The Hidden Soul of Financial Innovation: An Agent-Based Modelling of Home Mortgage Securitization and the Finance-Growth Nexus Economic Modelling

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Abstract: This paper investigates the interaction between financial innovation and securitization. To this end, it introduces the rate of financial innovation (RoFIN) as an endogenous variable in an Agent-Based Model (ABM) set up and studies its interaction with the non-fixed fraction of securitized mortgage loans. RoFIN is able to capture financial agents' business decisions on using financial innovation tools, processes and services, such as the home mortgage securitization process. In the aftermath of the 2007-2009 financial and economic crisis it has been argued that financial innovation and securitization have increased macro/finance systemic instability via, for example, non-linear two-way spillovers between the financial system and the macroeconomy. The ABM model proposed enables the capture of these dynamics. High values of RoFIN (i.e. exceeding the threshold of 50%) make financial innovation become harmful for the economic system, leading to a switch from a virtuous to an unvirtuous business cycle. When RoFIN reaches 90%, the numerical simulations come close to the macro/finance dynamics observed before and during the financial crisis. Given its potential role in triggering financial and economic instability, RoFIN is of interest for financial regulation and supervision. How this endogenous variable may be influenced by means of operational variables under the control of policymakers remains a subject for future research.

March 31st 2017

Professor Sushanta Mallick
Economic Modelling

Dear Professor Mallick,

Further to your e-mail of January 23rd 2017, I have now revised my paper "The Hidden Soul of Financial Innovation: an Agent-Based Modelling of Home Mortgage Securitization and the Finance-Growth Nexus" (ECMODE-D-16-00482R1). I have undertaken a thorough and comprehensive second revision, taking into account all the detailed comments and suggestions made by the referees and yourself. I provide in the attached file a response to each of the comments made by the referees, and I explain the contribution better. In general, the paper now provides a more accurate abstract, which stresses the contribution, clarifies the difference between the concepts of 'financial innovation' and 'rate of financial innovation', and highlights the critical level of 'rate of financial innovation' which creates financial instability and affects economic growth. The introduction has been integrated with the literature cited by the second Referee, and a brief introduction to the original ICEACE model is now available in Appendix 1, following the suggestion of the first Referee. A new and more detailed list of highlights has also been provided. Finally, the acknowledgements have been updated, and the paper has been proofread.

For a detailed explanation of the changes made, please see the attached response to the comments.

Thank you for your attention and consideration of this manuscript.

Yours sincerely

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Summary of the main changes to the paper

I thank the Editor and both Referees for their second review, which has helped transform and improve the paper further.

To the Editor

1. **Regarding the contribution, in line with the point raised by Referee 2 (see point 1, p. 3), the Editor believes that the paper is focused on the already well-known topic investigated in the literature, which argues that excessive innovation is bad for the finance-growth nexus and that too much financial innovation created the crisis.**

I thank the editor and Referee 2 for their comments on this point, and wish to clarify the novelty of the paper with respect to previous studies on this topic.

First, the paper makes a clear distinction between the concept of financial innovation and the introduced concept of rate of financial innovation (RoFIN). RoFIN, as explained in the paper (see pp. 3, 9-10 and the revised version of the abstract) captures financial agents' business decision on how to use financial innovation tools, processes and services (speculative or non-speculative). RoFIN behaves as an endogenous variable of financial innovation. This distinction is based on the assumption that financial innovation on its own cannot be blamed for generating financial instability and eventually financial crisis. "Innovation" in principle is a positive development, which promotes progress in the economic system. However, progress (or innovation) can be disruptive (see Disruptive Innovation Theory, Christensen and Raynor, 2003. For an excellent review, see Yu and Hang, 2010); in particular, if there are rapid diffusion and adoption of the innovation (Sinkey, 1992). According to Mullineux (2010) and Roger (2003), widespread adoption – the relative speed with which an innovation is adopted by the agents of the system - exploits "network effects," encouraging the underpricing of risks in order to gain "first mover" advantage and to increase profits. Rogers (2003) explains that some aspects of the diffusion of innovation have a systemic nature, hence the analysis cannot be limited only to the study of the individual behaviour of agents. More specifically, with regard to the financial system, Mullineux (2010) argues that rapid and widespread adoption of financial innovation is promoted to generate higher profits in the financial industry. As a result, this generates a tendency to underprice risks. In fact, securitization (which is analysed in this paper) on its own cannot be necessarily defined as a disruptive innovation. However, securitization combined with asset underpricing (in other words, the business model applied and its evolution; for example, the Subprime or Junk Bond markets) creates financial instability with an ensuing impact on the real economy. Therefore, the business decisions (and their development over time) of the financial agents operating in the financial system are crucial. These business decisions lead the level of development of the financial innovation tools, processes and services within the financial system. They govern the speed at which financial innovation spreads through the market and starts to be adopted widely by each level of financial operators. The wider the adoption and diffusion of financial innovation from the high end to the low end of the market, the higher the risk of underpricing assets. Hence, this can result in disruptive innovation, leading to destabilising effects on the financial and economic systems.

More specifically, the model presents a non-fixed securitization ratio at the bank level which changes over time and there exists a 'max securitization ratio' which represents the financial system's maximum capacity to securitize assets (see sections 4 and 5 of the revised paper). However, what governs the dynamics and changes the securitization ratio here, as well as loosening the credit standards mirrored by the variable Beta (see section 4, p.10), is the RoFIN and not just the securitization (so the financial innovation in itself).

The main contribution of the paper is that it can clearly show something more interesting and relevant for policy purposes: the RoFIN threshold level. According to the simulation results, when RoFIN exceeds the level of 50% it begins to make financial innovation become harmful for the economy. However, the model can also show that with a RoFIN level of under 50% (in the ABM exercise, 40%), financial innovation actually has a positive impact on the economy and promotes growth. When RoFIN reaches 90% (with a beta of 0.45) the ABM model is able to reproduce dynamics close to those observed before and during the financial crisis (see previous 'response to comments', Referee 2, point 5, p.5 for the explanation regarding the choice of the numbers of RoFIN in order to compute Beta).

2. **The Editor asks whether I can show in the paper a clear threshold level of financial innovation beyond which it would be harmful for growth. If yes, he suggests highlighting it in the abstract and in the highlights.**

Following the explanation provided at point 1, the abstract and highlights have been revised.

3. **The Editor invites me to make sure that the paper is error-free in the next version.**

The paper has been double checked with the proofreader, and it is now error-free.

To Referee 1(#2)

1. **The Referee feels that it may be better to introduce a formal model part with a strong mathematical flavour to explain the securitization asset clearing process in the whole economy. Therefore, he suggests inserting a formal introduction to the ICEACE model in the paper.**

An introduction to the original version of the ICEACE model has been provided in Appendix 1. The main text refers to this appendix at the beginning of Section 2, p. 6. There are two reasons why I chose to insert the introduction to ICEACE as an appendix: 1) to avoid increasing the length of the main text; and 2) to keep the reader focused on the incremental exercise, as explained in Section 2, p. 6.

2. **The Referee believes that the monetary environment in the model does not change because of the presence of a fund with fixed liquidity. He asks the author to defend this point very well and suggests doing more computational exercises with variable funds.**

I apologise to the Referee because I did not specify an important aspect in my previous 'response to comments' to the point raised here. The Fund for modelling purposes is simply initialized as a fixed exogenously given liquidity when the fund initial balance sheet is set up (see code in Appendix 4 - III, IV, V- pp. 41-42). Moreover, the model assumes that the fund is liquid in the condition of normality. However, this does not mean that the liquidity available in the Fund does not change over time. As explained in my previous 'response to comments', in the model a securitization target for the financial

system operates, which is adjusted to the fund liquidity available at each point in time. In fact, the model considers the case that securitization demand can be rationed because of lack of liquidity in the Fund (for a more extensive explanation, see the previous 'response to comments', Referee 2, point 4, p. 4 and the revised version of the paper, section 5, p. 11-12).

With regard to the definition of the monetary environment in the model, I assume that the monetary channel transmission is governed by the Central Bank (one of the agents of the ABM model; see Appendix 1, p. 34). The Central Bank has two main roles in the model. First, it sets the interest rate according to a Taylor rule, taking into account both unemployment and the rate of inflation (this implies that banks set mortgage rates based on the CB interest rate). Second, the Central Bank acts as a liquidity provider for the banking sector (this also implies that CB liquidity is always more costly compared to the liquidity obtained from the Fund through the securitization process).

Finally, in previous experiments, I did the exercise suggested by the Referee, and incresed the level of liquidity of the Fund balance sheet initialization, which proved to be irrelevant for the overall outcomes of the simulations. Reducing the initialised liquidity of the fund below the capacity of the financial system does not make sense, on the assumption that the fund in the condition of normality is always liquid.

To Referee 2(#3)

1. **The Referee, as well as the Editor, is concerned about the contribution. He feels that the contribution is small and suggests shortening the length of the paper and presenting the results of the ABM exercise conducted in a simple and concise manner.**

See the explanation provided above to the Editor about the contribution (point 1, p. 1). The request of the second Referee to shorten the paper further conflicts with the request of the first Referee and Editor to add explanations, which I have done in the attached revised paper. The main changes are listed in the covering letter.

Finally, I took into account the references provided by Referee 2, whom I thank, because these helped me to improve the literature review (see Introduction, p. 2).

References

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Highlights

1. The paper introduces the rate of financial innovation (RoFIN) as an endogenous variable of financial innovation.

2. RoFIN captures the financial agents' business decisions on how to use financial innovation tools, processes and services.

3. An Agent-Based modelling approach is applied to study the interaction between RoFIN and the mortgage securitization process.

4. The study postulates the existence of two business cycle scenarios: virtuous and unvirtuous.

5. The numerical simulation shows that a threshold of between 50% and 90% makes financial innovation become harmful for economic growth.

6. RoFIN is of interest for financial regulation and supervision.

The Hidden Soul of Financial Innovation: an Agent-Based Modelling of Home Mortgage Securitization and the Finance-Growth Nexus

Abstract

This paper investigates the interaction between financial innovation and securitization. To this end, it introduces the *rate of financial innovation (RoFIN)* as an endogenous variable in an Agent-Based Model (ABM) set up and studies its interaction with the non-fixed fraction of securitized mortgage loans. *RoFIN* is able to capture financial agents' business decisions on using financial innovation tools, processes and services, such as the home mortgage securitization process. In the aftermath of the 2007-2009 financial and economic crisis it has been argued that financial innovation and securitization have increased macro/finance systemic instability via, for example, non-linear two-way spillovers between the financial system and the macroeconomy. The ABM model proposed enables the capture of these dynamics. High values of *RoFIN* (i.e. exceeding the threshold of 50%) make financial innovation become harmful for the economic system, leading to a switch from a virtuous to an unvirtuous business cycle. When *RoFIN* reaches 90%, the numerical simulations come close to the macro/finance dynamics observed before and during the financial crisis. Given its potential role in triggering financial and economic instability, *RoFIN* is of interest for financial regulation and supervision. How this endogenous variable may be influenced by means of operational variables under the control of policymakers remains a subject for future research.

1   Introduction

The need to understand the finance-growth nexus and the role of financial innovation within it, in particular with regard to the process of endogenous money/credit creation, has led to this research paper. The modern financial system is complex, globalized and highly technologically advanced, characterized by financial innovation and speculation (Bezemer, 2012; Nguyen, 2014). Econometric

papers such as those by Amore et al. (2013) or Beck et al. (2016) show that there exists a strong connection between finance and technological innovation. Studies focusing on understanding the U.S. subprime mortgage crisis, such as those of Mian and Sufi (2009), Keys et al. (2010) and Dell'Aricchia et al. (2012), have found evidence of the linkage between the securitization process and lax lending standards. Mallick and Sousa (2013) show how changes in financial distress conditions can explain output fluctuations. Others have clearly highlighted the existence of the finance-growth nexus (e.g. Greenwood and Jovanovic, 1990; Bencivenga and Smith, 1991; King and Levine, 1993; Levine, 2005; Greenwood et al., 2010; Creel et al., 2015) and demonstrated that financial innovation combined with deregulation has on one hand fostered a rapid development of the financial system, but on the other has increased financial instability and complexity over time (e.g. Brunnermeier and Sannikov, 2014; Grydaky and Bezemer, 2013; Bezemer, 2012; Dosi et al., 2013; Palley, 2011). This has contributed to a shift from the OTH (Originate-To-Hold)[1] model to the OTD (Originate-To-Distribute)[2] model (Berndt and Gupta, 2009; Bord and Santos, 2012; Scannella, 2011). The latter, characterized by the use of financial innovation instruments and trading strategies to promote credit risk transfer, triggers the creation of multi-leveraging phenomena within the financial sector. In principle, the OTD model helps to improve the diversification of risk. According to Allen and Carletti (2006), this is true only if the demand for liquidity is uniform. Otherwise, when there are idiosyncratic liquidity risk and hedging behaviours, credit risk transfer (and multi-leveraging) can become harmful to the economy. However, the empirical studies conducted to explain and understand the last financial crisis and the nexus between finance and growth mostly identify financial innovation with the securitization process, when in fact the concept of financial innovation is much more extensive.

There are few theoretical and empirical studies specifically focused on the broader concept of financial innovation (e.g. see Rousseau, 1998; Levine, 1997, 2005; Klein and Olivei, 2008; Lerner and Tufano, 2011). However, these studies define and model financial innovation in a way that overlaps with the concept of innovation used in the manufacturing sector. They focus their attention on a more generic and not very well identified concept of financial innovation, analysing its impact on financial depth and its resulting effects on economic growth. Therefore, the role of financial innovation still remains unclear and not well modelled.

The paper contributes to the ongoing discussion in the literature on financial innovation. In particular, it applies the concepts of 'disruptive innovation' (Christensen and Raynor, 2003) and 'diffusion and

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[1] The Originate-To-Hold (OTH) model is based on traditional bank business - collecting savings to make loans.

