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When complexity meets finance: A contribution to the study of the macroeconomic effects of complex financial systems

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Abstract

In the last decade, complexity economics has emerged as a powerful approach to the understanding of the most relevant factors influencing economic development. The concept of economic complexity has been applied to the study of different economic issues such as economic growth, technological change and inequality. With this work we aim at extending the application of this concept to the study of the financial side of the economy, and, in particular, of the macroeconomic effects of rising *financial complexity*. In this paper, we present an agent-based model integrating an increasingly complex financial sector with a real side of the economy populated, among other sectors, by heterogeneous households. We test the systemic impact that the increasing complexity of both the financial system and the financial products it manufactures bear on economic growth, macroeconomic stability and inequality. We find mixed results with respect to the positive economic implications the existing literature ascribes to products complexity and deepening production capabilities. Despite higher *financial* complexity may lead to faster growth, our model suggests that this comes at the cost of heightened financial fragility, a more crisis-prone economic system, and increasing levels of income and wealth inequality. According to these findings, and consistently with pioneering insights from Minsky, we claim that rising complexity does not always entail positive consequences for the well-being of the economy. This is particularly true when it comes to financial innovations and financial complexity.

Keywords: AB-SFC model, financial complexity, securitization,
JEL Classification: E44, G01, G23

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1 Introduction

Complexity is not a new concept in the economic discipline. This fact notwithstanding, in the last decade it has been recurrently applied to an expanding variety of fields of analysis adopting different meanings and pursuing different goals.

At the origin of the story, complexity came to economics as a new methodology for the study of the evolution of economic system, which could represent an alternative to the standard equilibrium- and calculus-centered mainstream approach. In this sense, complexity was mainly conceived as *system* complexity, i.e., a vision of the economy as a complex set of interactions among heterogeneous agents, which *endogenously* determine the environment they live in and to which they constantly react to by changing, revising and adapting their actions (Arthur et al., 1997; Arthur, 2014).

Since mid of the 2000s, thanks to the theoretical and empirical contributions by Hausmann et al. (2007), Hidalgo and Hausmann (2009), and Felipe et al. (2012), complexity has been also adopted with the meaning of *product*, *production* or, more broadly, *economic* complexity. In this context, complexity stands for set of technological knowledge and capabilities, as well as organization and managerial competencies through which different countries may develop different productive systems and, as a consequence, give rise to different development trajectories.

After the outbreak of the 2007-2008 worldwide financial crisis, the concepts of system complexity as well as *financial* product complexity have been largely applied to the study of modern financial systems with the purpose of better understanding the origin and development of the financial crisis itself. On the one hand, economists have started to apply the main pillars of system complexity theory to the study of financial systems in order to stress how boom-and bust cycles, tipping points, and contagion phenomena may emanate from the interaction between heterogeneous agents in complex financial networks, as well as from the *positive* (hence destabilizing) endogenous feedbacks that such interactions may give rise (Battiston et al., 2016). On the other hand, an expanding body of literature has put emphasis on the increasing complexity of some financial products, namely securitized assets such as asset-backed securities and collateralized debt obligations, as a relevant source of rising riskiness, both at the level of the single (underlying) asset, as well as of the system as a whole (Furfine, 2012; Ghent et al., 2017).

In this paper, we connect and create a bridge between these three strands of literature by analyzing the macroeconomic implications of increasing financial complexity. We first run a parallelism between complexity in the financial system and the more standard notion of product or economic complexity. We capture financial complexity as both the expanding variety of financial instruments through which the financial system provides finance to real-side economic activities (i.e., banks' loans or commercial papers), and the intrinsic complexity of some financial products (i.e. collateralized securities) manufactured by financial institutions at the benefit of final investors. We aim at analyzing the effects that rising financial complexity might bear on the growth performance of the economy, its macroeconomic stability and the level of inequality characterizing income and wealth distribution. Secondly, accordingly with the system complexity approach, we carry out our analysis through a complex agent-based (AB) stock-flow-consitent (SFC) featuring multiple financial sectors and heterogenous households. Consistently with Arthur (2014), a central feature of our model is the existence of *positive feedbacks* in the continuous interactions between heterogeneous households, the productive non-financial sector, and financial institutions giving rise to endogenous boom-and-bust credit cycles.

