin down key great ratios, which are matched with the data counterparts of the Maltese economy. The rest influence the steady state of the model, its dynamics, or both, and are set in line with the literature. We start discussing these first.

The model is calibrated to quarterly frequency. We set the discount rate for borrowers at 0.95, which make them borrowing constrained in and in the proximity of the steady state. The inverse labour elasticity of substitution between sectors ς is set to 1, as estimated in Horvath (2000) and Iacoviello and Neri (2010). The maximum LTV ratio is set at 90% and the CAR at 10%. These are values typically used in the literature and they are also in line with Maltese data.[27]

The quasi-share of labour in construction α_h is set at 0.75 and the elasticity of subsitution in the production sector (θ_H) at 3. We set these values somewhat arbitrary as we use other parameters, detailed below, to target the share of construction labour income to total labour

[25] At the lower limit, i.e. $\upsilon_T = 0$, $T_{b,t}$ is equal to 0, while $T_{s,t}$ is equal to $\frac{1}{\varpi}T_t$. At the upper limit, i.e. $\upsilon_T = \frac{1}{(1-\varpi)}$, both $T_{b,t}$ is equal to $\frac{1}{1-\varpi}T_t$ while $T_{s,t}$ is equal to 0. When $\upsilon_T = 1$ taxes and transfers are symmetrically distributed, i.e. $T_{b,t} = T_{s,t} = T_t$.

[26] In the absence of any microdata we set these largely following values typically used or estimated in the literature. These are parameters relating to habit formation, adjustment costs, elasticities of substitution (markups), price indexation and shock persistence parameters. See Appendix B for a full list of parameters and their values.

[27] An LTV ratio of 90% is the typical leverage limit at origination observed in mortgages in Malta, see Spiteri (2019). This statistic is based on a quarterly real estate survey. The ratio not only affects state leverage but contributes to off steady state dynamics through a financial accelerator that arises from the endogenous borrowing constraint (16). The higher is this ratio, the higher is steady state leverage and the more amplified are responses to shocks which affect housing wealth. The average Tier 1 Capital ratio and Leverage ratio for core banks in Malta averaged 14% and 6.4% respectively over the past 5 years. Since there is only one bank asset in the model these two ratios collapse to the same number for our bank. The mean of the two ratios in the data is 10.2%, coinciding with the target CAR that we impose on the banker.

income in the model. We fix the depreciation rate of construction capital δ_{KH} at at 0.03 as in Iacoviello and Neri (2010) and housing δ_{KH} and 0.0035, the latter implying an annual maintenance cost of housing of about 1%. We allow all taxes to be levied on savers and therefore set υ_T to

Table 1: Parameters

Parameter	Description	Value
β_b	Discount factor: borrowers	0.95
ς	Labour inverse elasticity of substitution between sectors	1
$\overline{\mathsf{m}}$	Steady state LTV ratio	0.90
$\bar{\mathsf{c}}$	Steady state CAR	0.10
α^H	Quasi-share of labour in construction	0.8
μ^H	Elasticity of substitution in construction	3
δ_{KH}	Depreciation rate: construction capital	0.03
δ_H	Depreciation rate: housing	0.0035
υ_T	Share of tax levied on borrowers	0
ξ_B^D	Bank adjustment cost: deposits	0.15
ξ_B^L	Bank adjustment cost: loans	0.15
ρ_{m}	Inertia in LTV rule	0.90
ρ_{c}	Inertia in CAR rule	0.90
τ_{m}	LTV rule: coefficient on credit gap	1
τ_{c_B}	CAR rule: coefficient on credit gap	4

0. The parameters on bank adjustment costs ξ_B^D and ξ_B^L are both equal to 0.15, and they control the reaction of bank credit to a rise in house prices.[28] In this paper we set the LTV and CAR response parameters τ_{m} and τ_{c_B} to 1 and 4 respectively; arbitrary numbers used for the sake of broadly gauging the effects of time-varying requirements on the Maltese economy. We stress that these response parameters do not reflect any particular implementation of these policies by the Central Bank of Malta. The persistence parameters of these policy rules are both set to 0.90, to reflect the fact that these ratios are typically not revised frequently in practice.