[2] The Originate-To-Distribute (OTD) model is the newly established financial system architecture. The OTD model makes it possible to split some activities in the value chain of mortgage and loan supply. Each financial agent can transfer risk forward to other financial agents along the chain.

adoption of innovation' (Sinkey, 1992; Rogers, 2003)[3]. Therefore, from this perspective, the paper defines financial innovation as the interaction between securitization and the more specific concept of the *rate of financial innovation.* This concept captures the level of development of financial tools, processes and services, given the financial operators' business decisions on how to make use of them (in terms of operational business decisions[4]). Is there any role played by financial innovation (securitization times the rate of financial innovation) in affecting endogenous money/credit creation? If there is, how does it impact on the finance-growth nexus?

It would appear that the link between securitization and the rate of financial innovation has yet to be investigated in the literature. The interesting paper of Leaven et al. (2015) investigates for the first time the coevolution of the interaction between finance and technology and introduces the concept of financial innovation as the 'rate of financial system improvements' in the Schumpeterian economic growth model. However, the authors are focused on analysing how the interaction between finance and technology affects the financial system screening process to fund entrepreneurs. They do not model the role of the financial system in diversifying risk and they do not provide any discussion on how exceeding certain levels of diversification (i.e. the rate of financial system improvements) can lead to asset mispricing and increasing systemic instability, which were the conditions at the heart of the last global financial crisis.

Additionally, this research assumes the existence of two temporally opposite cycles; namely, the *virtuous* and *unvirtuous* cycles. The *virtuous cycle* characterized the post-world war II period, an era of rapid progress (the golden age). Until the 1970s/80s, the economy had modest inflation rates, low unemployment rates, and rapid economic growth. In the *virtuous cycle* the presence of a developed structure of financial institutions channels high levels of savings into the productive sector, spurs investments for innovation projects in the economy and fosters a high level of economic growth. However, the technological revolution in the 1970s/80s promoted the creation of an "IT network economy", making the financial system a complex environment. The will of the financial and economic operators to diversify risk by complex financial integration of the economy was accompanied by an increasing level of indebtedness in the economy and the risk of associated emerging externalities, marking the passage from a period of prudential attitude, when debt use was careful, to a period of prosperity, when the debt exposure of all the agents operating in the economic system grew rapidly (Minsky, 1986). Therefore, the alternative perspective seems to entail an *unvirtuous cycle,* in which the growth-finance relationship is reversed into the finance-growth nexus. Part of the wealth created in the business cycle is captured and, thanks to the presence of sophisticated

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[3] Innovation can be disruptive; in particular, when there is a rapid diffusion and adoption of it. A widespread adoption – the relative speed with which an innovation is adopted by the agents of the system - exploits 'networks effects', encouraging underpricing of risks in order to gain 'first mover' advantage and increase profits (Mullineux, 2010).

[4] Operational business decisions are a collection of business rules which help to automate operational choices, such as the number of mortgages to send to the securitization process.

financial innovation tools, it is not allocated to the productive sector, but diverted into speculative channels for the financial operators' self-seeking profit interests. This bad cycle has supported the reinforcement of monopolistic financial positions (financial power concentration), which had already started in the *virtuous cycle* as a natural consequence (externality) of the development from a period of prudential attitude to a period of prosperity (Minsky, 1986). It has resulted in a financial market and political power in the hands of the financial sector. This strengthens the possibility that increasingly aggressive 'boom and bust cycles' are created over time, with wider gaps with respect to potential GDP, and a reduction in the length of time between the occurrence of one boom-bust and another.[5] The increasing level of volatility created in the business cycle makes the economy more fragile, raising the possibility of turning easily from simple financial/real shock to severe economic crises. As a consequence, business and innovation investments slow down, and the level of growth declines until, in the worst case scenario, there is a recession and negative growth (as was observed after the 2007-2009 financial crisis). Regulatory loopholes emerge, and current regulation becomes inadequate. Thus, a crisis forces re-regulation and a switch to a virtuous cycle for a certain period. However, when the financial capitalists exert new pressures for liberalization (as the length of time since the last crisis increases), the virtuous cycle gradually tends to turn bad again, as the political influence of financial capitalists and regulation laxity increases, until the next crisis erupts. Hence, more regulatory tightening will be applied, and so on. A 'regulatory dialectic' (Kane, 1977) seems to underpin the passage from one cycle to another.

Regarding the choice of methodology, this study takes into account the fact that after the global financial crisis a wide debate in the literature has questioned the reliability of the dominant paradigm in macroeconomics. Several studies have revealed the inadequacy of the mainstream macroeconomic models and the difficulties these models have encountered in proposing adequate policy solutions (e.g. see Colander et al., 2008; Kirman, 2010; Keen, 2011; Bezemer, 2011; Romer, 2016 - forthcoming). However, it is interesting to observe that, although in the literature there is a wide debate on, and relevant evidence for, the non-neutral and non-exogenous role of the financial system within the economy, the leading monetary policy analysis approach is still founded on the general equilibrium models (based on the General Equilibrium Theory - (Walras, 1874, 1877)), and the resulting complex DSGE (Dynamic Stochastic General Equilibrium) models[6] developed are still widely used by monetary authorities and governments to decide policy strategies and actions. These models and related assumptions (e.g. representative independent agents, full rationality and full information, perfect markets, etc.), provide impressive mathematical toolkits, but present artefact

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[5] ... as some of the literature has also highlighted (e.g. Koo, 2014).

[6] The DSGE models, developed by a new generation of economists such as E.S. Phelps, R. Lucas, N. G. Mankiw and others, are micro-founded general equilibrium representative agent models, able to capture non-linear dynamics. They bring together the neoclassical (Real Business Cycles) and the New Keynesian models.

elements with no clear link to reality (Verspagen, 2004), distorting the correct interpretation of phenomena such as the 2007-2009 financial crisis, and constraining the identification of the problem and its solution (Tovar, 2009). In particular, for these models the banking sector and credit creation and debt are a marginal exogenous problem that can only create temporary shocks which cannot affect the long-run macroeconomic dynamics. Moreover, the more sophisticated form of these models, represented by the DSGE models, do not produce appreciable results on capturing emergent phenomena and in modelling financial system behaviour.

Since the crisis, mainstream macroeconomists have tried to compensate for the lack of realism in their models by introducing a more detailed theoretical specification of the micro-economic foundations; in particular, with regard to the heterogeneity of the agents and financial system interactions with the economy. An interesting example is the work of Jakab and Kumhof (2015), which introduces the mechanism of banks financing themselves through money creation. However, this remains limited to the 'credit multiplier' concept at the commercial bank level, without incorporating any mechanism of securitization processes or financial innovation, and without integrating any other kind of leverage amplification mechanism.

Interest in alternative and multidisciplinary approaches has risen drastically over the last decade, as the ESRC has also highlighted in its recent call for proposals "Understanding the Macroeconomics Network Plus." Among the alternatives, Agent-Based methodology, applied to the analysis of macroeconomic dynamics, has emerged as an interesting modelling approach (Tesfatsion and Judd, 2006 ; LeBaron and Tesfatsion, 2008). ABM models consist of dynamically interacting rule-based agents. The system within which they interact can create real-world-like complexity. One of the important aspects of using ABM is that one is more focused on the robustness of the model in order to capture complexity and the emergence of phenomena, rather than being simply focussed on the steady state. Emergent phenomena cannot be understood by analysing the single parts of the system separately and then adding them up. In fact, emergent phenomena are often counterintuitive, given the nonlinear reactions to small changes in the system parameters. An ABM can or cannot generate equilibriums. However, this is not assumed ex-ante but arises as a result of the tangled agents' interactions computed by the model. The agent-based modelling approach seems to be a "better financial crisis predictor" (Bezemer, 2012), flexible and able to model financial and economic dynamics as non-deterministic and stochastic phenomena. In addition, heterogeneous agents with cognitive and adaptive capabilities are considered and characterised by non-Markovian behaviours (Bezemer, 2012). ABM can help to overcome the methodological limitations of the neoclassical-based macroeconomic models in shaping the new reality of the financial system characterized by complexity, heterogeneous and diversified agents, adaptive profit-seeking strategies, financial innovation, moral hazard and regulatory arbitrage.

The paper shows, through an Agent-Based Exercise (ABE), that the economy's financial instability resides mainly in the financial structure, where financial innovation plays a relevant role. The experiment shows clear evidence for the existence of the *unvirtuous cycle* and sheds light on the switching mechanism from the virtuous to the unvirtuous cycle led by the increasing rate of financial innovation.

The remainder of the paper is organized as follows. Sections 2 to 6 present the ABE, explaining how the experiment was implemented and presenting an analysis of the outcomes and the relative statistics. Section 7 provides some policy implications, indicating the direction for future research and the conclusions.

2   The ABM Exercise

The ICEACE (Erlingsson et al., 2014) Agent-Based model (ABM) has been chosen to conduct the ABE. ICEACE[7] is an open source ABM (http://iceace.github.io/home/) and is an excellent base for use in the present research study. ICEACE contains the main real and some of the financial variables that were at the heart of the 2007-2009 subprime crisis. In addition, the ICEACE ABM uses the stock-flow balance-sheet approach, which is a methodology introduced in ABM to test the consistency of the model, checking its solidity and economically sound foundation (Teglio et al., 2010).

An incremental modification of the main code has been made (see Appendix 4), inserting the core of what generates the unvirtuous cycle to test its existence (i.e. the securitization process and rate of financial innovation). It is not the intention of this paper to provide a review of the entire ICEACE model; instead, the paper is centered on its incremental implementation. For this reason, there follows here and in section 3 a summary of the main conceptual aspects and technical elements of the model that are needed to understand the ABE. However, a brief introduction to the original model setup is available in Appendix 1 (see also Appendices 2 and 3 for initial values and parameters). For a more extended and detailed explanation of the ICEACE modelling framework and its underlying mechanism it is recommended to refer to Erlingsson et al.'s (2014) paper.

There are other macro ABM models, such as those of Cincotti et al. (2010, 2012) and Raberto et al., (2012), both EURACE models, and of Dosi et al. (2015) and Riccetti et al., (2016), which consider heterogeneous commercial banks and investigate the evolutionary dynamics of the link between real variables and credit provision. However, these macroeconomic models are more focused on the real

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[7] The name ICEACE denotes Agent-Based Computational Economics for Iceland, founded by the Icelandic Centre for Research.

side of the economy and related shocks, concentrating marginal attention to an analysis of the financial aspects, in which financial shocks remain described as exogenous phenomena. ICEACE, instead, is mainly focused on the effects of the presence in the economy of the housing market and its central role in business cycles when mortgage defaults are manifested. Households usually apply for mortgages from banks to buy a house. If they cannot repay the debt, banks' balance sheets suffer a shock on the asset side. In particular, in the presence of outstanding shocks, the reduction in the level of granting of credits inevitably affects the real economy. The ICEACE model, as its authors explain, investigates ".... the financial aspects of the market, such as housing prices, mortgage payments, household debt, the fragility of the banking sector and the effect on the real economy through the wealth effect of housing and the credit market" (Erlingsson et al., 2014, p.4). However, in the ICEACE model there is no focus on the established OTD (Originate-To-Distribute) model of the financial system, in which financial agents are not only represented by banks. Adding the role of the rate of financial innovation and the securitization process into the model improves the ability of the financial sector to diversify risk (impacting on the banks' capital adequacy ratio and mispricing assets). As a consequence, given the reduced perception of risk and uncertainty, the financial sector eases regulation constraints and concentrates power in its hands, increasing its monopolistic positions and interfering with political power (financial market abuse). Financial market power and political power become tightly linked, boosting self-gain interests and triggering a conflict between public and private interest. Erlingsson et al. (2014, p. 24) claim that "...the volatility of GDP increases when a higher amount of credit money is allowed to enter in the economic system" and "the more you lend, the more you grow"; this is true and in line with the perspective of this paper. However, they have based their analysis on a beta value (representing the budget constraint) that sets banks' behaviour when they evaluate household capability to repay a mortgage loan before granting it. A lower beta means that the banks are careful when granting a mortgage; on the other hand, a higher beta means they grant mortgages loans more easily, even if the borrowers are riskier. They show how more permissive financial system (represented only by commercial banks) behaviour initially spurs a higher GDP growth rate and subsequently drags the economic system into deep recessions. They assume that beyond this behaviour there is a policy incentive (defined by Stiglitz, 2010, p.388 as "unbridled liberalization"), as that makes the financial system willing to increase the level of mortgages. Of course, accommodating policies play an important role in this scheme, but from another perspective that is not considered by Erlingsson et al. (2014). A more permissive policy has led to the easier promotion of the diffusion of the financial innovation tools, processes and services, facilitating access to new financial instruments and products. This has contributed to a shift from the OTH to the OTD model, as explained in the introduction, fostering the use (or abuse) of a higher beta and then increasing mortgage (and loan) lending. However, financial regulations in favour of the financial system without a technologically advanced financial transformation would not have instigated any change in the behaviour of banks in terms of creditworthiness conditions (or it would be very partial

and not relevant). What has made the difference is the increasing level of resort to financial innovation (in terms of the securitization process and rate of financial innovation) and the building up in the last two decades of what we call the *technologically advanced financial sector*. Therefore, this paper sheds light on why banks decided to change their attitude towards borrowers and what the key element is that makes them more willing to grant mortgages more easily to any risk-typology of borrowers; this key element is indeed the rate of financial innovation.

3 Agents and timing

The ICEACE modified version (see Erlingsson et al., 2014 for the original version) presents an economy constituted by households (HHs), firms (Fs), construction firms (CFs),[8] banks (Bs), a capital fund (EF), a special purpose vehicle (SPV), the government (G), and a central bank (CB). The day is the basic time step of the simulation. All the events are pooled on weekly, monthly or quarterly sequences, and they are simultaneous. Commercial banks supply loans to Fs and CFs and provide real estate mortgages to HHs. Bs collect private sector deposits from HHs, Fs, and CFs and may borrow from the CB if they have a shortage of liquidity. There is information asymmetry. Lending activity by Bs is constrained by a minimum capital requirement (Basel rules). Regarding the equity of the borrower, Fs and CFs must have positive equity to receive a loan, while HHs must fulfil a minimum equity ratio requirement (i.e. net wealth must be ≤ than a fraction φ of the total wealth[9] - see Appendix 1 for more details).