The results of our computational model suggest that when complexity meets finance, it may bear rather different macroeconomic effects with respect to those ascribed to the more standard phenomenon of product or economic complexity. The existing literature about economic complexity usually identifies it as a relevant positive source of economic progress (Hausmann et al., 2007; Hidalgo and Hausmann, 2009; Felipe et al., 2012). Our simulations suggest that the macro implications of financial complexity are much more nuanced, to say the least. On the one hand, we find that financial complexity may lead to faster economic growth by allowing financial institutions to extend more resources to both households and real economy firms, which are then enabled to increase both consumption and investment expenditures. On the other hand, better growth records are matched with heightened macroeconomic volatility and, perhaps more relevantly, with a considerably higher tendency to the endogenous generation of large financial shocks. Last but not least, the introduction in financial markets of complex financial products tends to give rise to worsening income and wealth distributions, which in turn seems to stimulate even further the production of such opaque financial commodities in the context of what might be labelled as a rentier-friendly economy. Actually, this finding is completely at odds with the empirical evidence put forward by Hartmann et al. (2017) according to which higher degrees of economic complexity (rather than financial complexity) contribute to reduce income inequality.

The paper is organized as follows. Section 2 presents a short review of the existing literature on financial innovation, financial complexity, and its relations with the real-side of the economy. In this section, we also explain how the underlying philosophy to the concept of economic complexity may somehow applied to the financial world. Sections 3 and 4 illustrate the main features and the rationale of our AB-SFC macro model. Section 5 presents the simulation results. Section 6 draws conclusions on the peculiar macroeconomic effects of financial complexity.

2 Literature review

The relationship between finance and economic development dates back to Schumpeter's description of the economic development process in capitalist economies. On the one hand, Schumpeter (as well as other evolutionary economists such as Carlota Perez later in his tradition - see Kregel (2009)) attributes to innovation initiatives and innovative ideas by entrepreneurs in the real sector of the economy, in manufacturing in particular, the primacy as leading forces behind economic dynamics. On the other hand, however, Schumpeter itself recognizes the fundamental importance of bankers as the economic actors that effectively enable entrepreneurs to carry out "new combinations" (of goods and processes) by extending to them the required financial resources (see Schumpeter (1934)). In a way, whilst innovation in the real sector of the economy is the "king" of economic dynamics, finance and banker "is the ephor of the exchange economy" (Schumpeter, 1934, p.74).[1]

In a series of more recent contributions, Levine (1997) and Levine (2005) tend to emphasize the role of *financial development* as independent and autonomous source of economic dynamics regardless of possible first moves in the real side of the economy. According to this view, a more developed financial system, i.e., a financial system capable to intermediate a larger amount of resources between savers and investors via both bank-centered and market-centered mechanisms, may boost growth by improving the monitoring, screening and information-generating functions performed by financial systems, by reducing transaction costs, by providing better hedge against risks, and ultimately by improving the efficient allocation of funds among alternative investment projects. A similar reshuffling of the balance between finance and the real economy, even though in a completely different theoretical framework and with different systemic and policy implications, comes from Minsky. Indeed, from Minsky's own words, "those who finance a Schumpeterian innovator always have novel problems in structuring the financing [so that] two sets of new combinations, in production and in finance, drive the evolution of the economy" (Minsky, 1988, p.3). And Kregel (2009) puts this point even more bluntly by stating that "it is financial innovation in the financial sector that provides the increased financing that allows for the exploration and installation of the new technological paradigm" (Kregel, 2009, p.205).

There is not a one-to-one matching from Levine-type financial development to Minskyan financial innovation and, ultimately, to financial complexity at the centre of our analysis. Yet, the processes of economic and financial development Levine describes seem to be associated with a change in the structure of finance from a bank-based to a more market-based financial system (Demirguc-Kunt and Levine, 1999). Such a change in turn implies institutional innovations (the emergence of institutional investors, pension and hedge funds, money market mutual funds and broaker-and dealers) as well as innovations in terms of new financial products, i.e., issuance of new financial instruments such as certificates of deposit, derivatives, commercial papers, and asset-backed securities. Finally, there are little doubts that these innovations give rise to an increasing degree of complexity characterizing financial systems and financial products.

There are at least two dimensions through which we can detect the increasing complexity of finance, and by which we can somehow show the similarity between our concept of financial complexity and the

[1] The "ephor was an elected magistrate of Sparta who exercised supervisory powers over the kings" (see (Minsky, 1988, p.8)).

concept of economic complexity as it is normally understood.

First, the above-mentioned development of financial systems undoubtedly generated an expansion in the variety of financial products offered by financial institutions to their clients. The introduction of commercial papers and of securitized financial products, i.e. the financial product innovations at the center of our computational analysis, are clear examples of such *expanding variety*. In the jargon of economic complexity, this may be conceived as a *finance version* of a more diversified productive system and production *space*.

