

# 11 Credit-driven business cycles in an agent-based macro model

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## Introduction

This chapter addresses the crucial issue of the interplay between credit and business cycles in an economy by means of an enriched version of the agent-based model and simulator Eurace. Eurace is a fully specified agent-based economic model, which includes different types of agents and integrates different types of markets (Cincotti et al., 2010, 2012; Raberto et al., 2012; Teglio et al., 2012, 2015). Agents include households, which act as consumers, workers, and financial investors; consumption goods producers as well as a capital goods producers; banks; a government; and a central bank. Agents interact in different types of market, namely, markets for consumption goods and capital goods; a labor market; a credit market and a financial market for stocks and government bonds. Except for the financial market, all markets are characterized by decentralized exchange with price-setting behavior on the supply side. Agents' decision processes are characterized by bounded rationality and limited information gathering and computational capabilities (Tesfatsion, 2003; Tesfatsion and Judd, 2006); thus, agents' behavior follows adaptive rules derived from the management literature about firms and banks, and from experimental and behavioral economics of consumers and financial investors. Furthermore, the Eurace model presented in this chapter has been enriched by a housing market where households are allowed to buy and sell homogeneous housing units and can borrow mortgages from the banking system.

The Eurace model is particularly suited to investigate the interplay between credit and business cycles as it fully addresses the endogenous nature of credit in modern economies (McLeay et al., 2014; Werner, 2014). The dynamics of credit in the model depends on the supply side by the banking system, which is constrained by Basel capital adequacy regulatory provisions (Blum and Hellwig, 1995; Santos, 2001), while, on the demand side, credit depends on firms' liquidity needs to finance production activity and, in the enriched version of the model presented here, also on households' mortgage demand for house purchases.

Previous results pointed out a dependence of real economic variables, such as gross domestic product (GDP), unemployment rate, and aggregate capital stock, on the amount of credit in the economy that was exogenously controlled by the value of banks' capital adequacy ratios (Raberto et al., 2012; Teglio et al., 2012).

This dependence varied significantly according to the chosen evaluation horizon. In general, regulations allowing for a high leverage of the banking system, i.e., banks' low capital ratios, tended to boost the economy in the short run, while resulting in chains of bankruptcies and economic depression in the medium and long run. On the contrary, a tighter regulatory framework of capital ratios was shown to provide a slower growth rate in the short run but a higher and less volatile medium- and long-term growth. In this study, we further investigate the role of credit in the economy by considering the additional source of endogenous credit-money creation given by households' mortgage demand for house purchase. To this purpose, considering also their recognized relevance for the economy (Muellbauer and Murphy, 2008), we have designed a housing market and a mortgaging mechanism in the Eurace agent-based macroeconomic model.

Despite its acknowledged importance for financial stability, the literature provides only a few agent-based models of the housing market. Furthermore, in most of these models, the main focus is the market mechanism and price formation, while the housing market is standalone and does not interact with the rest of the economy. In particular, the model by Gilbert et al. (2009) consists only of sellers, buyers, and real-estate agents, while households' income as well as other variables are provided exogenously. The study by Ge (2014) shows that a loose debt-to-income constraint for households leads to a high volatility of housing prices; however shocks to the model are again exogenously given. The model by Axtell et al. (2014) is specifically tailored for the housing market in the city of Washington, DC. The model has a micro-level focus on households' real-estate purchasing behaviors and is able to generate a housing bubble of approximately the same size as occurred earlier in Washington. Finally, Erlingsson et al. (2014) developed a housing market model integrated within a real economy and pointed out the relevance for both housing bubble formation and economic stability of the maximum amount of debt service-to-income ratio allowed to households.

The remainder of the paper is organized as follows. The next section gives an overview of the Eurace housing market model, followed by a presentation and analysis of the computational experiment results, and lastly we outline the conclusions and the future directions of research.

### **The Eurace model**

In this study, we have enriched the original Eurace model by introducing homogeneous housing assets, mortgage lending, and a housing market into the artificial economy. The new modeling features introduced in this study are described in the following section.