In the original version of the ICEACE model, neither investment banks nor financial innovation is examined. Therefore, the new version of ICEACE considers the Universal Bank Model, assuming that Bs play the dual role of commercial and investment banks. The commercial banks, through the SPV, operate the securitization of mortgages, pooling and packaging them into CMO (Collateralized Mortgages Obligation) derivatives. In ICEACE, Fs employ labour and homogeneous capital goods to produce homogeneous consumption goods (K and L are constant over time). The Fs are characterised by Leontief production technology. Unit production costs are the ratio between labour costs plus the debts costs for Fs to banks and previous production. Prices are set with a fixed mark-up on the average unit production costs. Based on their production plans, Fs will form their labour demand and base their expected sales on previous production. Fs are 'profit oriented' (profit maximization). No innovation or imitation investments are considered. The CFs employ labour and homogeneous capital goods to produce new homogeneous housing units. The HHs provide a homogeneous labour force to Fs and CFs, buy homogeneous consumption goods from Fs and new houses built by CFs and

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[8] In ICEACE, firms employ labour and homogeneous capital goods to produce consumption goods, whereas construction firms employ labour and homogeneous capital goods to produce new homogeneous housing units.

[9] Total wealth is the sum of housing wealth, liquid wealth, and capital fund share wealth (see Erlingsson et al., 2014, p.14).

exchange with each other their stock of housing units. The labour market is decentralised and the turnover phase is random. The G collects taxes on both labour and capital income, and pays unemployment benefits to HHs. The CB fixes the interest rate, sets the policy of standing facilities and provides loans to the G if needed. The EF accepts the equity shares of Fs, CFs and Bs and collects the dividends; it may also provide liquidity to Fs and CFs. EF shares are equally distributed among HHs. For the ABE, the EF purchases the financial products issued by the commercial banks/investment banks, providing fresh liquidity that is used by the Bs to grant new mortgages.

4   How securitization and the rate of financial innovation are implemented in ICEACE

The ICEACE model shows the balance sheets of the main economic agents present in an economy. The initialisation of the balance sheet of economic agents and other initial variables are drawn with limited degrees of freedom, setting initial conditions and parameters based on statistical data,[10] common knowledge, literature, assumptions designed to be consistent with a realistic economy, and best-guess estimates and conventions when working with agent-based models. Calibration is not the aim of the exercise. For a detailed explanation of the set of initial values and parameters of the simulation setting, refer to Erlingsson et al.'s (2014) paper[11] (see also appendices 2 and 3 of this paper for the implemented list of the general parameters and initial values used in the model). Once the balance sheet for each agent is initialised, the stock-flow balance sheet construction becomes the main tool for building the other components of the model. In particular, attention is focused here on the banks' balance sheet when the incremental ABE is made. The sum of the liquidity of firms, including construction firms, and the liquidity of households (which also incorporates mortgages taken out) are also the deposits of banks. Bank assets incorporate debts by all types of firms, mortgages granted to households and the banks' own liquidity, which is set as a ratio of the total assets. Other parameters such as 'mortgage duration' (40 years) and 'capital adequacy ratio' (0.05) are established according to Erlingsson et al. (2014) and the general literature to which they relate (i.e. Carrol et al., 2011 and Case, 2005). The 'initial capital adequacy ratio' for the single bank balance sheet initialization $\chi(0) = 10$ is the parameter used to establish the equity level. Bank debts to the central bank are used to equilibrate the banks' balance sheet, whose difference, at the end of each year, needs to be equal to 0. The added incremental parameters are the 'financial system's max securitization ratio' ($MAX\delta$), which is established at the value of [0.5] and the 'rate of financial innovation' ($RoFIN$), which is established at the values of [0.4, 0.5 and 0.9]. $MAX\delta$ represents the financial system's maximum capacity to securitize. It functions as a ceiling on the sum of mortgages the banks can securitize within

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[10] Empirical data from Statistics Iceland (statice.is).

[11] Subsection 3.1.

the financial system. This parameter is set in order to avoid the model exploding and producing misleading results (see section 5 for an extended explanation). *RoFIN* represents the business decisions on how to use the mix of financial innovation tools, processes and services. The numbers of *RoFIN* are chosen to design the simulation in a way to show the change in the financial operators' securitization propensity. The higher this propensity, the higher the resort to the securitization process.

ICEACE presents a parameter *β*, which is a fraction of a household's total quarterly net income, given the income from labour and capital owned *β(wL + wC)*. It sets the attitude of the banks towards lending. Thus, this parameter represents the banks' ability to evaluate household robustness to repay the mortgages granted. Unlike the original version of the ICEACE model, in which beta is a fixed pre-established parameter, the HH budget constraint (beta) is now a variable and considered as a function of the securitization (*β = f(S)* with *S = securitization process*). More specifically, it is related to the financial system's max securitization ratio (*MAXδ*) and the rate of financial innovation (*RoFIN*):

$$\beta\ (t) = RoFIN(t)\ MAX\delta\ (t))$$

The numbers used to obtain the different levels of beta have been set in a way to reproduce through the simulation what happened before and during the 2007-2009 financial crisis. They are also intended to analyse the range of stability and identify the ranges in which instability occurs.

5 Simulation setting

The setting agent variables in the ICEACE model simulated are: 8000 households, 125 firms, 25 construction firms, 2 banks and 2 SPVs, 1 government and 1 central bank. To generate different stochastic processes, several random seeds have been run, in order to make the simulation of the model more in line with the real world and to obtain reliable results.

ABE makes an intentionally extreme simplification of the securitization process, adapting it within the ICEACE model architecture. However, why do banks decide on securitization? The main reasons are asset risk reduction; reduction of regulatory capital requirements; the creation of new liquidity (not from deposits or the central bank) at a reduced price; and transformation of profits from interest income (by lending) in profits from commission income (by intermediation).

The first step of the ABE was to implement the main ICEACE scripts in order to replicate the relationship between finance and the real economy (the list of the scripts implemented and the main script changes are available in Appendix 4).

Explaining the ABE exercise step by step (see Table 1), the securitization process is promoted directly by commercial banks (the Universal Bank Model is assumed), which are simultaneously the Originator and Servicer[12]. At the beginning of the process, each bank creates an SPV and the securitization balance sheet is initialized (see interaction scheme in Table 1 and codes in Appendix 4). Thus, each commercial bank chooses a non-fixed fraction of credits (only mortgages for the sake of simplicity) and brings them off-balance in order to transfer them to the securitization process and thus to the SPV balance sheet.

$$\delta(t) = \frac{Mortgages\ Off\ Balance\ (t)}{Tot\ Mortgages(t)} = Securitization\ Ratio(t)$$

In the original ICEACE model, the banks' income statements are computed without differentiation between loans and mortgages. In the incremental experiment with securitization, this differentiation is made because only the mortgages are securitized. In addition, the securitization ratio depends on the fund liquidity available; hence, the securitization demand might be rationed. The total assets of each bank will be reduced by the bank off-balance quantity (percentage of credit sent to the securitization process). Therefore, there will be an important impact on the calculation of the 'capital adequacy ratio' ($\varphi(t) = Equity(t)/Tot\ Credit\ Exposure(t)$), which is the fraction of risk that a bank is allowed to take within a given time step, compared to its own liquidity. Hence, the capital required can be reduced to $\varphi(1-\delta)Asset(t)$ (given that the amount $\delta Asset(t)$ is the minimum capital required to be held on the balance sheet).

The SPV transforms the credits into CMOs[13] ($\delta(t)$ = CMOs(t)) - Collateral Mortgages Obligation - and transfers/sells them to the Fund (EF). The securitization by the SPV is made at the beginning of each quarter. Simultaneously, at the beginning of each quarter banks choose the mortgages to securitize and the HH interest payments are also at this time. It is important to highlight that the SPV role is similar to a transformation platform, through which simply the mortgages off-balance pass through, becoming CMOs and being transferred to the Fund. Each bank complies with the parameter of the *Max Securitization Ratio*, which represents the financial system upper limit for securitization. The parameter of the max securitization ratio is used to set the securitization target which is needed for designing the demand side of the financial system for securitization. Therefore, having set a securitization target in the system each bank will establish the securitization ratio (the amount of mortgages to send to the securitization process). This parameter is adjusted in line with the fund

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[12] Originator in terms of mortgage origination by a financial institution (in this case the bank) and Servicer in terms of collecting monthly payments from borrowers and sending monthly payments to the Fund by the SPV.

[13] The pooling and packaging process.

liquidity available at a certain point in time. Thus, the securitization balance sheet is initialized. If the Fund does not have enough liquidity to satisfy the securitization demand, the banks cannot securitize. Therefore, there can be two cases: 1) the mortgages put off-balance to be transferred to the securitization process can be smaller than the securitization target; thus, the securitization demand rises; and 2) the mortgages put off-balance to be transferred to the securitization process can be greater than the securitization target; thus, the securitization demand is rationed (banks are rationed to create CMOs by mortgages off-balance if the Fund has a lack of liquidity). This mechanism is established in order to compensate for the fact that the model does not present a market for CMOs. The number of mortgages securitized in CMOs is always variable over time.

CMOs are transferred/sold from the SPV to the Fund in exchange for 'fresh' liquidity, which is paid through the SPV to the banks. The Fund pays (transfers) to the commercial banks an amount equal[14] to the CMOs transferred. The banks receive the mortgage payments monthly, plus the interest from the HHs, and transfer them to the Fund, which uses the flow of mortgage payments plus interest on the CMO payments to investors. Banks, the SPV and Fund balance sheets are simultaneously updated. The reduction operated on the bank assets side of the credit exposure level gives the banks the possibility of taking a higher risk exposure within a given time step, rather than what would happen if we were in a bank operativity regime without the securitization process.

Finally, the banks' earnings are reduced by the proportion of mortgages securitized. When HHs make mortgage payments to the banks, the interest flows from the banks are diverted directly to the Fund through the SPVs (see Table 1). Therefore, Fund liquidity increases to the same extent as the proportion of mortgages securitized (mortgage repayments + interest flow). Banks keep the share of earnings from the mortgages that remain on the balance sheet.

In summary, banks transfer a variable proportion of mortgages issued to the SPV, the SPV collects and transforms the mortgages (a pooling or packaging process) into CMOs and transfers these to the Fund, which receives the new CMOs and transfers liquidity to the banks through the SPV. Therefore, the banks have fresh liquidity on their balance sheets to make new mortgages and loans. Again, a percentage of the new credits issued by banks are sent to the securitization process, and so on and so forth. As a result of this mechanism the risk is pushed forward in the financial system. In this way, the commercial banks cannot only push forward risks, reducing the asset risk level (the risk of their mortgage loans not being repaid by borrowers), but they can also collect new liquidity more easily at a reduced price in order to make new credits. This process behaves like a loop, repeating itself continuously until a shock intervenes to interrupt the cycle.

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[14] To simplify, it is usually a little lower than the nominal value.

A modelling gap exists with regard to the rigidity of the scheme implemented, given the will to keep the ABE as simple as possible at this stage of the research. In addition, the securitization at this time regards all mortgages equally, without setting any risk differentiation (separation between mortgages with varying degrees of risk of not being repaid).

Table 1: Interaction Scheme of the AMB Exercise in ACEACE.
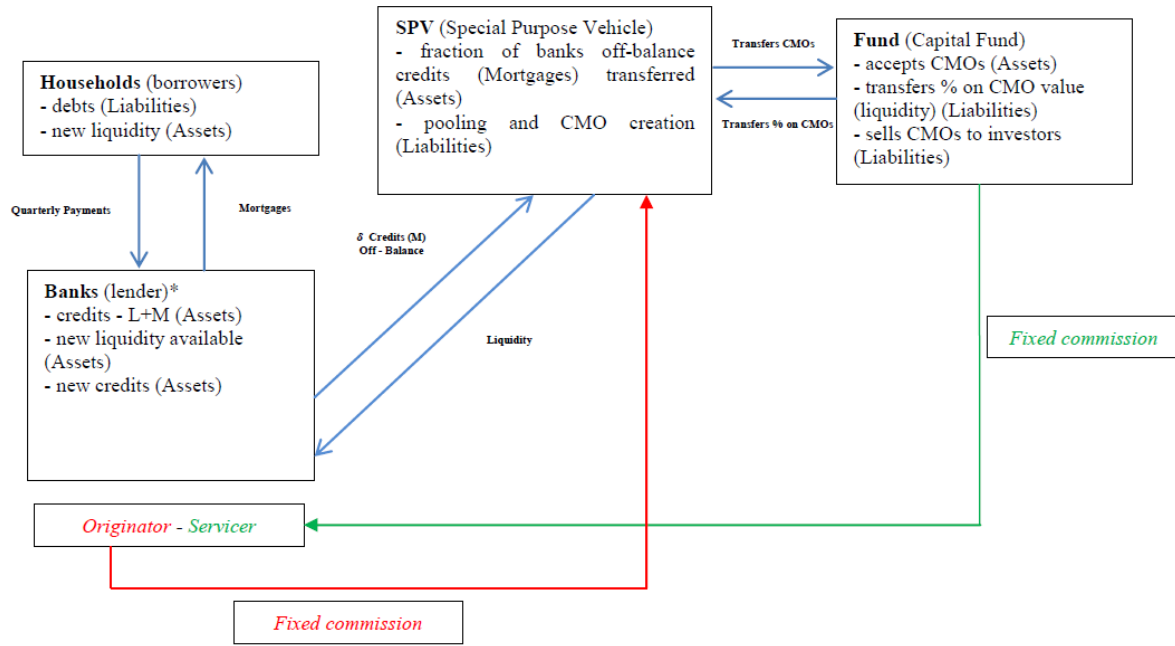
Source: Author's elaboration

5.1 Multi-leveraging

Most of the macroeconomic models in the literature are designed with a representative commercial bank and as a consequence only one bank leverage (credits/deposits) is considered. However, in the real world there are multiple leverages operating in the financial system, given the OTD architecture established (e.g. see Tan et al. (2015) for an interesting discussion on arbitrage and leverage strategies). Therefore, in ABE a simplified version of this multi-leveraging effect is reproduced, setting two leverages rather than one: $Leverage1 = \frac{Loans+Mortgages}{Deposits^b}$ represents the leverage at the commercial bank level. $Leverage2 = \frac{\sum_{b=1}^{n} TC_T}{EQ^b}$, of which TC_T is the value of the total credits transferred to the securitization process and EQ^b is the value of the bank equity, represents the

leverage operating at the investment bank level. While Leverage 1 is subject to regulation to assure that banks do not become excessively exposed, Leverage 2 is not and the commercial banks can use it to impact on their Capital Adequacy Ratio (CAR) and increase their profits. Introducing the multi-leverage mechanism operating in the financial system is indispensable for understanding how systemic risk develops and how the financial operators extract more profits from their financial activities. Therefore, it is highly desirable for the future research agenda to investigate extensively the multi-leverage mechanism and the ensuing multi-multiplicator effect generated.