We use a subset of the parameters to target key moments, as listed in Table 2. The model is highly sensitive to parameter values and we are unable to find a steady state that satisfies all the calibration targets. We set the steady state weight on housing in the utility function $\bar{\epsilon}^H$ to 0.181, a figure close to Iacoviello and Neri (2010) and Gerali et al. (2010) and which generates a housing

[28] In the absence of estimates for these parameters, the calibration of ξ_B^D and ξ_B^L is somewhat arbitrary and is guided by the shape of impulse responses.

wealth to output ratio of 4.55, reasonably close to the ratio in Maltese data.[29]. The share of savers in the economy ϖ is 0.206, such that the aggregate credit to GDP ratio in the model is about 30%, close to the average total secured credit to ouptut ratio in Malta over the period 2004–2019. We set the discount factor for the bank β_B at 0.969; such that for the given steady state CAR ratio it delivers a steady state interest rate spread of 1.0% in annual terms.[30] As a result, the annualised lending interest rate is 4%. The steady-state productivity level of construction capital $\overline{A}^H$ is set at 1.407, such that we obtain a nominal construction wage bill to total labour income of 5.2%, close to the long run average in Malta over the period 2000–2018. Conditional on the depreciation rate of construction capital, we set the depreciation rate of capital used in the non-tradables sector δ_{KNT} at 0.036, such that the investment share of output is 20.5%, close to the figure in MEDSEA. Similarly, we set the parameters $\overline{g}$, ζ, α_C, α_I, α_X and $\overline{K}^{XD}$ to values which deliver the same or similar great ratios as in MEDSEA. Finally, we adjust the parameter on the number of non-tradables used to distribute the final export good θ to 0.276, such that it delivers a distribution margin of about 14%.

Table 2: Selected parameters and steady state targets

Parameter	Description	Value	Target	Model
$\overline{\epsilon}^H$	Utility weight on housing services	0.181	$\frac{qH}{4Y} = 400\%$	455%
ϖ	Share of saver households	0.206	$\frac{P^C L}{4Y} = 38.3\%$	29.4%
β_B	Discount factor: Banker	0.969	$\widetilde{R}^L - \widetilde{R} = 1.0\%$	1.0%
$\overline{A}^H$	Productivity of capital in real estate sector	1.407	$\frac{W^H N^H}{\sum_m W^m N^m} = 4.0\%$	5.2%
δ_{KNT}	Depreciation rate: capital in NT sector	0.036	$\frac{P^I I}{Y} = 20\%$	20.5%
$\overline{g}$	Government expenditure share: NT good	0.19	$\frac{P^N Y^G}{Y} = 19\%$	19.0%
ζ	Long run foreign debt to output ratio (log)	-1.922	$\frac{TB}{Y} = 0.434\%$	0.434%
α_C	Quasi-share of imports in consumption good	0.529	$\frac{P^M Y^M}{P^C Y^C} = 50\%$	49.8%
α_I	Quasi-share of imports in investment good	0.666	$\frac{P^M Y^M}{P^I Y^I} = 64\%$	63.8%
α_X	Quasi-share of imports in export good	0.336	$\frac{P^M Y^M}{Y} = 106\%$	103.8%
$\overline{K}_{XD}$	Level of foreign capital	2.209	$\frac{P^K \overline{K}^{XD}}{4Y} = 40\%$	39.8%
θ	Basket of NT used to distribute export goood	0.276	$\frac{P^X - P^{XW}}{P^X} = 15\%$	13.8%

Note: $\widetilde{R}^L$ and $\widetilde{R}$ denote annual net interest rates.

[29]The estimate from the data is based on mean and median hedonic prices from Ellul et al. (2019) and estimates of housing stock from Gatt (2019a) for the period 2010–2018.

[30]The average spread between the interest rates on loans and deposits is about 1.5% in the data for new business transactions. However, importing this spread into the model means that we lose a lot of the accelerator effects from a rise in house prices, as mortgage financing becomes very expensive for borrowers and they scale back on consumption.

The parameters that affect the dynamics, such as adjustment cost and shock persistence parameters, are largely kept at the same values as in MEDSEA; see Appendix B for more details. In the absence of estimates about differing wage rigidities across sectors, we set $\xi_W^{NT} = \xi_W^{XD} = \xi_W^H = \xi_W$=38.8 in line with the original calibration of MEDSEA. Turning to the variance of shocks, in this paper we limit our analysis to shocks to housing services ϵ_t^H. We calibrate its variance such that a one standard deviation shock causes real house prices to rise by 1% relative to their steady state value.