Secondly, a possible definition of financial complexity consists in the costs one has to incur in order to search, collect, process and understand all the information needed to evaluate the performance of a given financial product (Awrey, 2012). Well: in the case of the securitized products at the centre of the last financial crisis, "even the most (ostensibly) sophisticated counterparties failed to grasp their technical nuances, [and supposedly well-informed] market participants did not fully appreciate how the unique structure of sub-prime mortgages made the MBS and CDOs into which they were repackaged particularly sensitive to volatility in the underlying home prices" (Awrey, 2012, p.250). Indeed, the production and issuance of such products have been made possible only by recent advances in financial theory, information technology and computer-based computations. And these advances has been in turn achieved only through the astonishing increase in the share of physicists, mathematicians and engineers increasingly employed in the finance industry with respect to other sectors (Philippon and Reshef, 2012; Marin and Vona, 2017). From our perspective, such evidence closely resembles the idea, so central in the literature on economic complexity, of (non-financial) products complexity as indicator of the organizational, managerial, institutional and technological capabilities implicitly needed for their production.

An additional factor of complexity, perhaps specific to the case of structured financial products, is worth mentioning. It is more related to the concept of system complexity if not product complexity. Indeed, the returns of complex structured financial products relies upon the performance of potentially a myriad of underlying assets, say loans or tranches of loans to different households and firms. This fact tremendously increases the degree of "disperse interaction" and interconnectedness of the economy. In fact, the financial behavior (i.e., the capacity to meet outstanding payment commitments) of a relatively restricted bunch of agents, say sub-prime borrowers, may affect the decisions and future actions of the much wider set of nodes, i.e., securitizing institutions and/or investors, now involved in "originate-and-distribute" networks with respect to what is usual in the traditional "originate-and-hold" scheme.[2]

Given the similarity between the concept of economic/product complexity and the concept of financial complexity just discussed, it is worth wondering whether similarities persist even as to their economy-wide implications. More specifically, a higher degree of economic complexity is usually seen as indicator of more advanced economic development and predictor of brighter economic opportunities in the future. Can we attribute these same positive features to increasing financial complexity?

The mainstream literature on financial development would likely provide a positive answer. For instance, this is the case of Levine (1997) when he stresses the positive effects on economic growth of international financial liberalization, enabling foreign banks to introduce a larger variety of financial products such as commercial papers in hosting countries. A similar conclusion might be drawn from the fact that commercial papers represented a cheaper and counter-cyclical source of finance (with respect to banks' loans) for those non-financial firms that managed to enter the commercial papers market (Calomiris et al., 1995).

As far as complex structured financial products are concerned, they were originally meant as useful financial instruments enhancing financial intermediation and, hence, supporting economic growth. The creation of large secondary market for mortgage-backed securities, for instance, was considered as a powerful vehicle for allowing mortgage originators to extend mortgages even to credit-constrained households, traditionally cut off from credit circuits. This would have in turn fostered (US) home ownership and the expansion of the housing sector. By the same vein, massive issuance of securities backed by a variety of

[2]The expression "originate-and-distribute" refers to a financial system in which assets generated by financial institutions (mainly banks) via the concession of credit were kept on the balance sheets of the originating institutions. Accordingly, they monitored with care the extension of new loans and, at the same time, were tightly monitored by monetary authorities (Dymski, 2010). In the more recent "originate-and-distribute" scheme, original assets, and the corresponding risks, are transferred to a multitude of actors, with the effect of giving rise to a much looser screening of borrowers' riskiness and a much more dispersive (and hard to control) network of financially interconnected actors.

loans such as home-equity loans, car loans, student loans and credit card receivables[3] might have helped to support consumption and allow for the emergence of a finance-led consumption-centered growth regime (Boyer, 2010).[4]

The outbreak of the last financial crisis has severely shacked the above belief in the virtues of financial innovations and of the connected complexity. At a micro level, economists questioned the alleged high degree of safety characterizing complex asset-backed securities. Indeed, structured financial products turned out to be much more exposed to systemic risks than thought before (Coval et al., 2009; Gorton, 2010). And their high degree of complexity and opaqueness actually turned out as voluntary outcomes of asset-backed securities and CDOs producers' production techniques aimed at exploiting asymmetric information, and hidden mismatch between (effective) returns and risk, resulting in higher mark-ups (Furfine, 2012; Celerier and Vallee, 2017; Ghent et al., 2017). In a similar vein, the common perception of commercial papers as liquid, reliable and (almost) risk-free financial instruments providing (financial and non-financial) corporations with cheap external funds twisted. This is particularly true for *asset-backed* commercial papers mostly issued by financial institutions, due to the newly-settled mistrust in the complex underlying assets (say mortgage-backed securities). But the same could be said for simple commercial papers directly or indirectly (i.e., via the intermediation of financial subsidiaries) by large non-financial corporations, which, in the wake of the crisis, had to divert to other long-term much more expensive forms of external finance (Kacperczyk and Schnabl, 2010).