5.2   The Bankruptcy Hypothesis

The bankruptcy hypothesis occurs when mortgages are not repaid by borrowers (bad debts). When HHs are unable to repay their mortgages, the Fund does not receive mortgage principal repayments or interest flows, and consequently it registers a liquidity problem, because it becomes unable to transfer fresh liquidity to the banks. In turn, the banks register a liquidity crisis, which means they increase their solvency risk until they reach the bankruptcy level. Given the stock-flow control operating in the model, banks always need to balance their assets with their liabilities. When the value of the assets is less than the value of liabilities and the capital held is not enough to cover the losses, they will become insolvent.

6   Analysis of the outcomes

Figures 1-9 show the time series of single numerical simulation runs. In Figure 1a, the aggregate real GDP (sum of the real production of firms) is plotted. The dynamics of the real GDP are associated with the different levels of βs , given the rate of financial innovation [0.4, 0.5, 0.9] and the max securitization ratio, fixed at [0.5]. The black line corresponds to $\beta = 0.2$; with this value, banks look carefully at HHs' capability to repay the loans before granting mortgages. The green line corresponds to $\beta = 0.25$ and the red line to $\beta = 0.45$. The red line, in contrast to the black one, shows the case where a high level of securitization, given the high rate of financial innovation, allows banks to loosen the credit trustworthiness conditions required to approve mortgages, increasing endogenously the level of βs . This is translated into a change in the mortgage amount issued (see also Figure 4).

Attention here is focused on analysing how the increasing rate of financial innovation raises the use of securitization tools, eventually increasing the βs value. This process creates a lowering of risk perception because the level of uncertainty of repayment default by HHs has been cut drastically. When the value of beta is high, the crisis becomes realistic, and the whole economic system falls into deep recession. In Figure 1a, the red line shows that the economy reflects a higher real GDP growth rate in the first period around years 1-3 and the second period around years 4-6. However, at a certain point the economy starts to register a deep recession around years 6-7, with associated greater

volatility, which makes the economy become more fragile. On the contrary, the black line, although it is more stable, registers a low growth rate. The green line is an intermediate case.

Running the real GDP plot for 15 periods (Figure 1b), it is possible to show clearly how the increasing rate of financial innovation in the financial system impacts on economic growth, anticipating the economic crisis and making it deeper. In fact, comparing the green line (beta 0.25) with the red one (beta 0.45), the simulation shows that the economic recession starts later in the case of the former and also the extent of the crises shows an appreciable difference.

Figure 1: a) Real GDP 7 years
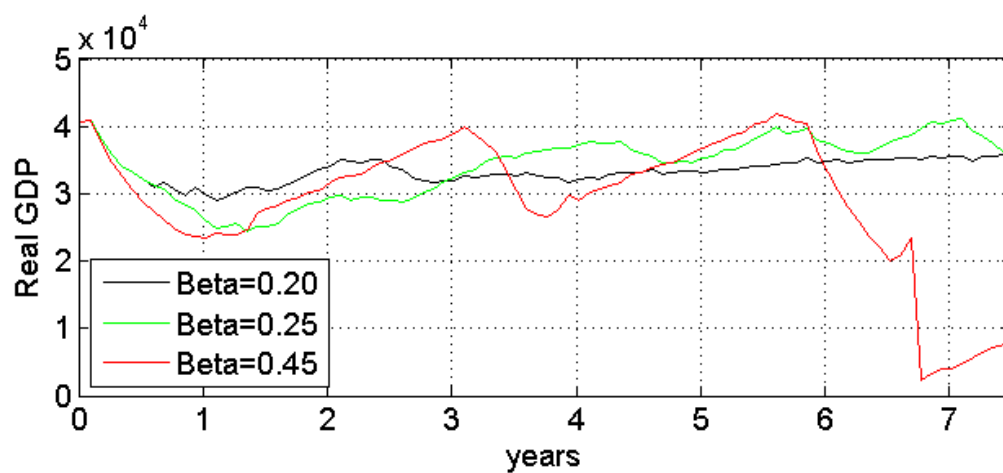
b) Real GDP 15 years
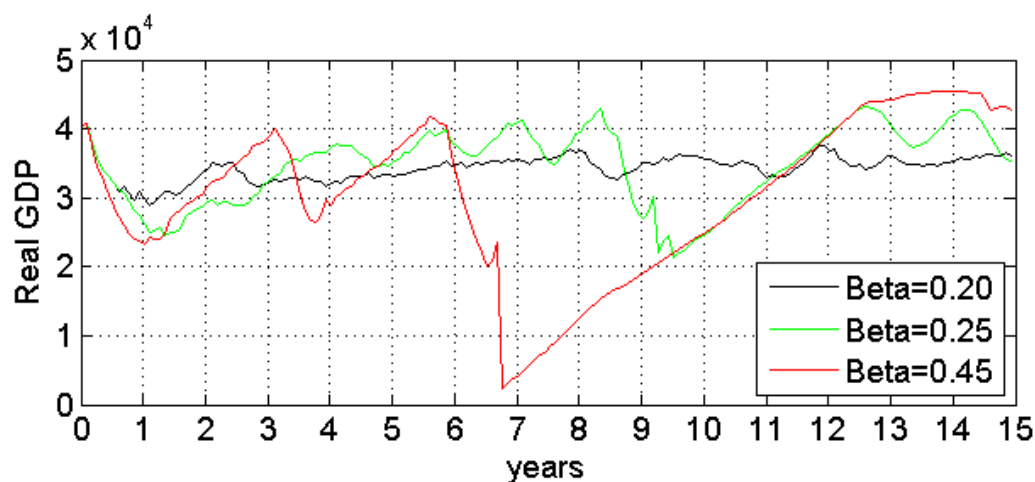
Source: Author's elaboration

In figures 2 and 3 it can be seen how a high rate of financial innovation increases the percentage of mortgages brought off-balance (δ) and introduced into the securitization process to be transformed into CMOs (see the red line, in particular, when $\beta = 0.45$). In figures 2 and 3 it can also be observed how whenever the banks shrink the level of mortgages given the occurrence of shocks, they do not reduce their level of leverage (neither leverages 1 nor 2) within the financial system when they reduce the level of lending. They restart their lending activity after confidence is restored in the economy and within the financial system at higher and higher leverage levels.

Figure 2: Mortgages Off-Balance
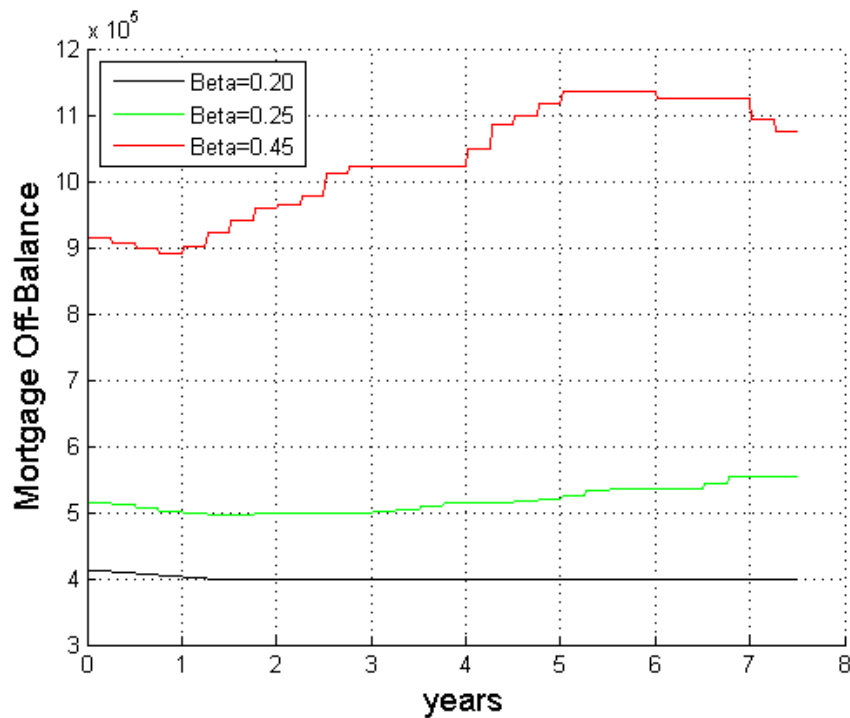
Source: Author's elaboration

Figure 3: CMOs Created and Transferred to the Fund
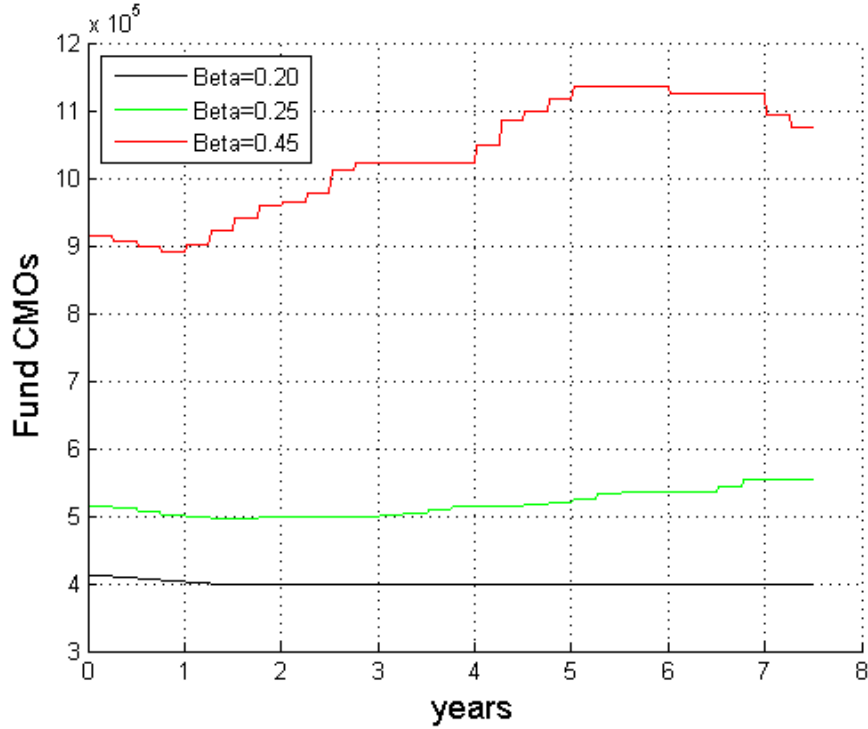
Source: Author's elaboration

Figure 4 presents an interesting result. It shows increasing aggregate HH debts, given the increase in mortgages issued by the banks ($\sum_h Mortgages^h$). This means that HHs have more money available to buy consumption goods and real estate. In addition, the mortgages issued reflect an increase in deposits. This confirms the assumption that the banks create deposits *ex nihilo* (Schumpeter, 1934; see also Ryan-Collins et al. (2011) for a clear explanation of this mechanism). If the agents (in this case HHs) in the economy choose to increase their liabilities, the banks are able to increase the size of their assets first. Only consequently will the banks register an increase on the liabilities side (deposits) and not vice versa (see Figure 6). Therefore, it can be seen that when banks are confident in themselves and in the market, they will create new bank money by the credit process and then new deposits for borrowers. If the level of confidence decreases, given the increase in the level of uncertainty, the banks will cut lending, limiting the creation of bank money. If confidence falls (as happened in the unprecedented situation in 2007-9), then banking system bankruptcy can involve the whole economic system (the contagion effect; see Kaufman, 1994). The plot of real GDP (Figures 1a-1b) and the HH mortgages (Figure 4) shows an initial lack of confidence around periods 3-4 (red line), which could be linked (as a connection with reality) to the ICT "New Economy" bubble around 2000 or, more realistically, with the first signals coming from the UK real estate bubble around 2004. A tolerable reduction in the confidence level creates a temporary contraction in the lending process. When confidence is restored, the lending process restarts and, as seen in Figure 4, it grows faster than in the

previous period. Figure 5 simply shows the sum of HH mortgages and firms loans, presenting a clearer picture of the debt accumulation dynamics in the economy.

Figure 7 shows the impact of securitization, given the different rate of financial innovation, on the calculation of the 'capital adequacy ratio' for the two banks in the model. Both clearly show the tendency to reduce the CAR ratio and how they can easily do this using the highly-technologically advanced financial innovation tools. Around periods 3-4 and 6-7 it can be seen (from the red line) that the banks try to restore an adequate level of CAR when shocks occur, but eventually, when the financial system has registered a collapse as a whole, they have serious problems in satisfying the capital ratio required.