4 Properties of the macroprudential policy rules

How do the two macroprudential tools work to contain an exessive rise in credit? To answer this question through the lens of the model, we simulate the economy under a temporary but persistent shock to housing preferences ϵ_t^H. 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. First, we simulate the model while switching off the two policy rules (67) and (68), that is, the macroprudential authority does not respond to the changing environment and keeps the LTV and CAR limits at their steady state values of 90% and 10% respectively. We label this the ‘no active policy’ scenario. Then, we run the same simulation but we switch on one rule at a time, keeping the other rule off. Finally, we run the simulation with both rules active. In this way, we can comment on the seperate and joint effects of using these policy tools on economic outcomes. We solve for the policy functions using a second order perturbation around the model’s stochastic steady state.

4.1 The financial accelerator

Figure 2 shows the impulse response functions of key variables in the ‘no active policy’ scenario. An increase in the marginal utility of housing raises demand for housing services, which pushes up house prices. Savers and borrowers react differently to the shock. Saver households find it optimal to sell some of their holdings of housing to borrowers, to work more hours and to save via deposits in an effort to smoothen their consumption. On the other hand, the increase in house prices relaxes the borrowing limit via the collateral constraint (16) and allows impatient households to borrow more, using these resources to purchase more houses but also to increase their consumption of the non-durable good. As a result, borrowers experience a wealth effect and increase their labour supply by much less on impact. The rise in demand for credit cannot be met one-for-one, as the bank has to ensure its capital position respects the regulatory CAR. Since the nominal deposit rate is fixed with respect to domestic conditions and deposits are determined by saver households, equilibrium in the credit market that satisfies the (fixed) CAR requirement necessitates a rise in the lending interest rate.[31] This causes the nominal spread to rise by 0.4 percentage points on impact, which translates to about 1.8 percentage points in annualised terms.[32]

[31] In this simulation the CAR requirement is binding throughout, meaning that the bank capital to assets ratio does not fall below 10% in any period.

[32] Note that the interest rate response in Figure 1 is presented in annualised terms.