From a more structural and macroeconomic perspective, i.e., the focus of this paper, the financial crisis sparked concerns about the fragility of the macroeconomic regime that the above financial products and the connected financial complexity gave rise to. A regime which was mainly based on high consumption expenditures carried out by increasingly indebted households in the context of increasingly unequal economies (Boyer, 2010; Russo et al., 2016; Botta, Caverzasi and Tori, 2018; Caverzasi et al., 2018). On the other hand, the crisis confirmed the original Minsky's conviction that financial innovations play a fundamental destabilizing role and can lead to boom-and-bust dynamics out of period of relative tranquility, so that "explosive business cycles rather than steady growth is likely to be the normal result of the financing process" (Minsky, 1988, p.11). On the other hand, it also casted doubts on the long-run "dynamic efficiency" of a modern economy dominated by "money managers", i.e., large institutional investors, hedge and pension funds, money market mutual funds, whose demand for maximum returns at minimum risk structured financial products and commercial papers were meant to cater.

As said before, in this paper we do not focus on potentially non-linear long-run relationship between recent financial developments, financial complexity and economic growth, which has been recently pointed by a series of complementary contributions (see Cecchetti and Kharroubi (2012); Law and Singh (2014); Arcand et al. (2015)). We rather put our attention on the pure macroeconomic regime that, in a demand-driven economy, can emerge from the production of increasingly complex financial products and from the development of an increasingly complex financial system. In sections 3 and 4 below, we provide a detailed description of the main features of our model.

3 The model

We propose a hybrid AB-SFC model with all sectors at the aggregate level but the households sector. This methodology preserves the main advantages of both approaches (Caverzasi and Russo, 2018). In a nutshell, the AB approach allows to analyse the emergence of macroeconomic phenomena from the interaction of heterogeneous agents at the micro level. The rigorous macro accounting structure inherited from SFC models (Godley and Lavoie, 2007; Caverzasi and Godin, 2014) ensures that all inter-sectoral flows and feedbacks are accounted for. We limit heterogeneity to the households sector only in order to make the interpretation of the results much clearer than in full-fledge AB models, but we maintain the network complexity ensuing from the structured financial products considered in this model.

[3]According to Awrey (2012), between 1985 and 2011 the stock of non mortgage-related asset-backed securities astonishingly increased by 1800 percent.

[4]Consistently with this logic, Hoffmann and Nitschka (2012) note that the international commercialization of mortgage asset-backed securities positively contributed to smooth domestic credit cycles and consumption volatility associated to shocks.

The model builds on Botta, Caverzasi, Russo, Gallegati and Stiglitz (2018) and aims at representing the development of the financial system. As discussed in Section 2, this evolution is portrayed as a four-stage process. We model the increase in financial complexity as both the rise in the number of financial assets and institutions, as well as the increasing sophistication of financial instruments (see Appendix A).

We start with a closed economy composed of five sectors (*stage 1*): a collection of N heterogeneous households, and four aggregate sectors, namely non-financial firms (NFFs), commercial banks (CBs), investment funds (i.e. non-bank financial intermediaries - IF henceforth), and the government. This stage is characterized by a rather underdeveloped financial system. The only external source of funds for NFFs are CBs' loans, while government's bonds are the only financial asset available for investment funds, besides banks' deposits.

In *stage 2*, the financial market evolves. NFFs have direct access to the financial market and issue commercial papers, which represent a cheaper source of funds with respect to CBs' loans and allow them to circumvent possible banks' credit rationing.

Stage 3 reproduces a developed financial system. Structured financial products come into play. A new financial sector – Special Purpose Vehicles (SPV) – emerges and allows CBs to move a portion of their loans out of their balance sheet. Loans will then be transformed into collateralized debt obligations (CDOs) and eventually sold on demand to IFs.

Finally, in *stage 4* commercial papers disappear and the financial system specializes in structured financial products. All the sectors of our economy but the government are directly involved in the process that leads to the production and allocation of CDOs. Just as in the real world, in our model the securitization of loans determine a *disperse interaction* between a multitude of different borrowers and financial investors.

Each of the various financial institutions has different characteristics and plays a different role in the economy.

- The *commercial banks* sector creates (credit-)money in the form of deposits by issuing loans to households or NFFs, and buys all the government bonds not purchased by IFs. CBs apply a specific interest rate to each individual household and to NFFs according to each borrower's creditworthiness. This, coupled with considerations on its own financial stability, may lead banks to ration credit. In stages 3 and 4, CBs pass the interests collected on the securitized loans and profits in the form of dividends to IFs.

- *IFs* represent non-banking financial intermediaries which collect funds from households by issuing IFs' *shares*. IFs allocate collected funds among the financial assets available in each stage of financial development. At stage 1, IFs make a portfolio choice between government bonds and banks' deposit only. In stage 2, we introduce commercial papers, whilst in stage 3 also CDOs are available as additional investment options. In stage 4, commercial papers are called off. Returns on financial assets are entirely transferred to the owners of IFs' shares.