Figure 4: Household Mortgages granted
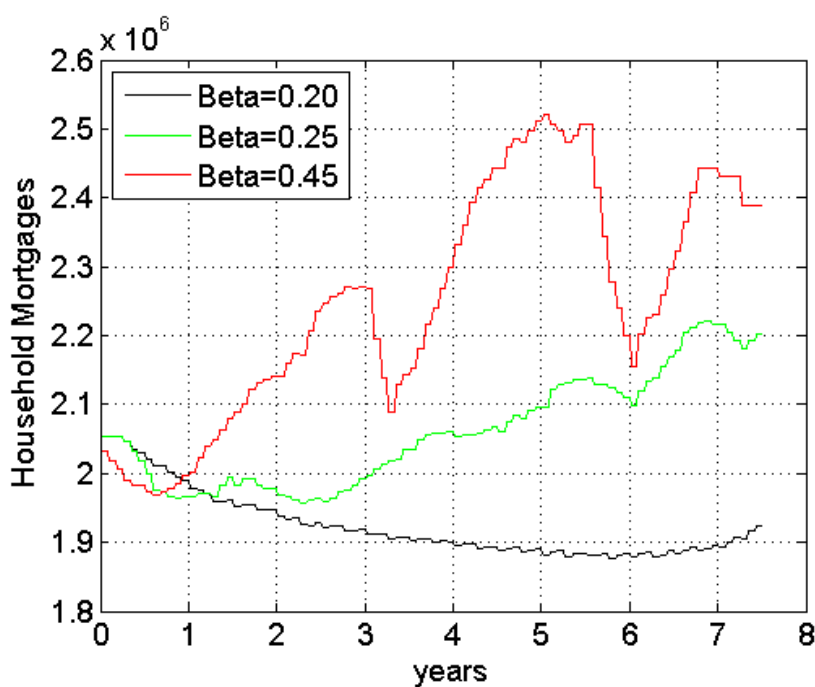
Source: Author's elaboration

Figure 5: Household Mortgages plus Firm Loans
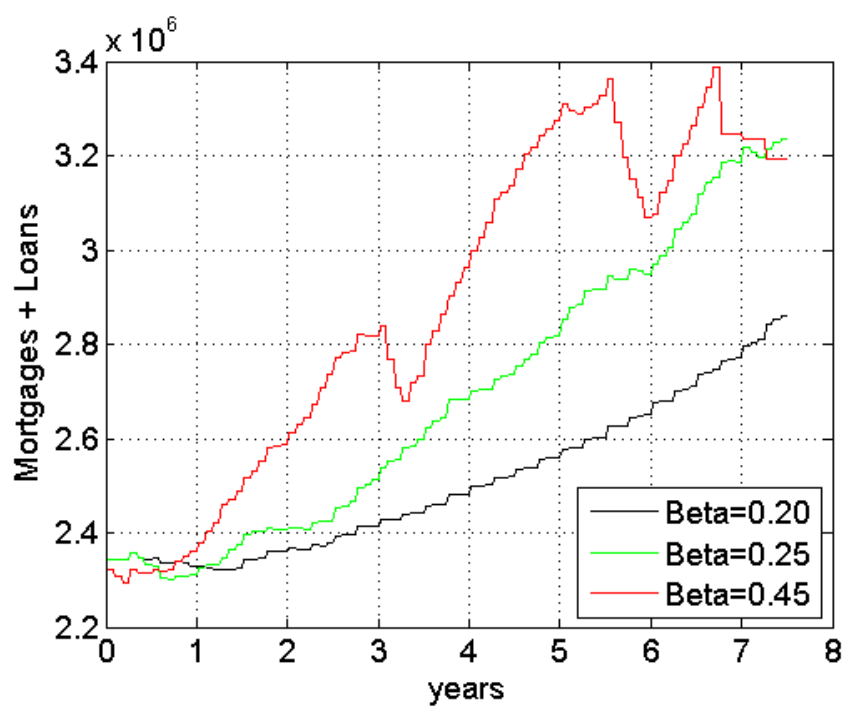
Source: Author's elaboration

Figure 6: Deposits
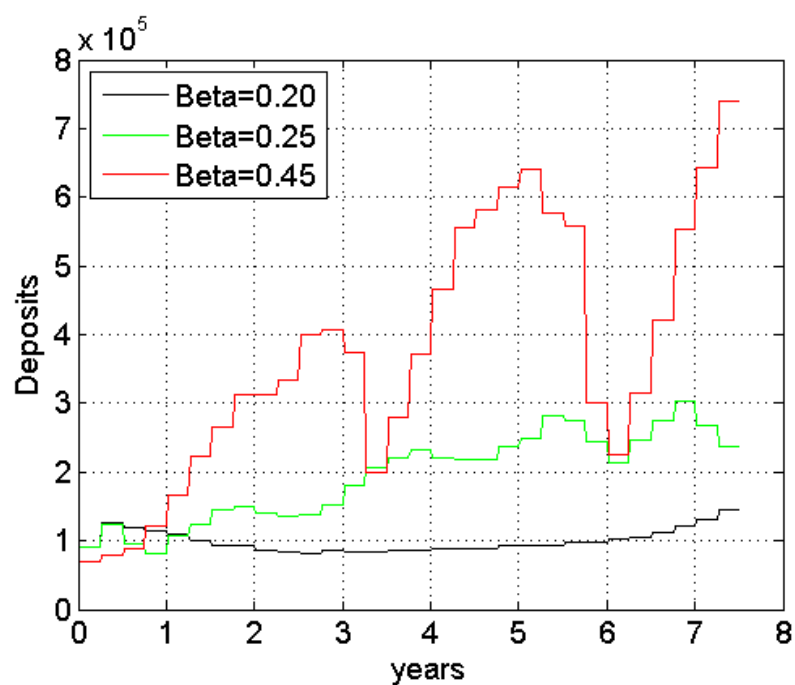
Source: Author's elaboration

Figure 7: CAR Banks 1 and 2
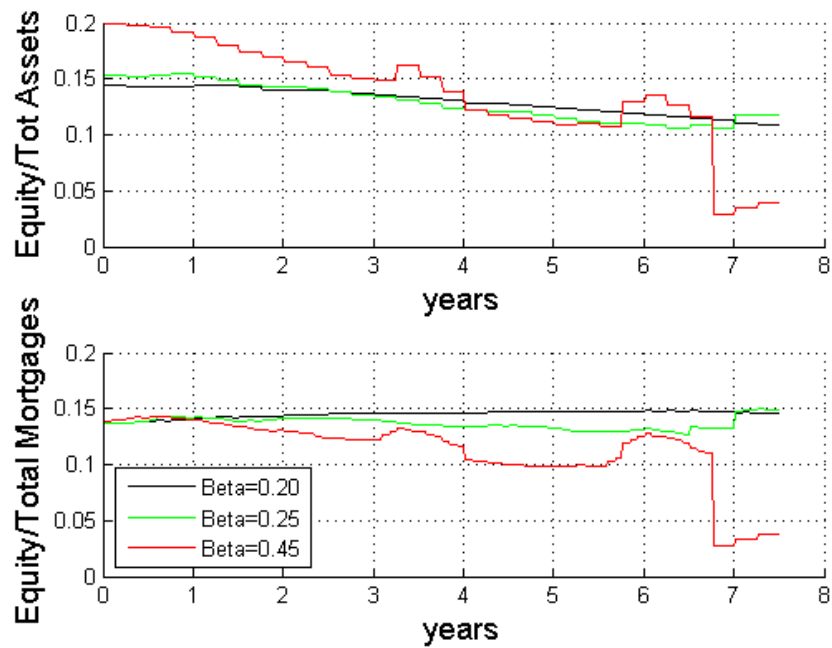
a) Bank 1 Capital Adequacy Ratio Analysis.
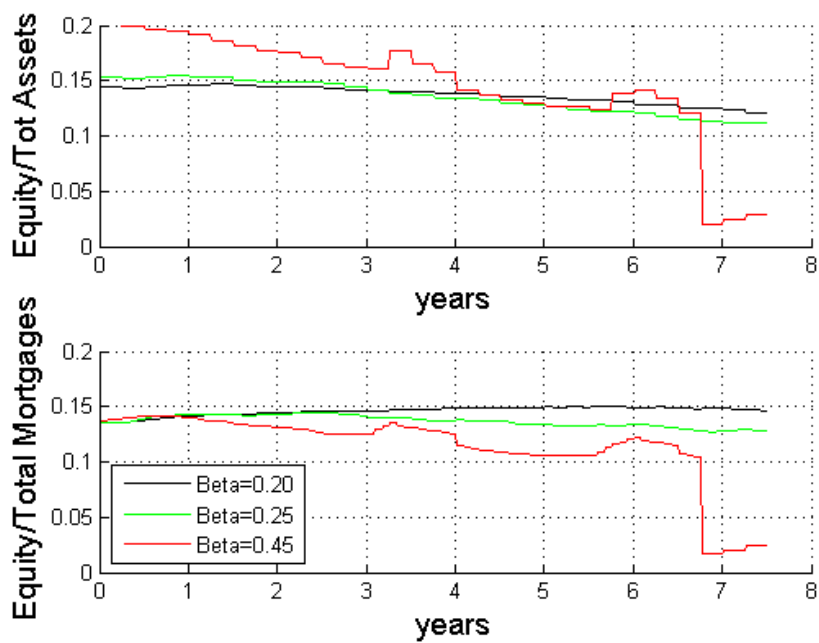
b) Bank 2 Capital Adequacy Ratio Analysis.

Source: Author's elaboration

With regard to the central bank assets[15] (Figure 8), while the black and green lines have a similar path, it is possible to observe from the red line that the banks have the tendency to reduce central bank debt because financial innovation helps them to find new liquidity at a cheaper price. In normal times, thanks to financial innovation, banks can diversify the liquidity collected, reducing the demand for funds by the central bank. Usually, in the presence of low levels of financial innovation, during financial and especially banking crises, banks' demand for central bank liquidity may sharply increase to compensate for declines in other forms of bank liabilities, often resulting from withdrawals of bank deposits (see the green line). However, the demand for central bank liquidity does not work in the red line, where the deleveraging mechanism by the central bank seems to operate. The central bank in periods 4-5 and later in 6.5-7.5 makes a reduction in central bank assets. In fact, it reduces leveraging to shrink assets faster than equities, which are already falling. This is what happened before and after the financial crisis: the shift from the North Atlantic liquidity squeeze (Mullineux, 2008) to a solvency crisis (i.e. Lehman Brothers - Buckley, 2011).

Figure 8: Central Bank Assets
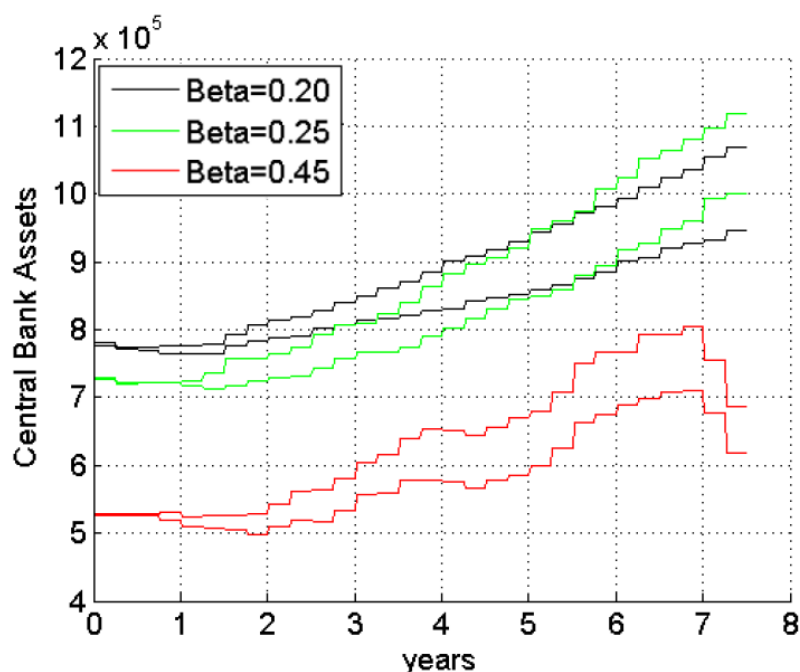
Source: Author's elaboration

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[15] Credits granted to commercial banks by the Central Bank.

A higher level of liquidity has a wealth effect. On one hand, both lead to a building up of demand for goods, which in turn leads to higher consumption. On the other hand, if HHs cannot continue to pay the interest on the mortgages taken out, a liquidity squeeze takes effect; the price dynamics will reflect the events of the inflated flow of credit/bank money in the economic system, building up bubbles. At the end of the chain of events, the result is a severe solvency crisis, which impacts on growth (as seen in Figures 1a and 1b) and unemployment (see Figure 9).

Figure 9: Unemployment (% Rate)
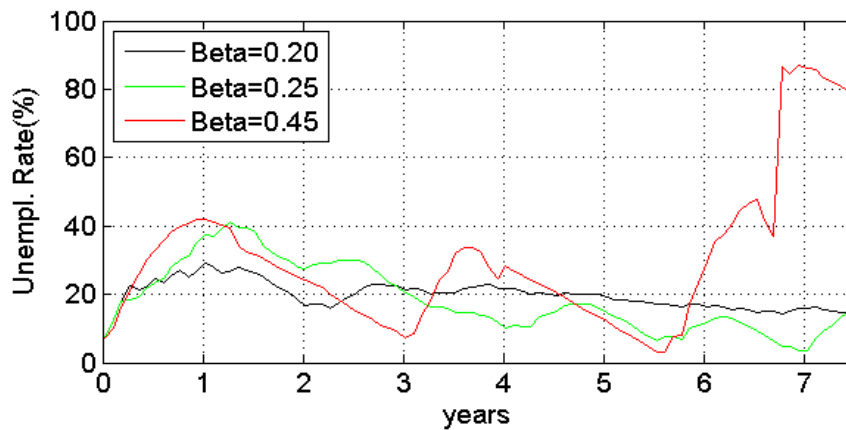
Source: Author's elaboration

However, at this stage of the experimentation, the 'structural change' is not considered in the model implementation, which is an important gap to resolve. In fact, if the model is run at 15 years a GDP is obtained which is not a close-fitting representation of the real business cycle, in particular after the crises occurred. A structural change will shift the parameters of a certain entity, which can be represented by significant changes in numerical data. This means that the model needs to be adapted to the new economic conditions. However, real GDP compared with the real data (see the plot in Appendix 5) shows that the long economic recovery after the severe crisis seems to be realistic and in line with reality, even though it is too linear. Moreover, the structural change effect could be considered as a relevant effect of the introduction of financial innovation in the ICEACE economy. Indeed, financial innovation has the property to modify the economic variables radically; in fact, this kind of problem is not found in the business cycle presented by Erlingsson et al. (2014).