The original Eurace model has been extensively described in the Appendix of Teglio et al. (2015). It is worth remembering here that every agent in Eurace is described by a double-entry balance sheet that reports agents' assets and liabilities. Table 11.1 presents the balance sheet entries of the different agent types populating the model, including the new entries introduced in this study, i.e., housing units and mortgages. Balance sheet entries can be regarded as the state

variables of any agent and the state of the Eurace economy can be described as the whole set of the balance sheet variables of any agent along with the prices formed in the different markets. The dynamics of balance sheet variables is determined by agents' plan and the resulting interaction among different agents in the relevant markets (see Teglio et al., 2015, for further details). The balance sheet approach to agents' modeling allows us to check the consistency at any time step between stocks and flows in the model, both at the level of the single agent and at the aggregate one. We believe that this is a critical feature in particular in a model where the creation/destruction of the endogenous money stock plays a crucial role in determining economic activity.

A simulation time step can be considered as a business day and is characterized by financial market operations, i.e., the trading of stock shares and government bonds; however, agents' economic planning and actions occur with a periodicity set at multiples of the elementary time step, i.e., 5 business days (say a week), 20 business days (say a month), or even 240 steps (say a year). For instance, the housing market is active once a month, households set their consumption budget on a monthly basis but make purchases with a weekly periodicity, firms' decision about production, hiring, pricing, investments, and financing are made on a monthly basis but are asynchronous, i.e., each firm is characterized by a particular day of the month when it is supposed to take its decisions. Finally, at the beginning of every month, the Central Bank sets the policy rate and the government issues an amount of government bonds to cover its liquidity needs; tax rates instead are adjusted on a yearly basis according to the predefined fiscal policy.

*Table 11.1* Balance sheets of agents populating the Eurace economy

<i>Agent</i>	<i>Assets</i>	<i>Liabilities</i>
Household	Liquidity Stock shares portfolio Government bonds Housing units	Mortgages Equity
Consumption goods producers	Liquidity Capital goods Inventories	Debt Equity
Capital goods producers	Liquidity	Equity
Bank	Liquidity Loans Mortgages	Deposits Standing facility with the Central Bank Equity
Government	Liquidity	Outstanding government bonds
Central Bank	Liquidity Loans to banks Government bonds	Outstanding fiat money Deposits Equity

**The Eurace housing market**

This extended version of the Eurace model integrates a housing-estate market into the Eurace artificial economy and enables us to explore the role of housing market and mortgage lending within the economy and their impact on business cycles. Households and banks are the players in the housing market; households are endowed with homogeneous housing units that they can trade among themselves; banks can grant mortgages to households under their request to allow the buying of housing units in the case that households' liquidity is not sufficient.

The main features characterizing the Eurace housing market that have been introduced in this study concern: (i) households' seller and buyer behaviors in the housing market; (ii) house-pricing mechanism; (iii) households' mortgage requests and banks' mortgage lending behavior; and (iv) households' mortgage fire sale and default conditions. Figure 11.1 presents a scheme of Eurace components, including the new one related to the housing market.

Households' decision making in the housing market is mainly subject to random behavior, as we wanted to focus our attention more on the credit aspects of the housing market, and their impact on the economy as a whole, than on the behavioral ones. In particular, the parameter  $\Phi$  sets the probability for each household to be active in the housing market on the first day of each month. Furthermore, any household, if randomly selected to be active, can assume the role of buyer or seller with equal likelihood. However, we also consider the case where a household is financially distressed, i.e., facing mortgage payments (interests + principal) higher than a given fraction  $\theta_{fs}$  of income<sup>1</sup> (labor + capital), where both mortgage payments and income refer to the last quarter. In this case, say fire sale case, we stipulate that the household enters the housing market to