- We add *SPVs* to the economy in stages 3 and 4. They play the very specific role of performing the securitization process and transforming financial inputs into more complex financial assets (Caverzasi and Russo, 2018). SPVs buy loans from CBs and transform them into CDOs. SPVs perform a rather passive role, as they issue on demand the CDOs requested by the financial market, and obtain from CBs, still on demand, the loans needed as input for the production of structured securities. SPVs pass all cash flows on securitized loans to the buyers of CDOs, namely IFs.

To better capture the impacts of the evolution of the financial sector on the economy, the real side of our model is kept rather simple. NFFs produce a homogenous good used for both consumption and investment purposes. Investment in real capital and the desired level of deposits are financed primarily through retained profits and, whenever these are not enough, through external financing, i.e., banks' loans or issuance of commercial papers (in stages 2 and 3). In the event of banks' credit rationing, or insufficient demand for commercial papers, NFFs may need to diminish deposits in order to meet their financial or investment needs.

Households have two sources of income: (i) labor income (*i.e.,* wages); (ii) financial income, i.e., returns on IFs' shares. Moreover, they can meet their desired levels of consumption and financial accumulation by applying for loans to CBs. If credit is rationed, households revise their decisions, starting from assets holding down to effective consumption.

Finally, the *government sector* issues bonds, bought by CBs and IFs, to finance outlays not covered by the tax revenues.

3.1 The sequence of events

The timeline of events in each of the T simulation periods is the following:

1 *Households receive their labor income and pay taxes on wage.*

2.1 *Financial payments: returns on non-structured financial assets (i.e., interests on government bonds, interests on households' and NFFs' loans) are paid; CBs' profits are transferred to IFs.*

2.2 *Returns on commercial papers are paid by NFFs to IFs (in stages 2 and 3).*

2.3 *Interests on securitized loans pass from CBs to IFs via SPVs in order to remunerate CDOs' holders (from Stage 3).*

3 *IFs compute returns on their assets to remunerate holders of IFs' shares. Non performing loans due to households missing payment commitments diminish returns on CDOs and, consequently, on IFs' shares.*

4 *Households make consumption and savings decisions.*

5 *If needed, households apply for loans to CBs.*

6 *CBs decide whether to accomodate households' demand for loans.*

7 *In case of credit rationing, households revise their decisions.*

8 *The government implements spending decisions.*

9 *NFFs define investments in real capital and the desired level of deposits.*

10 *If retained profit do not fully cover their decisions, NFFs increase their liabilities by applying for loans to CBs or, in stages 2 and 3, by issuing commercial papers.*

11 *CBs decide whether to fully accomodate NFFs' demand for loans.*

12 *In case of credit rationing, NFFs revise their decisions, scaling down their stock of deposits.*

13 *The government finances its deficit by issuing public bonds.*

14 *IFs perform their portfolio choice, allocating collected funds among government bonds, deposits, commercial papers (stages 2 and 3), and CDOs (stage 3 and 4).*

15 *CBs buy all bonds not purchased by IFs.*

4 Behavioral equations

Let's now move to the description of agents' and sectors' behavioral equations. Due to space constraints, here we present only the main equations of the model. See Appendix B for a complete list. The following notations apply through all the model: the suffices i and t define individual households and the simulation period, respectively.

4.1 Commercial Banks

CBs make two key decisions. First, they set households' and NFFs-specific interest rates on conceded loans. Second, based on borrowers' creditworthiness, they decide whether to ration credit. These decisions can be conceived as a three-step process.

First, the expected specific interest rate for each individual household and for NFFs applying for loans is computed as a mark-up on previous period bond rate i^B_{t-1}. Unlike individual households, the NFFs sector may be subjected to partial credit rationing only. We therefore assume the expected and actual interest rates to coincide for the NFFs sector.

$$E[r^h_{i,t}] = i^B_{t-1} + i^B_{t-1}\frac{Lh_{i,t-1} + \Delta Lh^*_{i,t}}{yn_{i,t}} \tag{1}$$

$$E[r^f_t] = r^f_t = i^B_{t-1} + i^B_{t-1}\frac{Lf_{t-1} + \Delta Lf^*_t}{Pf_t} \tag{2}$$

Equations (1) and (2) tell us that the higher the ratio of the 'notional' (i.e. assuming the loan ΔL^* being granted) level of indebtedness over, respectively, net households' income and NFFs' revenues, the higher the mark-up. $yn_{i,t}$ stands for net households' income as given by the net wage $(w_{i,t} - tax^w_{i,t})$ plus the returns on (IFs') share holding $(r^{sh}SH_{i,t})$. Pf_t represents NFFs' revenues.