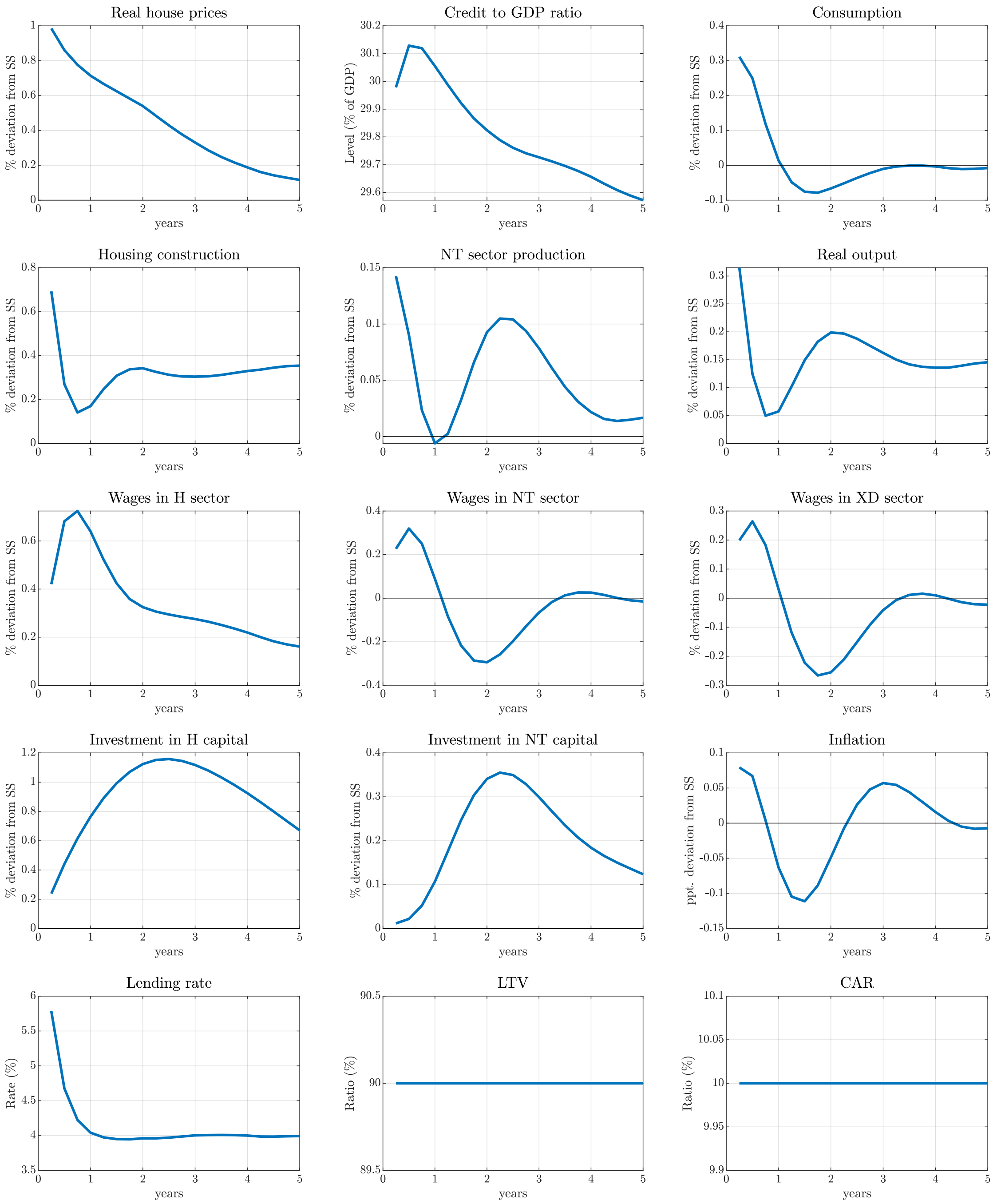


Figure 2: Impulse response to a housing demand shock – no active policy

Notes: The lending rate is expressed in annualised terms. Inflation relates to movements in the price of consumption goods P^C, in annualised terms. Wages are expressed in nominal terms.

The increase in credit to borrowers causes aggregate consumption to rises, stimulating the production of intermediate goods. Higher house prices also stimulate the construction sector to produce more houses, employing more labour and capital. This slowly increases the housing stock. The economy experiences a boom in both the H and NT sectors in the first year following the shock, driven by the financial accelerator, and causes wages and prices in all sectors to rise.[33] In

[33]Despite the imperfect labour mobility across sectors, wages in the export good producing sector XD also rise in order to retain the labour input. This raises the price of the final export good, which slightly lowers exports.

the second year of the shock, borrower households start a process of deleveraging, which causes them to reduce their consumption. This temporarily slows down some sectors of the economy, causing demand for labour across all sectors to fall, leading to lower final goods prices. However, this raises the competitiveness of Maltese exports and stimulates production of the export good, which improves Malta's trade balance. Meanwhile, real estate construction picks up following the temporary lower expansion, on the back of lower operating costs. Note that the construction sector supports real output growth throughout the shock.[34] Investment in construction capital increases demand for the investment good, and this rekindles production in the NT sector, which stimulates further investment in capital used in the NT sector. In summary, the economy experiences a leverage-deleverage cycle which creates two cycles in the first 5 years. The boost in economic activity continues for some more years and eventually subsides and the economy returns slowly to its steady state.[35]

4.2 Leaning against the wind

We now focus on how this story changes when the macroprudential authority uses the LTV and CAR rules (67) and (68) countercyclically. Figure 3 shows the impulse response functions of key variables for the same housing demand shock discussed above. It shows the transmission of the shock when either the LTV or the CAR rule is switched on, and when both are active simulteneously. The 'no active policy' scenario is also included in the figure for ease of reference. Since the calibration of the policy response parameters τ_{m} and τ_{c} is arbitrary, we do not make any statements on the effectiveness of any one particular tool over the other to stabilise the economy.

Starting with an active LTV policy only (small dashed lines), we note that a gradual reduction in the maximum LTV ratio dampens credit growth and consumption by tightening the borrowing constraint. In effect, such policy tries to counteract the rise in house prices that stimulates credit growth and fuels consumption. Note that the policy *per se* does not affect house prices, as it does not address the housing demand shock. Rather, it addresses the distortion – the collateral constraint – that links house prices and consumption. As a result, consumption rises by less and households deleverage quicker compared to the 'no active policy' scenario. Wages and prices also rise by less, and total output is higher in the first year of the shock. Since there is less outstanding debt one year into the shock, the deceleration and rebound in output that is driven by the correction in wages and prices occurs earlier and is somewhat less pronounced.