6.1 Statistics

For the sake of clarity and completeness of the simulation section, Table 2 shows the aggregate average values of the real variables (Real GDP, Unemployment and Government Deficit); the financial variables (Deposits, Total Mortgages, Tot Mortgages transferred to the securitization

process, central bank assets and central bank rate); and three important ratios (the securitization ratio, first level of financial leverage and second level of financial leverage). The average values have been computed for 30 and 60 quarters, considering 40 different random simulation seeds, and provide full support to the single numerical simulation run (see Figures 1-9). From the average values, the impact of the securitization process and the rate of financial innovation (different level of RoFIN) on the real economy (see values for Real GDP, Unemployment and Government Deficit) emerge clearly. The financial variables also register interesting dynamics, confirming the endogenous money/credit creation (*ex nihilo*) mechanism, when in particular there is an enlargement of the securitization ratio given the increasing level of RoFIN (see the level of deposits). Leverage 1 increases at different levels of beta and leverage 2 rises drastically when RoFIN = 0.9. Finally, the table presents interesting results that highlight the different impact of the securitization process, given the different levels of RoFIN, whether we are analysing the short or long run (i.e. see the number of total mortgages, mortgages off-balance, securitization ratio, and leverage 2).

Table 2: Aggregate values (on average) for the three different levels of β.

	Quarters	β = 0.2 (with RoFIN= 0.4)	β = 0.25 (with RoFIN= 0.5)	β = 0.45 (with RoFIN= 0.9)
Real GDP	60	34,344.0	34,701.34	30,503.92
	30	38,420.00	39,943.66	34,224.96
Unemployment	60	1,407.26	1,497.12	2,298.51
	30	1,583.87	1,486.94	2,396.311
Government Deficit	60	-7,898.64	-56,034.13	-56,4222.30
	30	-59,697.72	-25,703.70	-55,996.14
Deposits	60	97,679.15	217,892.7	400.919.0
	30	73,021.52	117,998.1	370,128.3
Total Mortgages	60	995,335.4	384,703.0	547,821.1
	30	965,301.4	1,093,614.00	1,191,190.0
Mortgages Off-Balance	60	200,831.4	100,759.3	241,293.4
	30	199,756.9	277,214.0	537,711.2
Securitization Ratio	60	0.2018	0.2676	0.5803
	30	0.2096	0.2541	0.45
Central Bank Assets	60	0.19035	-0.9013	0.1234
	30	0.1449	0.1396	0.03094
Central Bank Rate	60	0.005	0.005	0.1058
	30	0.005	0.005	0.005
Leverage 1 *(deposits/tot mortgages)*	60	0.09813	0.5663	0.7318
	30	0.07564	0.10789	0.3107
Leverage 2 *(mort. off balance/bank equity)*	60	1.0681	-0.2909	3.5919
	30	1.4272	1.8256	15.2881

Source: Author's elaboration

7   Conclusions

The research conducted in this paper shows the existence of what we call the virtuous and unvirtuous cycles (see section 2). The dynamics of the two cycles are characterized by non-linear causality interactions, which are influenced by securitization, given the different rate of financial innovation at any time, and by the structural leveraging subdivisions (the OTD model, Originate-To-Distribute) among the agents who are involved in the financial system. An ABM (Agent-Based Model) exercise (ABE) has been conducted in order to analyse the role of financial innovation and the concentration of financial power (which promotes the creation of an unvirtuous cycle). The experiment makes an intentionally extreme simplification of the financial industry. It does not differentiate risk among the different types of assets; there is neither an interbank nor derivative market; and in the securitization process only mortgages are processed and no other types of loans (e.g. credit cards). These are important limitations to overcome, which will be the object of study in the future research agenda. However, given the focus of the paper of understanding what makes finance good or bad, and how this impacts on the business cycle path, ABE undoubtedly provides us with first evidence about the unvirtuous cycle and of the role played by the securitization process, led by the change in the rate of financial innovation, which amplifies the endogenous money/credit creation ability of the financial operators. The rate of financial innovation and the securitization process are implemented within the ICEACE model (Erlingsson et al., 2014), showing political economy dynamics with non-linearity. The experiment shows how the different rates of financial innovation, through the use of securitization, modify the ability of the financial system to shift risk forward from one financial agent to another in the name of so-called "diversification" strategies (Markowitz, 1959). This drastically reduces the perception of risk and uncertainty, within both the financial and economic systems and, as a result, the financial operators misprice risky assets and increase their exposures; in particular, when the rate of financial innovation exceeds the threshold of 50% (see section 6).

With ABE, three main aspects have emerged that have important implications in terms of future policy analysis and macroeconomic research.

1) The role of financial innovation in fostering the development of a highly technological financial system characterized by complex and unintelligible instruments and products and unrecognizable from its original banking business purposes (the passage from the OTH to the OTD financial structure model). However, financial innovation cannot be blamed in itself for being good or bad. The discussion about good and bad finance (Zingales, 2015) is strictly linked to the business decisions that the financial agents take (financial innovation development), which is mirrored by the parameter in ABE identified as the *rate of financial innovation*. The individuation of RoFIN is crucial because RoFIN can create positive or negative externalities, producing amplified positive or negative financial effects that can

impact on the business cycle. The next step of the present research will be to investigate RoFIN further as a variable, rather than as a simple parameter.

2) The multi-leverage mechanism present within the financial system, which triggered what we call a multi-multiplier effect, namely the ability of financial agents to split the financial supply chain into more levels of activity, applying at each level a leverage that in ABE has been reproduced in a simplified version, introducing only two levels of leverage (Leverages 1 and 2). The presence of multi-leverages in the financial system greatly increases the quantity of money/credit created endogenously in the economic system. However, little is still really known about its mode of operation and impact on financial instability. To identify, isolate and study the single levels of leverage operating within the financial system is part of the future research plan.

3) Last but not least, the creation of regulatory black holes owing to highly interconnected and complex financial structures (regulatory dialectic; Kane, 1977). Investigation into how to contain their distortive effects is vital to avoid the business cycle switching from a virtuous to an unvirtuous cycle over time.

Furthermore, the above-listed points highlight the need to investigate alternative policies when the finance-growth nexus governs the economy. The problem is structural, and the policies implemented until now (such as the low interest rate regime and quantitative easing, among others) have demonstrated that they are unable to identify and resolve the structural factors which make monopolistic financial power concentration possible (Blundell-Wignall and Roulet, 2013). A mix of regulatory, macroprudential and structural proposals needs to be studied and developed carefully by scholars and decision-makers to bring the economy back to the virtuous cycle and to create a certain level of financial stability based on "social utility" rather than "rent-seeking maximization", which should prevent the virtuous cycle from becoming a bad one again.

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Appendix 1

Brief introduction to the main components of the ICEACE model

This appendix aims to summarise the main components of the ICEACE model setup (see Erlingsson et al., 2014 for a more extended and detailed explanation) which are essential to understanding the ABE. ICEACE is a macro agent-based model (ABM) which studies the effect of a housing market boom and bust on the real economy. The model presents an economy constituted by four markets: the housing market, labour market, consumption goods market and the credit market. The agents operating in this economy are households, firms, construction firms, banks, an equity fund, the government, and a central bank.

Firms (Fs) and Construction Firms (CFs)

Fs (producing consumption goods) and CFs (producing housing units) are modelled according to a Leontief production function with two inputs, labour L and capital K.

$$\text{F:} \qquad q^f = min(\gamma_L \, L^f, \gamma_K \, K^f) \qquad\qquad (1)$$

$$\text{CF:} \qquad q^s = min(\psi_L L^s, \psi_K K^s) \qquad\qquad (2)$$

where γ_L and ψ_L represent the productivity of labour and γ_K and ψ_K represent the productivity of capital. f and s are respectively the indices of Fs and CFs.

Fs model setting:

1) Neither depreciation nor investments. Capital is constant and $\gamma_K = +\infty$ for any F.
2) Endowment of physical capital is initialized to a specific amount (fixed capital price P_K applies).
3) Production takes place the last day of any month and is available for sale from the first day of the following month.
4) Fs' sales expectations $\hat{q}^f$ are set equally for the present and following month and depend on the previous month's sales, unless in the previous month all the inventories I^f were sold out. If this is the case, expected sales are set equal to an amount of 10% higher than sales in the previous month.
5) Fs' production plans $\tilde{q}^f$ for the present month are set at the beginning of each month. This takes into account a weighted average between previous production q^f and the supposed optimal plan, $\eta \in (0,1)$, to avoid possible unrealistic and too wide oscillations of output.

$$\tilde{q}^f = \eta q^f + (1-\eta)(\hat{q}^f - (max(I^f - \hat{q}^f, 0)) \qquad\qquad (3)$$

   where $(\hat{q}^f - (max(I^f - \hat{q}^f, 0))$ represents the best production plan.
6) Fs' labour demand is also set at the beginning of each month and given the production plan in the present month Fs compute the labour demand L_d^f as:

$$L_d^f = \frac{\tilde{q}^f}{\gamma_L} \qquad\qquad (4)$$

   Fs decide to hire or fire employees by computing the difference between labour demand L_d^f and the present labour endowment L^f.

7) Unit production costs (from the previous monthly period) are computed as follows:

$$c^f = \frac{W^f L^f + r_L D^f}{q^f} \qquad\qquad (5)$$

   where $W^f L^f$ represents the labour costs, $r_L D^f$ is the cost for the debt service that Fs pay to the banking sector with an r_L (nominal loan rate) calculated as a 1% spread on the Central Bank rate r_{CB}, and D^f represents the debts that each F has with banks.

   The new average production costs $\bar{c}^f$ are also computed, taking into account the average production costs $\bar{c}_I^f$ of Fs' inventories I^f:

$$\bar{c}^f = \frac{\bar{c}_I^f I^f + c^f q^f}{I^f + q^f} \qquad\qquad (6)$$

8) Fs set prices (monthly) equal to the average unit production costs plus a fixed mark-up, μ (fixed over time and across Fs).

$$p^f = (1 + \mu)\bar{c}_I^f \qquad\qquad (7)$$

CFs model setting:

1) In order to control the growth of housing units in the model, CFs' production is constrained to an initial endowment of physical capital $K^s(0)$ (they cannot invest in new physical capital).

2) CFs take twelve months to produce each housing unit. They can face two possible issues: a) being rationed in the labour market or b) being rationed in the credit market.

3) CFs' production plan is driven by short-term profits and is influenced by housing market prices. Therefore, construction firms build more houses (randomly chosen and uniformly distributed in the interval $[\alpha^s, \psi_K K^s])$[16] if the price increases ($\Delta P_H > 0$) and reduce the production of houses (randomly chosen and again uniformly distributed in the interval $[1, \alpha^s]$) if the price decreases.

4) CFs, in a similar way to Fs, set their labour demand according to their production plans.

$$L_d^s = \frac{\tilde{q}^s}{\psi_L L^s} \qquad (8)$$

5) There is competition between new housing units and old housing units put up for sale in the housing market.

Households (HHs)

1) HHs provide a homogeneous labour force to firms and construction firms.

2) The labour income Z_l^h consists of wages W^h, unemployment benefits $\xi_u W^h$ and general benefits $\xi_g W^h$. Therefore,

$$Z_l^h = W^h + \xi_u W^h + \xi_g W^h \qquad (9)$$

3) Consumption is modelled according to the theory of buffer-stock saving behaviour (Carroll, 2001; Deaton, 1992).[17] Moreover, the wealth effect on consumption is taken into account. Therefore, the HHs' consumption budget C_B^h is set at the beginning of each month as a combination between the buffer-stock theory of saving and the wealth effect.

$$C_B^h = \Upsilon^h + \alpha_C(M^h - \rho_C \Upsilon^h) + \omega E^h \qquad (10)$$

where Υ^h is the disposable income after tax[18], α_C sets a consumption budget speed adjustment, M^h is the HHs' liquidity, ρ_C represents a target level according to the buffer-stock theory, the parameter ω sets the size of the wealth effect on consumption and E^h is the HHs' equity or net wealth.[19]

4) The consumption market opens on the first day of every week. HHs are randomly queued into it and they spend a fraction of their consumption budget saved from the previous week. HHs randomly select consumption goods firms that offer the lower prices. The consumption market closes when goods for sale run out or HHs have spent their entire weekly budget.

5) HHs buy houses built by CFs. HHs who are selected with probability ρ_H can enter the housing market as buyers or sellers with equal likelihood.

6) HHs in financial distress will be constricted to selling a housing unit if the following condition applies:

$$R^h > \theta\left(Z_l^h(1 - t_l) + Z_e^h(1 - t_e)\right) \qquad (11)$$

where R^h is the HHs' past quarterly mortgage costs (interest + principal payments), θ is a fraction of their total past quarterly net income (a parameter defined in the interval $(0, 1)$), Z_l^h and Z_e^h represent respectively labour income and capital income, while t_l and t_e represent respectively labour tax income and capital tax income.

Banks (Bs)

1) Bs collect private sector deposits from HHs, Fs and CFs.

2) Bs supply loans to Fs and CFs, and mortgages to HHs. Each B must respect the minimum capital requirement $E^b \geq \chi$ where E^b represents the bank equity of each bank b and χ is a fraction of the B's total risky assets.

Producers:

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[16] Where α^s is the current number of projects under construction and $\psi_K K^s$ is the maximum production capacity of construction firm *s*.

[17] Carroll, C. D. (2001). A theory of the consumption function, with and without liquidity constraints. Journal of Economic Perspectives, 15(3): 23-45.

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[18] Income tax t_l and capital tax t_e applies

[19] E^h is the result of the dynamics of housing prices.