Second, CBs compute *notional* borrowers' debt service ratios:

$$mh^*_{i,t} = E[r^h_{i,t}]\frac{Lh_{i,t-1} + \Delta Lh^*_{i,t}}{yd_{i,t}} \tag{3}$$

$$mf^*_{i,t} = E[r^f_{i,t}]\frac{Lf_{i,t-1} + \Delta Lf^*_{i,t}}{Pf_t} \tag{4}$$

Third, CBs compare notional debt service ratios with the endogenous threshold ψ_t, which is inversely related to CBs' financial soundness as measured by the distance of CBs' leverage from Basel-type capital requirements $(\bar{k})$. In Equation (5), ω is an exogenous parameter influencing CBs sensitivity to balance sheet's conditions, whilst $\bar{\psi}$ is the exogenous maximum acceptable level of debt service ratio. The higher CBs financial fragility, the more CBs will be hesitant to securing new loans. Equation (6) represents our proxy for CBs leverage, here measured as safe assets (i.e., government bonds) over CBs' total assets at stages 1 and 2. Equation (7), where z is the quota of securitized loans, refers to stages 3 and 4.

$$\psi_t = max\left(\bar{\psi}, \quad \bar{\psi} + \omega(k_{t-1} - \bar{k})\right) \tag{5}$$

$$k_{B,t} = \frac{B_{B,t}}{[L_t + B_{B,t}]} \tag{6}$$

$$k_{B,t} = \frac{B_{B,t}}{[(1 - z_t)L_t + B_{B,t}]} \tag{7}$$

It is self-evident how higher levels of z are associated with less prudent behaviors, and may therefore ease credit supply and the concession of riskier loans. Whenever m exceeds ψ, credit rationing takes place. In the case of individual households, this leads to a complete refusal of the loan. In the case of the NFFs sector, rationing is partial and the loan eventually granted (ΔLf) is diminished until $mf^*_{i,t}$ equates $\bar{\psi}$.

Next to their role of credit provider for the private sector, CBs purchase government bonds not bought by IFs. They finally pass all their profits to IFs. Both these behaviors are better described in the next section.

4.2 Investment Funds

IFs intermediate between households and financial markets. Their portfolio choices change significantly between the different stages of financial development, as their options increase with the complexity of the financial sector.

In stage 1, IFs update the demand for government bonds following an adaptive rule based on the observed year-to-year difference in bonds' yields, allocating the remaining funds to deposits. In our model, government bonds represent a safe asset. Bonds' yields stand as a premium for their lower liquidity with respect to CBs deposits. Liquidity is relevant to IFs insofar as it might protect them from the risk of a liquidity crisis may rentier households want to redeem a significant part of IFs' shares.

$$q^b_{if,t} = min\{0.1, q^b_{if,t-1}[1 - \beta(i^B_{t-1} - i^B_t)]\} \tag{8}$$
$$D_{IF,t} = (1 - q^b_{if,t})SH \tag{9}$$

Equation (8) tells us that the higher the return on public bonds with respect to the previous period, the more IFs will increase their demand for bonds. Moreover, the share of collected funds allocated to government bonds cannot be less than 10% of total IFs' assets. This is to capture the effects of regulatory constraints about portfolio compositions different kinds of financial intermediaries have to comply with. Parameter β represents the sensitivity with respect to this inter-temporal spread. The remaining funds are allocated to deposits (Equation (10)).

In stage 2, things get slightly more complex with the introduction of commercial papers, i.e., a riskier and more remunerative portfolio choice with respect to public bonds.

$$D_{IF,t} = \sigma SH_t \tag{10}$$
$$B^D_{IF,t} = q^b_{if,t} SH_t(1 - \sigma) \tag{11}$$
$$q^b_{if,t} = min\{0.1, q^b_{if,t-1}[1 - \beta[(r_{cp} - i^B_t) - (r_{cp,t-1} - i^B_{t-1})]\} \tag{12}$$
$$CP^D_{IF,t} = SH_t - D_{IF,t} - B^D_{IF,t} \tag{13}$$

In this stage, the stock of deposits is set as a fix amount σ of collected funds (Equation (10)). The share of remaining funds invested in government bonds varies with the change in their relative remunerativeness. Equation (12) differs from Equation (8) as the year-to-year change in the return on bonds is now compared with the change in the return on commercial papers (r_{cp}). Equation (15) defines the demand for commercial papers. If NFFs issue less commercial papers than IFs demand, IFs' deposits act as buffer stock.