Similar dynamics occur when the CAR is used as an active policy tool instead (long dashed line). Note that while the LTV ratio is reduced during credit growth, the CAR is raised to force the bank to hold more capital. As discussed above, since the interest rate on deposits is very inelastic, the only way the bank can abide by the CAR constraint and increase its capital relative to its assets is to issue more loans than deposits. This causes saver households to accumulate

[34] An earlier version of the model, discussed in Gatt and Rapa (2019), did not include a real estate sector. In that model, a housing demand shock led to a net fall in real output.

[35] We restrict our attention to the first 5 years following the shock in this paper. However, the return to steady state takes longer, and therefore cannot be seen in the figure. This higher persistence is a feature which the model inherits from MEDSEA and is partly a consequence of how we close the model via the UIPC.

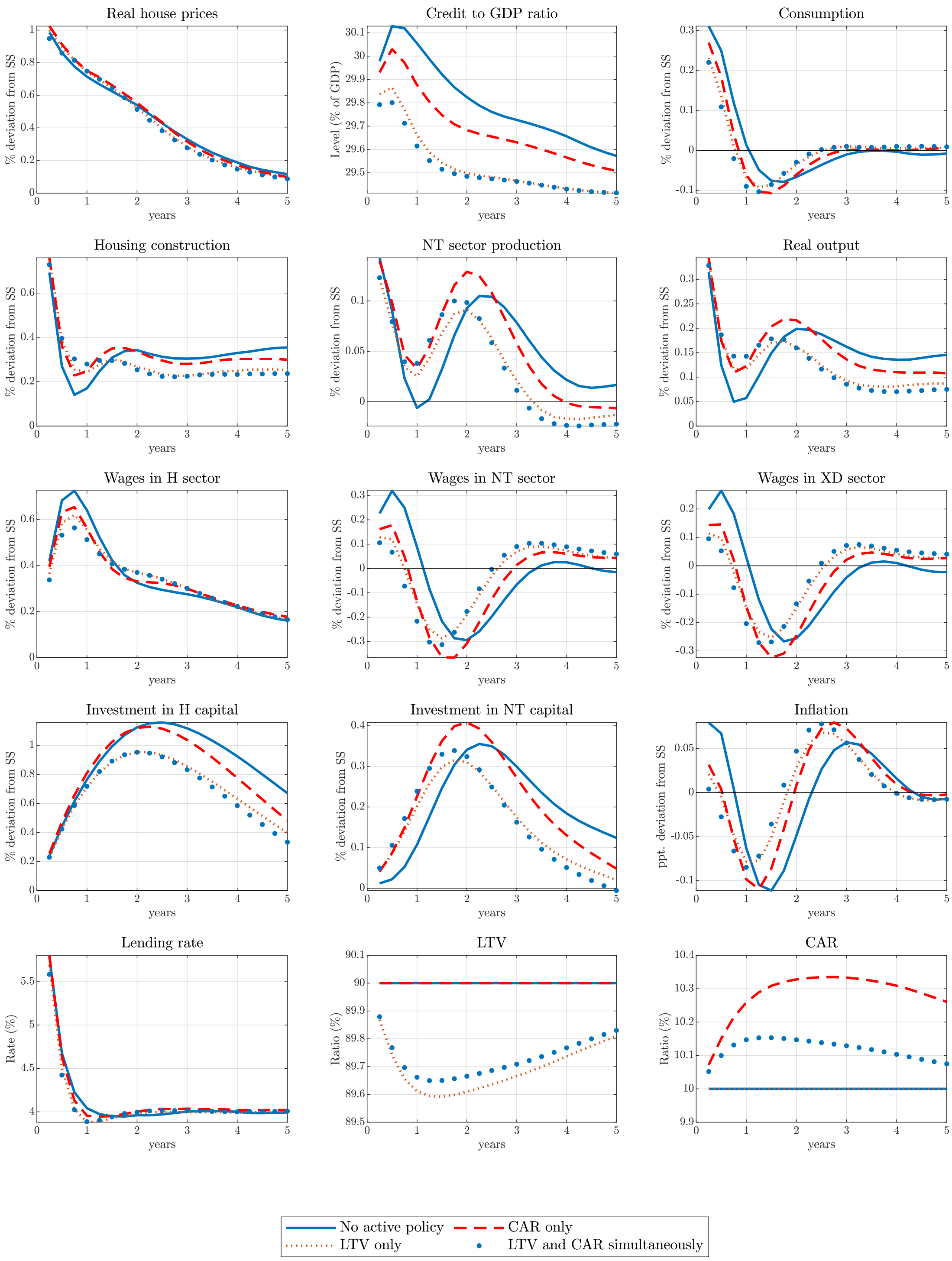


Figure 3: Impulse response to a housing demand shock – active policy

Notes: The lending rate is expressed in annualised terms. Inflation relates to movements in the price of consumption goods P^C, in annualised terms. Wages are expressed in nominal terms.

resources in other assets, such as capital, relative to the first two scenarios. As a result, investment in capital used in the NT sector rises, lowering its rental rate and boosting output in this sector. Wages are lower throughout most of the horizon as firms use relatively more capital in their production mix.

Finally, policmakers can use both tools simultaneously, coordinating the required changes to the LTV and CAR (circle markers). An immediate consequence of this is that each tool requires a smaller change, since they both work in the same direction.[36] Although both policy tools are revised by less, and the policy response parameters are unchanged, the combined effect on credit and consumption dampening is stronger than when either tool is used in isolation. The transmission of the shock is largely the same.

5 Conclusion

In this paper we describe the extension of the Central Bank of Malta's core DSGE model with financial frictions in the form of household collateral constraints and minimum bank capital requirements. We add housing as a durable good, impatient households which are borrowing constrained, a real estate construction sector and a bank which acts as a financial intermediary between savers and borrowers. A macroprudential authority controls the LTV and capital-to-asset ratios with the objective of maintaining financial stability, which is here defined as the prevention of an excessive rise in credit following a shock that boosts housing wealth.