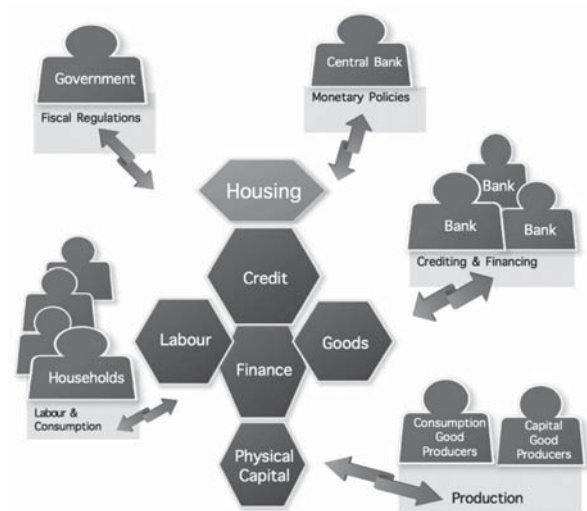


Figure 11.1 Overall components of the Eurace model with the housing market.

sell one housing unit at a discounted price with respect to the last average market price, in order to increase the likelihood of a transaction and then reduce the mortgage burden as well as the debt service.

The housing market is a posted-price market, where prices are set by suppliers and exchange is decentralized. Households can sell or buy one housing unit at a time. If a household is randomly selected to enter the housing market with a seller role, then that household posts one housing unit for sale at a price higher than the previous average market price by a percentage value which is a random draw uniformly distributed between 0 and  $\varphi_{up}$ . The rationale behind this modeling feature is that households which are randomly selected for the seller role do not have any particular necessity to liquidate their housing units and therefore are willing to sell only if they can realize a small random gain with respect to the latest average housing market price. Conversely, as anticipated in the previous paragraph, if a household enters the market with a seller role because financially distressed (fire sale case), then in order to facilitate liquidation, we assume this household posts one housing unit for sale at a price lower than the previous average market price by a percentage value which is a random draw uniformly distributed between 0 and  $\varphi_{down}$ .

Households that have been randomly selected as buyers are randomly queued and in turn select to purchase the cheapest available housing unit. A transaction takes place at the posted sale price if the household is able to get a mortgage from a bank to cover the entire value of the house. For the sake of simplicity, we assume that all granted mortgages are characterized by a loan-to-value ratio equal to 1; therefore households do not use their liquidity when buying a housing unit but just money borrowed from a bank. This modeling feature has been chosen in order to avoid direct and simultaneous interactions of the housing market purchasing behavior with saving and investing decisions in the financial market.

Where a transaction takes place, the selling agent repays to the bank the mortgage associated with the sold housing unit. The housing market session closes when all buyers had their turn or there are no more houses for sale. A new housing price is then computed as the average of realized transaction prices.

Banks can provide variable-rate mortgages to households; the annualized mortgage rate is determined on a monthly basis as a mark-up on the rate set by the Central Bank. Households are due to reimburse the mortgage over a period of 30 years through monthly mortgage payments which include both the interest and the principal instalment. Principal instalments for each mortgage are constant over the repayment period and are computed as a ratio between the initial mortgage amount and 360, i.e., the mortgage duration in months. Monthly interest payments are determined by the outstanding mortgage principal and the annualized mortgage rate divided by 12, i.e., the number of months in a year.

Banks, whenever they receive a mortgage request by a household, assess the household capability to afford mortgage repayments by comparing the household's net income (both labor and capital) earned in the last quarter with the household's expected<sup>2</sup> quarterly mortgage payments, including both old

outstanding mortgages and the new requested mortgage. Banks grant the requested mortgage only if the ratio between expected quarterly mortgage payments of the household and latest net quarterly income is lower than or equal to a pre-determined threshold, which is called debt service-to-income ratio.

### Computational results

A number of preliminary simulations have been performed with the Eurace artificial economy populated by 3,000 households, 50 consumption goods producers, one capital good producer, one government, three banks, and one Central Bank. The economy has been simulated for 30 years and 20 different seeds of the pseudo-random number generator have been considered. Due to the necessity for high computational power, the experiments are performed on a 64-node Linux cluster. The values of the main parameters related to the housing market are reported in Table 11.2. Concerning the values of the parameters used in the whole model, we refer to the same value used and reported in Teglioni et al. (2015).