In Stage 3, a further step is added to IFs' portfolio choice by introducing structured financial products, i.e., CDOs.

$$q^b_{if,t} = min\{0.1, q^b_{if,t-1}[1 - \beta[(rr - i^B_t) - (rr - i^B_{t-1})]\} \tag{14}$$
$$CP^D_{IF,t} = SH_t - D_{IF,t} - B^D_{IF,t} \tag{15}$$

At this stage, IFs compare the return on government bonds to a weighted average (rr) of the returns on risky assets, i.e., commercial papers and CDOs (Equation (16)). The quota of the demand for risky assets (RA^D) allocated to CDOs increases together with their relative remunerativeness, as shown in Equation (18).

$$CDO^D_{if,t} = (SH - D_{IF,t}-)min\{0.1, q^b_{if,t-1}[1 - \beta[(rr - i^B_t) - (rr_{t-1} - i^B_{t-1})]\} \tag{16}$$
$$RA^D_{IF,t} = SH_t - D_{IF,t} - B^D_{IF,t} \tag{17}$$
$$CDO^D = RA^D * \frac{r^{cdo}_t}{r^{cdo}_t + r^{cp}_t} \tag{18}$$

4.3 Special Purpose Vehicles

SPVs appear in our economy at Stage 3. Equation (19) shows that the demand for CDOs by IFs drives the portion (z_t) of heterogenous households' and NFFs' debt SPVs will buy from CBs in order to produce CDOs.

$$z_t \sum_{i=1}^{N} Lh_{i,t} + z_t Lf_t = CDO_{if,t} \tag{19}$$

$$r_t^{cdo} = \frac{z_t[(\sum_{i=1}^{N} r_{i,t-1}^{h} \widetilde{Lh_{i,t-1}}) + r_{t-1}^{f} Lf_{t-1}]}{CDO_{if,t-1}} \tag{20}$$

Equation (20) shows that the return on CDOs is given by a portion (z) of total interests paid on CBs' loans. The tilde in Equation (20) reminds us that non performing interests reduce the remunerativeness of CBs' credit and, consequently, of CDOs.[5]

4.4 Households

Households have two sources of income: wages $w_{i,t}$ and returns on IFs' shares r^{sh}. Similarly, they have two different obligations: one fiscal (taxes on wage) and one financial (interests to be paid on their outstanding stock of debt). These two components determine their disposable income (Equation (21)).

$$yd_{i,t} = w_{i,t} - tax_{i,t}^{w} + r^{sh} SH_{i,t} - r_{i,t-1}^{h} \widetilde{Lh_{i,t-1}} \tag{21}$$

All households are created equal in terms of wealth, as all assets are set equal to zero at the beginning of the simulation. However wages differ as the total wage bill - set exogenously as a fix proportion λ of the capital stock - is distributed according to a stochastic process. At the beginning, individual wage quotas are drawn from a log-normal distribution (with log-standard deviation θ). The ranking in wage income is kept constant but differences among individual wages emerge due to the evolution of the aggregate wage bill.

The model includes a progressive taxation system as the tax rate tax^{w} on wages increases above a certain threshold, set equal to the median wage rate. The last component of disposable income $r_{i,t-1}^{h} \widetilde{Lh_{i,t-1}}$ represents 'effective' interest payment. Indeed, households may be unable to meet their financial obligations, hence determining a non performing interest given by the difference between due and effective interest payments.[6]

Once disposable income is computed, households decide their desired level of consumption and define their portfolio choices.

$$c_{i,t}^{*} = c_y yd_{i,t} + c_n \bar{c}_{t-1} \tag{22}$$

$$\tag{23}$$

Desired consumption (Equation (22)) depends on the propensity to consume c_y out of disposable income plus a 'socially determined component' c_n, which depends on the previous period average consumption. This second component of Equation (22) has the double role of capturing the well-known fact that consumption propensity decreases with higher levels of income, as well as the influence of consumption norms (or external habit formation) on individual choices.

$$Dh_{i,t}^{*} = \eta WH_{i,t-1} \tag{24}$$

$$Sh_{i,t}^{*} = Sh_{i,t-1}[1 + \sigma(\frac{rsh_{i,t-1}}{Sh_{i,t-1}} - i_{i,t-1}^{B})] \tag{25}$$

[5]In this model we assume that households inability to meet their financial commitments impacts equally securitized and non-securitized loans.

[6]In stages 3 and 4, households paying interests on past debt concur in determining the return of CDOs and therefore the return on shares, which is one of the sources of income they may use to cover their outlays, financial obligations included. This circular mechanism is solved through a recursive process, in which returns on shares are used to cover due interest payments, which in turn determine a further flow of returns for the holders of IFs' shares. This process ends whenever a further round of payments cover less than 10% of due interests.

