Empirical and agent based modelling of credit cycles

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CONTENTS

1. MOTIVATION AND PREVIOUS RESEARCH

After the financial crisis, the relation of the banking sector and the real economy has become an important research area. While earlier it had been less important to investigate the macroeconomic effects of the financial intermediary system, recently more and more models have been developed to investigate this issue. The focus is primarily on the effect of the banking sector on aggregate demand, which can deviate output from its potential level in the short run. However, we need to emphasize that an efficient banking sector can help the macroeconomy in the long run as well, increasing the potential growth rate (cf. Beck et al, 2000, Pradhan et al, 2014).

The banking sector is procyclical, so it amplifies booms and recessions, since during a boom banks tend to issue out more loans increasing the consumption and investment levels of those who were given the loan, and through a spill-over effect it increases aggregate demand and output as well. While in a recession, increasing default rates make considerable loss to the banking sector, and thus the banking sector decreases its lending activity what exacerbates the recession. During a boom banks might be less risk averse and they tend to lend more money to riskier partners which have a higher probability to default if a shock hits the economy. This kind of lending activity builds up systemic risk, which has a more serious feedback in case of a negative shock. But less prudent lending may lead to a recession in an endogenous way as

well, without an additional macro shock.

The aim of macroprudential policy is to prevent the build up of such systemic risks. Though in the short run financing riskier debtors may increase output, it does not necessarily imply an effective allocation of resources, and when risks materialise it may even decrease the trend of potential output (Cerra and Saxena, 2008). Thus, an efficient macroprudential policy may enhance financial stability and promote higher output in the long run. Macroprudential instruments decrease lending activity in the short run and if regulators prescribe too severe rules, potential growth can even decrease. For higher but sustainable long run growth, economic actors should take some risk or the financial system will not allocate enough resources to investment projects which would lead to higher output.

A too stringent macroprudential regulation could do just as much harm to the economy as a too loose regulation. To find the proper level of different macroprudential instruments, it is important to understand the effect of different instruments on lending and the economic feedbacks of lending. In the thesis we try to make the fundamentals of a macroprudential model which could later help us to estimate the effect of different macroprudential regulations on lending and economic performance and to have a better understanding of the interaction of various macroprudential instruments. Understanding the interactions of the instruments and their effect on economic performance may help regulators to form an efficient macroprudential policy which enhances financial stability without unnecessarily decreasing output.

We developed two agent based models: one is a macromodel with corporate lending, the other one is a model of the housing market with mortgage lending. These two models have features which may help to develop a more complex macromodel with a detailed banking sector and macroprudential in-

struments to find the optimal regulation.

The thesis consists of an econometric analysis, a literature review of agent based macromodelling and then it presents the aforementioned two agent based models. The econometric analysis compares some filtering techniques to decompose the Hungarian credit-to-GDP time series to trend and cycle components in order to measure the credit gap. According to the Basel Committee on Banking Supervision (2010), macroprudential authorities should consider the credit gap when determining the countercyclical capital buffer rate. Unfortunately, since a considerable deepening of the financial intermediary system has begun after the millennium, the recommended technique to determine the credit gap (using a univariate Hodrick-Prescott filter) has misleading results in the case of Hungary, but in can be unreliable in other cases as well (Edge and Meisenzhal, 2011). Thus, we developed a multivariate Hodrick-Prescott filter which can better capture the specificities of lending in Hungary and is also more robust.

In the econometric analysis we calculated the credit gap separately for the corporate and the household sector and both sectors produced a credit cycle. Thus we started the development of agents based models, one for the corporate credit cycle, and one for the household credit cycle. The first model is a macromodel based on the model of Dosi et al. (2015), while the second one is a housing market model without feedbacks to the macroeconomy. Later these two models need to be merged. While the mortgage model is calibrated to Hungary, the macromodel is not, it is a first attempt to generate credit cycles which may be longer than business cycles.

Before presenting the agent based models we also give an insight into agent based macromodelling for two reasons. First, it helps to understand why it might be preferable to use agent based techniques to model the macroe-

conomy for macroprudential purposes. Second, it sheds light on how agent based macromodelling can be performed and highlights some advantages and disadvantages. We summarize the main components of three agent based macromodels with a financial system (Assenza et al., 2015; Erlingsson et al., 2014; Dosi et al., 2015). We consider the selected models to be a good representation of what agent based macromodelling is capable of now.