We show how tightening credit conditions during a credit boom helps to stabilise the economy by dampening the rise in credit and consumption. As a result, the delevering process that occurs as the credit boom subsides has a smaller impact on total output. We also show how a shock in the housing market propagates to other sectors through the labour market, which is also extended with frictions relative to the core model. The effect on competitiveness and trade is also captured. Therefore, MEDSEA-FIN is a model suited to the analysis of macroprudential policies that target households and banks in Malta.

The specification of the LTV and CAR rules within this paper is not meant to capture the real-life implementation strategies that have been employed by the Bank in the recent past, but is rather targeted at gauging how the two rules could work in dampening the response of real variables to housing demand shocks. Moreover, since at the moment the calibration of the response parameters of these two rules is arbitrary, the present study is not meant to make quantitative statements on the relative efficacy of the two rules. Nonetheless, conditional on the correct specification and calibration of the two macroprudential rules, the framework presented in this paper does allow for a quantification of the effects of real-life macroprudential policies. Moreover, in the future, the model can also be used to estimate the joint optimal implementation of LTV and countercyclical capital buffers following shocks to housing demand, by taking in consideration the relative efficacy of both rules, whilst internalising any complementarities that may exist between the two policies.

[36]This scenario therefore does not correspond to the sum of the 'LTV only' and 'CAR only' scenarios.

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Appendix A General retailer problem

Here we sketch the problem of a general retailer, since we use this result several times in the body of the paper, and the notation is independent of what we use elsewhere. A perfectly-competitive retailer purchases differentiated goods $Y_{j,t}$ at price $P_{j,t}$ from a continuum of wholesalers indexed by $j \in (0, 1)$ and aggregates them into a bundle Y_t to maximize profits. The aggregation technology is a CES function with elasticity of substitution among varieties μ. Formally, the problem is given by:

$$\max_{Y_{j,t}} \quad P_t Y_t - \int_0^1 P_{j,t} Y_{j,t} dj \tag{A.1}$$

s.t.

$$Y_t = \left(\int_0^1 (Y_{j,t})^{\frac{\mu-1}{\mu}} dj \right)^{\frac{\mu}{\mu-1}}. \tag{A.2}$$

The maximization problem can be solved by substituting (A.2) into the objective function, and deriving the first order conditions for $Y_{j,t}$. The solution is a downward-sloping demand schedule:

$$Y_{j,t} = \left(\frac{P_{j,t}}{P_t} \right)^{-\mu} Y_t. \tag{A.3}$$

Additionally, an aggregate price index can be retrieved by substituting (A.3) into (A.2).