3) Fs and CFs receive a loan only if they have positive equity. HHs are provided with a mortgage only if they respect a minimum equity ratio requirement of $E^h \geq \phi$, where E^h represents their net wealth and ϕ is a fraction of each HH h total wealth $P_H X^h + M^h + P_F V^h$, where $P_H X^h$ (housing price times housing units) is the housing wealth, M^h is the HH liquidity and $P_F V^h$ is the equity fund shares.

4) Each quarter Fs and CFs can access the loan market and their demand for loans $L_d^{(f,s)}$ is set as follows:

$$L_d^{(f,s)} = \max\left(r_L D^{(f,s)} + \text{div}^{(f,s)} - M^{(f,s)}, 0\right) \tag{12}$$

where $r_L D^{(f,s)}$ is the interest payment on loans, $\text{div}^{(f,s)}$ denotes the dividends and $M^{(f,s)}$ is the liquidity of Fs and CFs. They apply for credit first from their preferred bank, randomly set at the beginning of the simulation. If they are rationed by the first bank they apply to a second randomly selected bank.

5) Fs and CFs can apply for financing from the EF if the loan obtained from the second bank is insufficient to cover the interest payment on loans. The minimum equity ratio for being accepted for financing by the EF is 5%. If producers have a ratio lower than this, they cannot access the EF and will face illiquidity bankruptcy. This results in a loss for the banking system and an increase in unemployment.

6) An entry and exit mechanism for Fs and CFs operates. Both illiquidity and insolvency bankruptcy of producers entails that the number of producers is constant over time.

Households:

1) HHs who wish to purchase a new housing unit and do not have enough liquidity to do so apply for a mortgage from the Bs. Each HH has its preferred bank. However, if HHs are credit rationed by the preferred bank, they do not apply for credit from a different bank (unlike producers).

2) The model assumes an adjustable-rate mortgage (ARM) lasting for 40 years. The changes in the financing conditions of the economy are mirrored by the changes in the annual mortgage rate r_M.

3) The mortgage rate changes quarterly and depends on changes in the CB interest rate r_{CB} plus a fixed 2% spread. There is no cap on interest rate or payment variation between quarters.

4) The annuity factor of each mortgage is given by:

$$A^m = \frac{1}{\frac{1}{4}r_M} - \frac{1}{\frac{1}{4}r_M\left(1+\frac{1}{4}r_M\right)^n} \tag{13}$$

where *n* is the remaining number of quarters before the mortgage contract ends.

5) The quarterly mortgage costs R^m are given by:

$$R^m = \frac{U^m}{A^m} \tag{14}$$

where U^m is the principal amount remaining to repay the mortgage *m*. Mortgage costs take into account the quarterly interest payment computed as $R_r^m = U^m \frac{1}{4}r_M$ and part of the principal repaid computed as $R_U^m = R^m - R_r^m$.

6) In order to obtain a new mortgage, HHs need to demonstrate to the Bs their ability to repay the flow of interests plus the principal of their portfolio of mortgages (composed by old and new mortgages) given their present income and the present mortgage rate.

7) The HHs' budget constrained in obtaining a new mortgages *m** is set by the following condition:

$$\sum_m R^m + R^{m*} \leq \beta\left(Z_l(1-t_l) + Z_e(1-t_e)\right) \tag{15}$$

where $\sum_m R^m$ represents the sum total of the quarterly costs of present mortgages, R^{m*} denotes the additional quarterly costs related to the new requested mortgage, and β is a fraction of the total quarterly net income, which includes both labour Z_l and capital income Z_e.

8) If HHs sell housing units, they use the amount received to pay back the entire mortgage and keep the remaining part of the amount (if any) as liquidity.

9) If the ability of HHs to service their debts is unsustainable $R^h > \theta_{high}\left(Z_l^h(1-t_l) + Z_e^h(1-t_e)\right)$, the Bs write-off these debts. As a consequence, the banks register a loss equal to the total debt write-off on the balance sheet (assets side).

Government (G)

1) The G manages fiscal policy in the economy. It collects taxes on both labour t_l and capital income t_e and it pays both general $\xi_g W$ and unemployment $\xi_u W$ benefits to HHs.

2) The G pursues a zero deficit policy by balancing tax and benefits. The parameter Γ, defined in the interval $(0,1)$, sets the ratio between the use of taxes and benefits to balance the budget of the G.

Central Bank (CB)

1) The CB sets the monetary policy and the policy rate r_{CB} monthly, according to a Taylor rule,

$$r_{CB} = \mathcal{I} + \frac{1}{2}(\mathcal{I} - \mathcal{I}_{CB}) - \frac{1}{2}\mathcal{U} \tag{16}$$

where $\mathcal{U}$ is the unemployment rate, $\mathcal{I}$ is the inflation rate and $\mathcal{I}_{CB}$ is the inflation target of the Central Bank.

2) The minimum interest rate is set at 0.5%

3) The CB provides banks with lending and deposit facilities and grants loans to the government if needed.

Equity Fund (EF)

1) The EF owns all the equity shares of Fs, CFs and Bs, collects their dividends and redistributes them to HHs.

2) The share of the EF is equally distributed among HHs.

3) If Fs and CFs are in need of financing or have been credit rationed, the EF can decide to retain part of the dividends received and provide them with financing.

The Housing Market (HM)

1) The HM is a posted-price market. Sellers post prices and buyers search for the cheapest one.

2) Sellers i (HHs and CFs) set their prices based on the current market price P_H (average transaction price from the previous monthly period). In this first case, sellers' selling decisions are not bound by financial needs. They sell the housing unit only if they can maximise the gain over the market price:

$$p_H^i = P_H(1 + \varepsilon^i) \qquad \text{with} \qquad i \in \{random\ sellers\ (Hh)\ and\ CF\} \tag{17}$$

where ε^i is a random draw by seller i from a uniform distribution defined in the interval between 0 and λ_H^{rnd}.

3) In the second scenario, sellers' selling decisions are bound by financial needs (in particular, the focus here is on HHs who are in financial distress). Therefore, they agree to sell the housing unit at a lower price than the market price.

$$p_H^j = P_H(1 + \hat{\varepsilon}^j) \qquad \text{with} \qquad i \in \{\text{Hh in financial distress}\} \tag{18}$$

where $\hat{\varepsilon}^j$ is a random draw by household h from a uniform distribution defined in the interval between 0 and $\lambda_H^{firesale}$.

4) Buyers (HHs) are randomly queued into the HM. They will buy the cheapest housing unit available. The transactions are completed if the HHs have the necessary financial resources or are able to obtain a mortgage from the Bs.

5) The HM closes when all buyers have had their chance to buy a housing unit or the supply of housing is depleted. Therefore a new housing price P_H is calculated as an average of the realized transaction prices.

Appendix 2

Table 3: Table of initial values in the ICEACE model by Erlingsson et al. (2014)

Variable	Description	Value
Price and interest rates		
$P_H(0)$	Initial price of a housing unit	$20W(0)$
$P_C(0)$	Initial price of consumption goods	0.0056
$P_K(0)$	Initial price of capital goods	$100*P_C$
$r_{CB}(0)$	Initial Central Bank interest rate	0.02
$r_L(0)$	Initial bank loans interest rate	$r_{CB}+0.01$
$r_M(0)$	Initial bank Mortgage interest rate	$r_{CB}+0.02$
Firms and Construction firms		
$W^{f,s}(0)$	Initial wage of firms and construction firms	5
Households		
$X^h(0)$	Households initial amount of housing units	5
$M^h(0)$	Households initial liquidity	$3W(0)$
Banks		
$\chi(0)$	Initial capital adequacy ratio of banks	0.1
$M^b(0)/(M^b(0)+U^b(0)+\mathcal{L}^b(0))$	Initial liquidity ratio of banks	0.091
Government and Central bank		
$t_\ell(0)$	Initial income tax	0.2
$t_e(0)$	Initial capital income tax	0.2
$\xi_U(0)$	Initial unemployment benefit ratio	0.5
$\xi_T(0)$	Initial general transfer benefit ratio	0.3
$\mathcal{U}(0)$	Initial unemployment level	0.1

Source: Erlingsson et al. (2014).

NOTE: for a description of all the variables that are not explained here, see Erlingsson et al.'s 2014 paper.

Table 4: Table of the additional financial innovation parameters

Parameter	Description	Value
Banks		
$MAX\delta$	Max Securitization Ratio	0.5
$RoFIN$	Rate of Financial Innovation	[0.4, 0.5, 0.9]

Source: Author's elaboration.

Appendix 3

Table 5: Table of general parameters in the ICEACE model by Erlingsson et al. (2014)

Parameter	Description	Value
Time constants		
T_D	Loan duration	$+\infty$
T_M	Mortgage duration in years	40
T_H	Housing construction time in months	12
Housing market		
ϕ	Minimum equity ratio of mortgage borrowers	$-\infty$
λ_H^{rnd}	Seller price interval for housing	0.025
$\lambda_H^{firesale}$	Fire sale price reduction interval	0.05
Households		
ω	Households wealth effect	0.07
ς	Households labor turnover probability	0.1
v^h	Households starting leverage	1
ζ_{min}	Minimum amount of housing units	1
θ	Household budget threshold for fire sale	0.6
θ_{high}	Household budget threshold for mortgage write-off	0.7
θ_{low}	Household budget ratio for mortgage write-off	0.5
α_C	Speed of adjustment of household savings	0.1
ρ_C	Household target ratio of liquid wealth over disposable income	1
Firms and construction firms		
v^f	Firms starting leverage	4
μ	Firms markup on consumption goods	1.1
γ_L	Firms labor productivity	1000
γ_K	Physical capital utilization of firms	$+\infty$
v^s	Construction firms starting leverage	1
ψ_L	Construction firms labor productivity	0.8
ψ_K	Physical capital utilization of construction firms	0.7
δ^s	Labor force share of construction firms	0.075
ρ^s	Maximum yearly growth rate of housing stock	0.015
Banks		
χ_{min}	Minimum capital adequacy ratio of banks	0.085
Government and Central bank		
Γ	Tax and benefit ratio policy parameter	0.9
$\mathscr{I}_{CB}$	Central bank inflation target	0.02

Source: Erlingsson et al. (2014).

NOTE: for a description of all the variables that are not explained here see Erlingsson et al.'s 2014 paper.

Appendix 4: New and Incremented ICEACE Scripts

1. Banks_securitization (completely new)
2. Banks_initialization (increment in the assets and liability side of the banks' balance sheet initialization, given the presence of the securitization process)
3. Households_repay_mortgage_to_banks (increment relating to banks and the fund securitization account update)
4. Fund_initialization (increment in the assets and liability side of the Fund's balance sheet initialization, given the presence of the securitization process)
5. Banks_pay_securitization_claims_to_Fund (the securitization flows of interests and principal are transferred to be collected by the Fund)
6. Fund_compute_balance_sheet
7. Banks_compute_balance_sheet
8. ICEACE_multilple_run
9. ICEACE_gathering_data_multiple
10. ICEACE_inizialization_multiple
11. ICEACE_plotting_multiple

I) Banks initialization

```matlab
%Banks_initialization

%% Banks initial state variables

BanksCentralBankDebt0 = 0;
BanksLiquidity0       = 0;
BanksCapitalAdequacyRatio0 = 10;
BanksRetainedEarnings0 = 0;
BanksParameters.MaxSecuritizationRatio = SimulationRunPar.BudgetConstraints;


%% Initialization of Banks Balance Sheets

for b=1:NrAgents.Banks
    Banks.LoansArray{1,b}.Amount = zeros(1,NrAgents.Firms);
    Banks.LoansArray{1,b}.InterestRate = zeros(1,NrAgents.Firms);
    Banks.LoansArray{1,b}.MaturityDay = zeros(1,NrAgents.Firms);
    Banks.LoansArray{1,b}.FirmsId = zeros(1,NrAgents.Firms);
    for f=1:NrAgents.Firms
        if Firms.DebtsArray{1,f}.BanksId == b
            Banks.LoansArray{1,b}.Amount(1,f) = Firms.DebtsArray{1,f}.Amount;
            Banks.LoansArray{1,b}.InterestRate(1,f) = Firms.DebtsArray{1,f}.InterestRate;
            Banks.LoansArray{1,b}.MaturityDay(1,f) = Firms.DebtsArray{1,f}.MaturityDay;
            Banks.LoansArray{1,b}.FirmsId(1,f) = f;
        end
    end
    Banks.TotalLoans(1,b) = sum(Banks.LoansArray{1,b}.Amount);
end
clear k b h

for b=1:NrAgents.Banks
    Banks.LoansArrayCstrF{1,b}.Amount = zeros(1,NrAgents.CstrFirms);
    Banks.LoansArrayCstrF{1,b}.InterestRate = zeros(1,NrAgents.CstrFirms);
    Banks.LoansArrayCstrF{1,b}.MaturityDay = zeros(1,NrAgents.CstrFirms);
    Banks.LoansArrayCstrF{1,b}.CstrFirmsId = zeros(1,NrAgents.CstrFirms);
    for c=1:NrAgents.CstrFirms
        if CstrFirms.DebtsArray{1,c}.BanksId == b
            Banks.LoansArrayCstrF{1,b}.Amount(1,c) = CstrFirms.DebtsArray{1,c}.Amount;
            Banks.LoansArrayCstrF{1,b}.InterestRate(1,c) = CstrFirms.DebtsArray{1,c}.InterestRate;
            Banks.LoansArrayCstrF{1,b}.MaturityDay(1,c) = CstrFirms.DebtsArray{1,c}.MaturityDay;
            Banks.LoansArrayCstrF{1,b}.CstrFirmsId(1,c) = c;
        end
    end
    Banks.TotalLoans(1,b) = Banks.TotalLoans(1,b) + sum(Banks.LoansArrayCstrF{1,b}.Amount);
end
clear k b h

for b=1:NrAgents.Banks
    Banks.MortgageArray{1,b}.Amount = zeros(1,NrAgents.Households);
    Banks.MortgageArray{1,b}.InterestRate = zeros(1,NrAgents.Households);
    Banks.MortgageArray{1,b}.MaturityDay = zeros(1,NrAgents.Households);
    Banks.MortgageArray{1,b}.HouseholdsId = zeros(1,NrAgents.Households);
    for h=1:NrAgents.Households
        if Households.MortgageArray{1,h}.BanksId == b
            Banks.MortgageArray{1,b}.Amount(1,h) = Households.MortgageArray{1,h}.Amount;
            Banks.MortgageArray{1,b}.InterestRate(1,h) = Households.MortgageArray{1,h}.InterestRate;
            Banks.MortgageArray{1,b}.MaturityDay(1,h) = Households.MortgageArray{1,h}.MaturityDay;
            Banks.MortgageArray{1,b}.HouseholdsId(1,h) = h;
        end
    end
    Banks.TotalMortgage(1,b) = sum(Banks.MortgageArray{1,b}.Amount);
end


%% Securitization: balance sheet initialization

Banks.MortgageOffBalance = zeros(1,NrAgents.Banks);
Banks.InnovationDegrees = ones (1,NrAgents.Banks);
Banks.SPV.Mortgages = Banks.MortgageOffBalance;
Banks.SPV.CMOs = Banks.SPV.Mortgages;
Banks.HousingInterestProceeds = zeros(1,NrAgents.Banks);
Banks.SecuritizationRatio = Banks.MortgageOffBalance./Banks.TotalMortgage;

Banks.Liquidity = 0.1*ones(1,NrAgents.Banks).*(Banks.TotalLoans + Banks.TotalMortgage - Banks.MortgageOffBalance);
Banks.TotalAssets = Banks.TotalLoans + Banks.Liquidity + Banks.TotalMortgage - Banks.MortgageOffBalance;

%Liabilities side:

Banks.Deposits = (Banks.TotalAssets./sum(Banks.TotalAssets))*((sum(Households.Liquidity)+sum(Firms.Liquidity))/NrAgents.Banks);
Banks.Equity   = Banks.TotalAssets/BanksCapitalAdequacyRatio0;
Banks.RetainedEarnings = ones(1,NrAgents.Banks)*BanksRetainedEarnings0;
Banks.CentralBankDebt = max(Banks.TotalAssets - Banks.Deposits - Banks.Equity - Banks.RetainedEarnings,0);

if (sum(find(Banks.Deposits + Banks.Equity>Banks.TotalAssets))>0)
    error('There is at least one bank with a wrong initial balance sheet')
end

%% Initialization of Banks Income Statement

Banks.Earnings = zeros(1,NrAgents.Banks);
```