We show in this section some preliminary results which give insight into the role of mortgage loans in the Eurace artificial economy. In order to consolidate our findings, further and deeper investigation is needed.

Empirical evidence points out that growth in loans to non-financial corporations tends to lag behind real GDP fluctuations, while loans to households tend to lead GDP growth (ECB Bulletin, 2013). Occasionally they are observed to follow a coincident pattern relative to GDP growth. We observed similar patterns in our experiments. Figure 11.2 displays a sample growth pattern over time. GDP vs. loan growth rates are shown in the upper panel and GDP vs. mortgage growth rates are plotted on the lower panel. The time series plots suggest that growth in mortgages in the economy leads to a growth in GDP which is followed by a growth in loans to firms.

Table 11.2 Values and description of parameters used in the housing market model

<i>Symbol/acronym</i>	<i>Description</i>	<i>Value</i>
$\Phi$	Probability for each household of being active in the housing market	0%, 50%
$\varphi_{up}$	Sale price offers: maximum price percentage increase	2.5%
$\varphi_{down}$	Fire sale price offers: maximum price percentage decrease	5%
$\theta_{fs}$	Fire sale threshold	0.6
$\theta_d$	Mortgage default/write-off threshold	0.7
DSTI	Debt service-to-income ratio	0.5



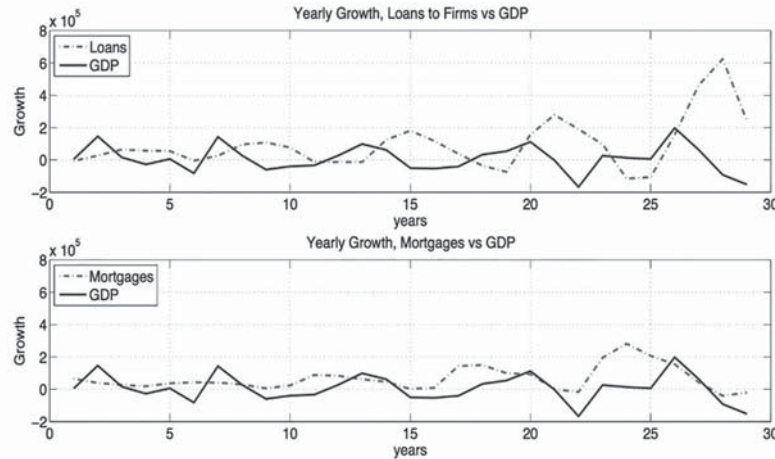


Figure 11.2 Growth in gross domestic product (GDP), loans, and mortgages within the Eurace artificial economy

In the current simulations, as discussed in previous sections, loan-to-value ratio is 1, which means that any housing transaction causes an injection of money in the economy whose size is equivalent to the nominal value of the housing unit. However, it should also be noted that households' financial credibility is checked according to different eligibility criteria prior to the release of the mortgage loan. In a way, the amount of mortgage in the current model follows empirical patterns of money supply in an economy. The lagging pattern of loans to firms over the business cycle may suggest that during recoveries, firms first finance investment expenditure using their internal funds, as cash flows improve during a recovery, and only later do they seek external financing. On the other hand, it may also suggest that during recessions the reduction of their equity capital prevents banks from granting credit to firms. The lead of mortgages suggests that mortgages function as injection of liquidity to households' consumption budget, and hence an increase in demand, production, and GDP growth in the system. This, in turn, increases demand for investment by producers, which leads them to request more loans from the banking sector. Overall, what we observe is a pattern of systematic responses, where money creation via mortgages is answered by a growth in GDP and later an increase in loan requests for further investment in productions.

The impact of money injection into the system via mortgages is further depicted in Figures 11.3 to 11.5, where we compare the different paths observed for the main monetary and real economic variables in the cases of both absence and presence of a housing market and mortgage lending. The two cases are controlled by the value of the parameter  $\Phi$  which sets the probability for households to be active in the housing market; where  $\Phi = 0.0$ , we have no transactions in the market and

therefore no mortgage requests and then lending to households by banks, while in the case of  $\Phi = 0.5$ , where on average half of households are active as buyers or sellers in the market, we have a relevant transaction and mortgage-lending activity. Furthermore, in Table 11.3 we present our results averaged over 20 seeds of the pseudo-random number generator.