After the literature review of agent based macromodelling, we present our own agent based macromodel, the main components of which are based on the work of Dosi et al. (2015) but we highlight the differences which were necessary to introduce a more complex financial system in which we could generate longer credit cycles than business cycles.

Finally, we present an agent based demand-driven housing market model, implementing a large degree of heterogeneity among households. The flats of the housing market are organized into buckets according to their size. Households try to purchase the highest available flat for their reservation price and their reservation price is mainly determined by their income. These approaches mimick the model of Baptista et al. (2016), who developed an agent based housing market model of the UK. In our model we generated one million households using granular Hungarian data. The mechanisms of the model are yet kept relatively simple but we will later relax the demand-driven aspect of the model. Still, we use the model to make some preliminary investigation of different combinations of payment-to-income (PTI) and loan-to-value (LTV) regulation.

Out of the four major parts of the thesis (the econometric analysis of the credit gap introducing a new, multivariate Hodrick-Prescott filter for the Hungarian economy; a literature review of agent based macromodelling with bank lending; an agent based keynesian macromodel for credit cycles; an

agent based demand-driven housing market model), two parts are already available in English: the econometric analysis is detailed in Hosszú et al. (2015), while the agent based keynesian macromodel is presented in Hosszú and Mérő (2017). For this reason, these two parts are not detailed in this summary. The literature review on agent based macroeconomics with a banking sector is to published in English in September, 2019.

2. APPLIED METHODS

Agent based macromodels with a banking system

After an introduction to agent based macromodelling, the chapter summarizes three agent based macromodels. Though we also share our own experiences on agent based modelling, the chapter is a literature review.

A demand-driven housing market model for the investigation of macroprudential instruments on mortgage lending

When we consider the riskiness of mortgage lending, it is not enough to have a representative agent to calculate the aggregate loss. To estimate the aggregate loss of the banking sector in the case of an unexpected shock (or the aggregate loss in different periods of a credit cycle), it is very important to incorporate household heterogeneity, since each mortgage contract has a different probability to default (based on household characteristics) and in case of defaulting, the amount of loss also depends on many different factors of the specific household. To incorporate household heterogeneity, we used agent based modelling, since with agent based modelling we can generate heterogenous agents along multiple dimensions (for example age, income, wealth and preferences regarding housing).

Agent based modelling is computer simulation in which we code the behavioural rules of agents and see how the system evolves (cf. Tesfatsion and Judd, 2016; Fagiolo and Roventini, 2017). These rules can be flexible and more realistic since we don't need to represent the decision rules as part of an equation system as in mainstream economics.

As in Baptista et al. (2016), the flats in the housing market only differ in size and the flats are organized into buckets. In each bucket the flats are of the same size. The household which decides to purchase a flat, determines its reservation price according to its income and preferences, and also according to the credit constraints if the PTI or the LTV regulation binds. Given a household's reservation price, it decides to buy the largest flat possible. In this stage of model development, we abstracted from housing market frictions and the housing market is demand-driven: a household can always buy a flat in the desired bucket and in case of moving (and not purchasing its first flat), it does not need to sell its former property to another household, but the market pays the market value of the flat immediately.

Our housing market model is yet more simple, but the generation of households is more complex than what is usual in the literature. We generated 1 million households using Hungarian granular data. We assumed that the households who were given a mortgage loan in 2016 might be a good starting point for the generation of households in the model. So when generating the households of the model, we drew observations from the mortgage loans issued in 2016, using the L11 database of the Central Bank of Hungary, which is a micro database with household credit contracts of loans issued since 1st January, 2015. Connecting the L11 database with the income tax database, we could generate the income of a household, the downpayment of a mortgage contract, the market price of the purchased flat and the age of the

debtor at the time of the purchase.

In the model we have a relatively stable normal time (which is close to equilibrium), but a macroeconomic shock may give rise to a recession. In order to be able to calibrate the model to normal times, we used uniform age distribution in the model.