$$P_t = \left(\int_0^1 (P_{j,t})^{1-\mu} dj \right)^{\frac{1}{1-\mu}}. \tag{A.4}$$

Appendix B Full calibration

Table B.1: Parameter Values

Parameter	**Value**	**Description**
β_s	0.993	Discount factor: savers
β_b	0.950	Discount factor: borrowers
β_B	0.969	Discount factor: banker
σ	2.000	Consumption risk aversion
χ	0.600	Habit formation
φ	1.000	Inverse of Frisch labor elasticity
ς	1.000	Labour inverse elasticity of substitution between sectors
$\bar{\epsilon}^H$	0.181	Utility weight on housing services
ω	0.206	Share of saver households
γ^N	0.650	Share of labour in NT sector
γ^{XD}	0.600	Share of labour in XD sector
α_H	0.800	Quasi-share of labour in construction sector
α_C	0.529	Quasi-share of imports in consumption good
α_I	0.666	Quasi-share of imports in investment good
α_X	0.346	Quasi-share of imports in export good
$\overline{A}^H$	1.407	Steady state productivity in real estate sector
δ_H	0.004	Depreciation rate: housing
δ_{KH}	0.030	Depreciation rate: construction capital
δ_{KN}	0.036	Depreciation rate: capital in NT sector
η_C	1.100	Elasticity of substitution: consumption good
η_I	1.100	Elasticity of substitution: investment good
η_X	4.000	Elasticity of substitution: export good
μ_W	4.333	Elasticity of substitution: labour market
μ_H	3.000	Elasticity of substitution: construction sector
μ_N	3.000	Elasticity of substitution: intermediate goods in NT sector
μ_M	3.000	Elasticity of substitution: intermediate imported goods
μ_X	6.000	Elasticity of substitution: intermediate wholesale export good
ζ	-1.922	Long run foreign debt to output ratio (log)
$\overline{K}^{XD}$	2.209	Steady state level of foreign capital
θ	0.276	Basket of NT used to distribute export good
$\overline{\Pi}$	1.000	Steady state inflation
$\overline{\mathsf{m}}$	0.900	Steady state LTV ratio
$\bar{\mathsf{c}}_B$	0.100	Steady state CAR
τ_{m}	1.000	LTV reaction parameter
τ_{c_B}	4.000	CAR reaction parameter
ξ_I	6.000	Adjustment cost: investment in K^{NT}
ξ_H	6.000	Adjustment cost: investment in K^H
ξ_W	38.800	Adjustment cost: wages
ξ_B^D	0.150	Adjustment cost: deposits

Table B.1 – Continued

Parameter	**Value**	**Description**
ξ_B^L	0.150	Adjustment cost: loans
ξ_{NT}	20.400	Adjustment cost: price of local good
ξ_M	58.300	Adjustment cost: price of imported good
ξ_X	58.300	Adjustment cost: price of exported good
ι^M	0.500	Price indexation: imported good
ι^{NT}	0.500	Price indexation: non-tradable good
ι^W	0.800	Wage indexation
ι^X	0.500	Price indexation: export good
$\overline{g}$	0.190	Steady state government consumption of NT good
υ_T	0.000	Tax load on borrowers
ρ_{m}	0.900	Inertia in LTV rule
ρ_{c_B}	0.900	Inertia in CAR rule
ρ_ϕ	0.0002	Interest rate premium sensitivity
$\rho_{K^{XD}}$	0.900	AR(1): shock to foreign capital
ρ_g	0.900	AR(1): shock to government spending
ρ_{P*}	0.900	AR(1): shock to foreign prices
ρ_{Y*}	0.900	AR(1): shock to foreign output
ρ_β	0.900	AR(1): shock to intertemporal preferences
ρ_R	0.900	AR(1): shock to risk premium
ρ_H	0.900	AR(1): shock to housing preferences
ρ_{AN}	0.900	AR(1): shock to technology in NT sector
ρ_{AXD}	0.900	AR(1): shock to technology in intermediate export good
ρ_{A^H}	0.900	AR(1): shock to construction capital productivity
σ_{ϵ^H}	0.100	St. deviation of housing preference shock