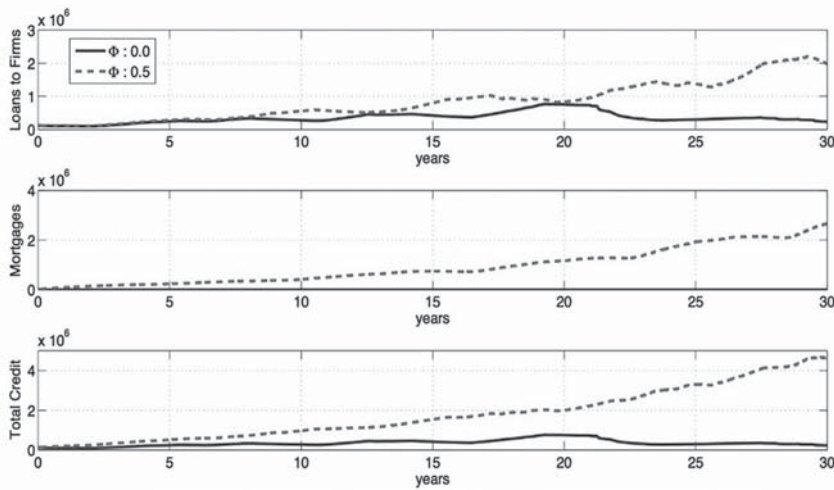


Figure 11.3 Loans to firms, mortgages to households, and total credit in Eurace artificial economy without mortgages (solid blue line —) and with mortgages (dashed red line - -).

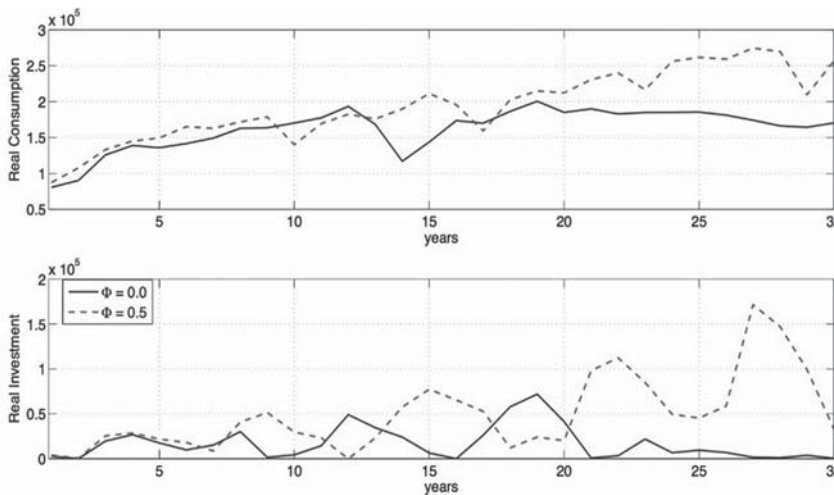


Figure 11.4 Real consumption and real investment in Eurace artificial economy without mortgages (solid blue line —) and with mortgages (dashed red line - -)