II) Banks securitization

```
%% Banks securitization

for b=1:NrAgents.Banks
    securitization_target = BanksParameters.MaxSecuritizationRatio*Banks.TotalMortgage(1,b);

    if Banks.MortgageOffBalance(1,b) < securitization_target
        securitization_demand = securitization_target-Banks.MortgageOffBalance(1,b);
        securitization_done = min(securitization_demand,Fund.Liquidity);
        Banks.MortgageOffBalance(1,b) = Banks.MortgageOffBalance(1,b) + securitization_done;
        Banks.Liquidity(1,b) = Banks.Liquidity(1,b) + securitization_done;
        Banks.SPV.Mortgages(1,b) = Banks.SPV.Mortgages(1,b) + securitization_done;
        Banks.SPV.CMOs(1,b) = Banks.SPV.CMOs(1,b) + securitization_done;

        Fund.Liquidity = Fund.Liquidity - securitization_done;
        Fund.CMOs = Fund.CMOs + securitization_done;

    elseif Banks.MortgageOffBalance(1,b) > securitization_target
        securitization_demand_razioned = Banks.MortgageOffBalance(1,b)- securitization_target;
        securitization_done = min(securitization_demand_razioned,max(0,Banks.Liquidity(1,b)));
        Banks.MortgageOffBalance(1,b) = Banks.MortgageOffBalance(1,b) - securitization_done;
        Banks.Liquidity(1,b) = Banks.Liquidity(1,b) - securitization_done;

        Banks.SPV.Mortgages(1,b) = Banks.SPV.Mortgages(1,b) - securitization_done;
        Banks.SPV.CMOs(1,b) = Banks.SPV.CMOs(1,b) - securitization_done;

        Fund.Liquidity = Fund.Liquidity + securitization_done;
        Fund.CMOs = Fund.CMOs - securitization_done;
    end
end

Banks.SecuritizationRatio = Banks.MortgageOffBalance./Banks.TotalMortgage;
```

III) Capital Fund initialization

```
%Fund_initialization

%% Initialize Fund balance sheet

Fund.Liquidity = 1e7;
Fund.CMOs = sum(Banks.SPV.CMOs);
Fund.Equity = Fund.Liquidity+Fund.CMOs;

%% Initialize Fund Income statement

Fund.DividendsRecieved = 0;
Fund.DivedendsPaid = 0;
Fund.DividendsRetained = 0;
Fund.FirmInvestment = 0;

%% Initialize other parameters

Fund.Parameters.MinEqRatio = 0.05;
```

IV) Banks and Capital Fund compute balance sheet

```matlab
%%Fund balance sheet calculation

Fund.Equity = Fund.Liquidity + Fund.CMOs;

%% Banks compute balance sheet

for b=1:NrAgents.Banks
    if (Banks.Liquidity(b) < 0)
        Banks.CentralBankDebt(b) = Banks.CentralBankDebt(b) - Banks.Liquidity(b);
        Banks.Liquidity(b) = 0;
    elseif ((Banks.Liquidity(b) > 0)&(Banks.CentralBankDebt(b) > 0))
        liquidity = Banks.Liquidity(b);
        Banks.Liquidity(b) = max(0,Banks.Liquidity(b)-Banks.CentralBankDebt(b));
        Banks.CentralBankDebt(b) = max(0,Banks.CentralBankDebt(b)-liquidity);
    end
end

Banks.TotalAssets = Banks.TotalLoans + Banks.Liquidity + Banks.TotalMortgage - Banks.MortgageOffBalance;
Banks.Equity = Banks.TotalAssets - Banks.Deposits - Banks.CentralBankDebt;
```

V) Banks pay securitization claims to Capital Fund

```matlab
%% Banks pay securitization claims to Fund

Banks.Liquidity = Banks.Liquidity - Banks.SecuritizationRatio.*Banks.HousingInterestProceeds;
Fund.Liquidity = Fund.Liquidity - sum(Banks.SecuritizationRatio.*Banks.HousingInterestProceeds);
```

VI) Households repay mortgages to banks

```
%Households_repay_mortgage_to_banks

Households.HousingPayment = zeros(1,NrAgents.Households);
Households.HousingInterestPayment = zeros(1,NrAgents.Households);

if REmarket.UseInflIndexedMortgages == 1
    OldPrice = PriceIndices.ConsumptionGoods_hist(d-TimeConstants.NrDaysInMonth);
    NewPrice = PriceIndices.ConsumptionGoods_hist(d);
    InflIndexChange = (1+(NewPrice-OldPrice)/OldPrice);
else
    RemainingQuarters = (TimeConstants.MortgageDurationDays-d+1)/TimeConstants.NrDaysInQuarter;
    PriceIndices.AnnuityFactor = (1/(PriceIndices.MortgageRate/4))-...
    1/((PriceIndices.MortgageRate/4)*(1+(PriceIndices.MortgageRate/4))^RemainingQuarters);
end

%Housing payments of mortgages (paym. of principal + interest)

for h=1:NrAgents.Households

    if REmarket.UseInflIndexedMortgages == 1
        AF = FuncAnnuityFactor(Households.MortgageArray{1,h}.MaturityDay,PriceIndices.MortgageRateSpread_IIM,d);
        Households.MortgageArray{1,h}.Amount = Households.MortgageArray{1,h}.Amount.*InflIndexChange;
        Households.TotalMortgage(h) = sum(Households.MortgageArray{1,h}.Amount);
        Households.HousingPayment(h) = max(0,Households.MortgageArray{1,h}.Amount./AF);
        Households.HousingInterestPayment(h) = max(0,Households.TotalMortgage(h)*(PriceIndices.MortgageRateSpread_IIM/4));
        PriceIndices.AnnuityFactor = AF;
    else
        Households.HousingPayment(h) = max(0,Households.TotalMortgage(h)/PriceIndices.AnnuityFactor);
        Households.HousingInterestPayment(h) = max(0,Households.TotalMortgage(h)*(PriceIndices.MortgageRate/4));
    end

    if Households.HousingPayment(h) > REmarket.MortgageWriteOffThresh*(sum(Households.QuarterlyLaborIncome(:,h)) + ...
            Households.QuarterlyCapitalIncome(h))

        %% the housing payment is lowered to X% of quarterly income
        HousingPayment_target = REmarket.MortgageWriteOffRatio*(sum(Households.QuarterlyLaborIncome(:,h)) + ...
            Households.QuarterlyCapitalIncome(h));
        Households.HousingPayment(h) = HousingPayment_target;
        MortageReduction = Households.TotalMortgage(h)-HousingPayment_target*PriceIndices.AnnuityFactor;
        Households.TotalMortgage(h) = HousingPayment_target*PriceIndices.AnnuityFactor;
        Households.MortgageArray{1,h}.Amount = HousingPayment_target*PriceIndices.AnnuityFactor;

        %% we track memory about the cumulated amount of mortagages written off
        Households.MortgagesWrittenOff(h) = Households.MortgagesWrittenOff(h) + MortageReduction;

        %% the bank accounts are updated accordingly
        Banks.TotalMortgage(Households.MortgageArray{1,h}.PrimeBankId) = ...
            Banks.TotalMortgage(Households.MortgageArray{1,h}.PrimeBankId) - MortageReduction;
        Banks.Earnings(Households.MortgageArray{1,h}.PrimeBankId) = ...
            Banks.Earnings(Households.MortgageArray{1,h}.PrimeBankId) - MortageReduction;

        %% the bank and the fund update their securitization accounts
        Banks.MortgageOffBalance(Households.MortgageArray{1,h}.PrimeBankId) = ...
            max(0,Banks.MortgageOffBalance(Households.MortgageArray{1,h}.PrimeBankId) - MortageReduction);
        Banks.SPV.Mortgages(Households.MortgageArray{1,h}.PrimeBankId) = ...
            max(0,Banks.SPV.Mortgages(Households.MortgageArray{1,h}.PrimeBankId) - MortageReduction);
        Banks.SPV.CMOs(Households.MortgageArray{1,h}.PrimeBankId) = ...
            max(0,Banks.SPV.CMOs(Households.MortgageArray{1,h}.PrimeBankId) - MortageReduction);
        Fund.CMOs = max(0,Fund.CMOs - MortageReduction);

    end

    Households.HousingPaymentOfPrincipal(h) = max(0, Households.HousingPayment(h) - Households.HousingInterestPayment(h));
    Households.Liquidity(h) = Households.Liquidity(h) - Households.HousingPayment(h);
    Households.TotalMortgage(h) = Households.TotalMortgage(h) - Households.HousingPaymentOfPrincipal(h);
    Households.MortgageArray{1,h}.Amount = Households.MortgageArray{1,h}.Amount...
        - Households.HousingPaymentOfPrincipal(h);
    Banks.TotalMortgage(Households.MortgageArray{1,h}.PrimeBankId) = ...
        Banks.TotalMortgage(Households.MortgageArray{1,h}.PrimeBankId) - Households.HousingPaymentOfPrincipal(h);
    Banks.Earnings(Households.MortgageArray{1,h}.PrimeBankId) = Banks.Earnings(Households.MortgageArray{1,h}.PrimeBankId)...
        + (1-Banks.SecuritizationRatio(Households.MortgageArray{1,h}.PrimeBankId))*Households.HousingInterestPayment(h);
    Banks.HousingInterestProceeds(Households.MortgageArray{1,h}.PrimeBankId) =
    Banks.HousingInterestProceeds(Households.MortgageArray{1,h}.PrimeBankId) + ...
        Households.HousingInterestPayment(h);
    Banks.Liquidity(Households.MortgageArray{1,h}.PrimeBankId) = ...
        Banks.Liquidity(Households.MortgageArray{1,h}.PrimeBankId) + Households.HousingPayment(h);
end
```
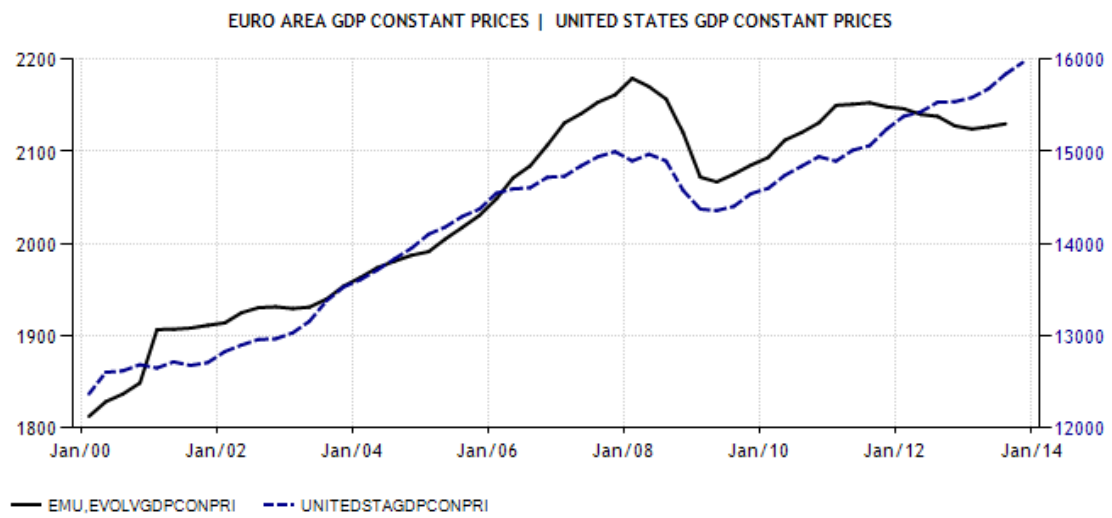
Appendix 5

EURO AREA GDP CONSTANT PRICES | UNITED STATES GDP CONSTANT PRICES

Source: Trading Economics (2014)