Households are classified into three groups according to education (households with primary, secondary and tertiary education). For different income levels and age, we calculated the probabilities of belonging to the different categories. In the model, the probability of unemployment is based on Hungarian data, and we used different probabilities for different education levels.

In the model the duration of the mortgage contracts is the same and the interest rate is fixed for all contracts, but the interest rate is set according to households' characteristics. To estimate the interest rate of a mortgage loan, we made a linear regression for the mortgage interest rate using the L11 database.

In the model, the major cause for default is unemployment, but in case of a macroeconomic recession we introduced moral hazard as another channel.

In the simulation we shocked the equilibrium like state of the model with an exogenous macro path, changing temporarily wages and the probability of unemployment which generated a cycle in the prices of houses and in the amount of outstanding loans. To investigate the PTI and LTV requirements, we calculated the affect of the shocks with different combinations of PTI and LTV: in the case of PTI, we used 30 percent, 40 percent, 50 percent and 60 percent, in the case of LTV, we used 60 percent, 70 percent, 80 percent and 90 percent. We calculated the effect of different combinations on the profitability of the banking sector, on the number of defaults and on average flat size. We compared the results to the prevailing regulation in Hungary

(PTI of 50 percent, LTV of 80 percent).

We made robustness check to see how different parameters may change whether a PTI-LTV combination can produce higher profitability or not. We investigated the length and the severity of the shock, households' reaction to the change in house prices and savings rate.

3. RESULTS OF THE THESIS

Agent based macromodels with a banking system

- In agent based macromodels banks finance through money creation and they are not modelled as intermediaries of loanable funds.
- Agent based macromodels with a detailed financial system may be more appropriate to make models for the investigation of macroprudential instruments.
- Rules applied in agent based models can be more realistic but the modeller needs to be aware of the possible interactions of the applied rules to get real world like dynamics.
- Using smoothing in the decision rules of agents can help to have less volatile dynamics.
- We need to be aware of the high computational needs of agent based macromodelling which can also prolong development time.

A demand-driven housing market model for the investigation of macroprudential instruments on mortgage lending

- We could generate one million heterogenous households using Hungarian data and calibrate a model in which the mortgage loans reflect the main characteristics of the mortgage loans issued in 2016, regarding the price of the house and the amount of loan for young and middle-aged households.
- We can generate an endogenous house price cycle by the following rule: households tend to buy more expensive (cheaper) houses if they experience that house prices are moving upward (downward). For this endogenous cycle to set off, the economy needs to be shocked out of the equilibrium.
- In our simulations the number of defaults and the loss of the banking sector due to an exogenous macro shock depends more on the length of the shock than the actual decline in income since the major driving force for defaults is unemployment and not the wage level.
- In our simulations less stringent regulation may lead to higher profitability in the banking sector and to greater average flat size during normal times.
- In our simulations less stringent regulation leads to higher losses due to a negative shock.
- Whether to prefer a PTI–LTV combination to the baseline combination (based on the profitability of the banking sector) depends on the expected length of normal times. If we assume that a major macro shock

(which increases unemployment rates by 3 percentage points for two and a half years) happens every 10-25 years, then there is no need to further tighten the prevailing LTV-regulation of 80 percent if we consider the profitablity of the banking sector but it might be preferable to decrease the PTI-limit. We need to keep in mind that average bank profitablity is only one aspect and the regulator also needs to consider other factors as well, i.e. the number of defaults and sudden capital need in case of large losses.

- In our simulations the LTV-regulation has a greater effect on the number of defaults than PTI-regulation. However, the reason for this observation is that in case of increasing the LTV-regulation, households which were credit constrained earlier may purchase more expensive houses and their PTI-levels increase. So increasing the LTV level actually leads to a shift to higher PTI-levels for the credit constrained households.

- Our results regarding the preferability of a less stringent LTV-regulation with a lower PTI-regulation (taking into consideration banking profitability only) holds for different macro shocks and holds when we strengthen or weaken households' reaction to changing house prices. Our results are not robust to the changes in the savings rate but it is something we would expect: if saving rates of households are lower, indebted households may default with a higher probability since they can accumulate less money.

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