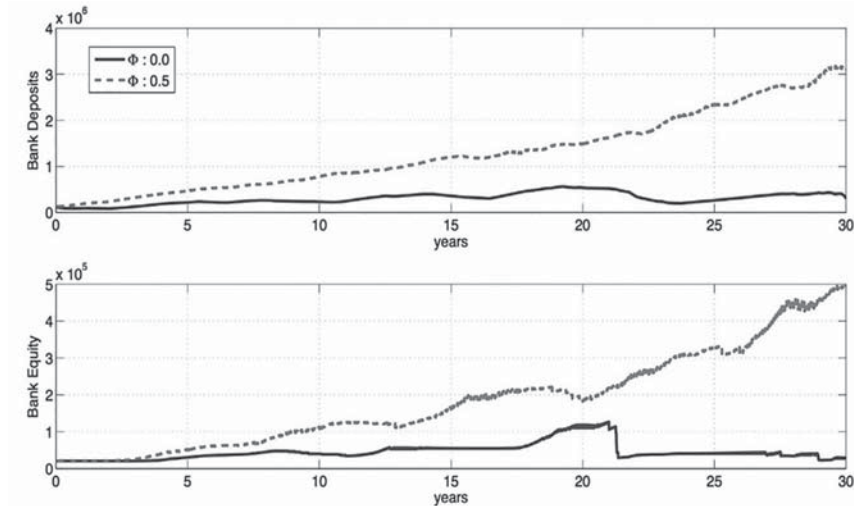


Figure 11.5 Bank deposits and bank equity of Eurace artificial economy without mortgages (solid blue line —) and with mortgages (dashed red line - -).

Table 11.3 Simulation results for the Eurace artificial economy with and without the housing market. The values are reported as a percentage (%) and are computed as ensemble averages over 20 different seeds (simulations) of time averages over any single seed (simulation). Standard errors are shown in parentheses

	Without mortgages ( $\Phi = 0.0$ )	With mortgages ( $\Phi = 0.0$ )
Real GDP growth	3.38 (0.08)	3.85 (0.10)
Real consumption growth	2.93 (0.19)	3.07 (0.08)
Real investment growth	6.09 (1.29)	9.74 (0.29)
Total credit stock growth	6.95 (1.22)	9.93 (0.08)
Unemployment rate	7.07 (1.00)	6.52 (0.01)
Money wage growth	6.51 (0.44)	7.28 (0.06)
Bank equity growth	7.13 (0.67)	9.87 (0.17)

In the simulation scenario where mortgaging is active ( $\Phi = 0.5$ ), it is shown that the additional mortgages create new money, raising households' consumption and firms' investments (Figure 11.4). The impact of money creation via mortgages can be observed by higher growth rates of wages and bank deposits as well as at banks' equity. Each one of these indicators has grown faster after having extended the artificial economy with a real-estate market. Comparative trends in consumption and investment are further shown in Figure 11.4. A clear increase in consumption as well as in investment is observed.

These results should be attributed to the higher endogenous money creation via households' mortgages (Figure 11.3). Furthermore, when the mortgaging mechanism is activated, the model produces a lower unemployment rate and higher wage, as presented in Table 11.3.

The presence of mortgage lending gives advantages to the banks through an increase of bank equity and bank deposits, as shown in Figure 11.5, which in turn eases the access to credit for firms' investment, as shown in Figure 11.4. Overall, results suggest that introduction of mortgages contributes to the macroeconomic system by increasing real consumption, real investment, wages, bank equity, bank deposits, and reducing the unemployment rate. This result is coherent with empirical facts on the global economy where real-estate markets play a significant role in driving an economic booms (Catte et al., 2004).

### Concluding remarks

We have presented a preliminary study on the effects of the addition of a housing market along with mortgage lending in the Eurace model. Mortgages are intended to finance households' purchase of housing units, and represent a new endogenous money creation device, along with loans to firms. We have shown that the model is able to reproduce the basic stylized facts that describe the relation between loans, mortgages, and GDP. We have also shown that the introduction of mortgages into the economic system tends to amplify the business cycle and to improve the performance of the economy. However, these generic results should be tested using more varied economic scenarios and, in particular, they should be tested under different regulation schemes. Our intuition is that there is a trade-off between higher growth and economic stability, depending on the amount of mortgages that are allowed to be channeled into the economic system. Further studies will focus on these aspects.

### Acknowledgments

The authors acknowledge EU-FP7 collaborative project SYMPHONY under grant no. 611875.

### Notes

- 1 Where the ratio between quarterly mortgage payments and income is higher than the threshold  $\theta_d$ , then the household undergoes a mortgage-restructuring process with a consequent loss on the equity of the crediting bank.
- 2 In estimating expected mortgage payments, banks make the parsimonious assumption to consider constant interest rates in the future.

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