The stock of deposits that households decide to hold is defined as a fix share of their individual wealth (Equation (24)). An adaptive process based on the difference between the returns on IFs' shares ($rsh_{i,t-1}/Sh_{i,t-1}$) and public bonds ($i^B_{i,t-1}$) determines the desired stock of shares (Equation 25)

$$\Delta Dh^*_{i,t} = Dh^* - Dh_{i,t-1} \tag{26}$$

$$\Delta Sh^*_{i,t} = Sh^*_{i,t} - Sh_{i,t-1} \tag{27}$$

$$\Delta Lh^*_{i,t} = \Delta Dh^*_{i,t} + \Delta Sh^*_{i,t} - s^*_{i,t} \tag{28}$$

The desired flows of deposits and shares simply result from accounting identities (Equations (26) and (27)), with $s^*_{i,t}$ as desired savings. Whenever desired consumption and the desired acquisition of IFs' shares and deposits exceed desired savings, households may apply for a loan from CBs (Equations (28)). If rationed, households are forced to scale down their investment and, if needed, stock of shares. May this not be enough, the same is done with deposits. Finally, consumption can be reduced to a bottom subsistence level. Conversely, if the flow of savings exceeds the target flows of deposits and shares, the surplus is used to deleverage: the stock of loans is diminished. In the event a household succeeds in paying back his whole debt, the surplus will be accumulated in the form of deposits.

4.5 Non-financial Firms

The NFFs sector takes three decisions: (i) how much to invest in real capital; (ii) the amount of deposit holding; (iii) how to finance their investment choices.

As to the investment in real capital (see Equation (29)), it is rather standard and depends positively on the observed profitability of the aggregate sector – as captured by the profit share (Π_{t-1}/Y_{t-1}) – and on the observed capital utilization ($u_{t-1} = Y_{t-1}/K_{t-1}$), with γ_1 and γ_2 being positive parameters. A stochastic element (Zt, with $\gamma_3 > 0$) is included in Equation (29) to capture the influence of entrepreneurs' *animal spirits*. NFFs choose to hold a stock of deposit equal to a fraction η of their capital stock for transaction and precautionary purposes.

$$I_t = \gamma_1 \frac{\Pi_{t-1}}{Y_{t-1}} + \gamma_2 u_{t-1} + \gamma_3 Zt \tag{29}$$

$$D_{f,t} = \eta K_t \tag{30}$$

In order to cover the difference between available funds (*i.e.* net retained profit) and the cost of their investment choices, NFFs revert to external funds. At stage 1 of financial development, this means simply CBs' loans.

$$Pf_t = (1 - \tau_3)\Pi_{F,t} - RL_{f,t} \tag{31}$$

$$\Delta Lf_t = I + \Delta D_{f,t} - Pf_t \tag{32}$$

In stages 2 and 3, they cover an exogenous share χ of their needs for external funds by issuing commercial papers, and revert to the banking sector for the rest.

$$\Delta CP_{f,t} = \chi(I + \Delta D_{f,t} - Pf_t) \tag{33}$$

$$\Delta Lf_t = I + \Delta D_{f,t} - Pf_t - \Delta CP_{f,t} \tag{34}$$

In the event that the demand for commercial papers falls short of the supply, or in the event of credit rationing by CBs, NFFs' deposits will act as buffer stock to accomodate NFFs' investments in real assets.

$$r^{cp} = (1 - \mu) r^f_{t-1} + ø \frac{CP^S_{f,t-1} - CP^D_{if,t-1}}{CP^S_{f,t-1} + CP^D_{if,t-1}} \tag{35}$$

Equation (35) tell us that the return on commercial papers is set as a *mark-down* μ on the previous period interest rate on NFFs' loans, but it can increase (or decrease), at the speed set by the exogenous parameter ø in case of an excess supply (excess demand) in the previous period.

4.6 Government

We assume a very simple rule for public purchases, which are a fixed proportion ξ of the previous-period aggregate consumption.

$$G_t = \xi C_{t-1} \tag{36}$$

The government collects taxes from both firms and households. To cover its deficit, it issues public bonds, which are purchased by CBs and IFs in a recursive process that mimics the auction for public bonds in the US economy. The process (see Equation (37)) starts with the previous-period interest rate. IFs, whose role simulates that of *competitive bidders*, set their demand according to their behavioral rule. CBs, i.e., *non-competitive bidders*, are ready to buy all the remaining bonds issued. In the event the share of bonds that CBs will need to buy to clean the market is higher (lower) with respect to previous period, the interest rate will increase (decrease) of a small amount (ϕ). A new round begins. IFs and subsequently CBs update their demand. The process ends when a further increase of the interest rate leads to an increase in IFs' demand lower than α.

$$i_t^B = i_{t-1}^B[1 + \alpha(\frac{B_{B,t}}{GD_t} - \frac{B_{B,t-1}}{GD_{t-1}})] \tag{37}$$

5 Simulations

The behaviour of the model, in its different stages, is analysed by means of computer simulations.[7] The values of the parameters are listed in Appendix C and, as consuetudinary in the literature, are set through model calibration and based on empirical grounds whenever is possible to identify a direct association with real data. To investigate the behavior of the economy in different scenarios, we run a battery of Monte Carlo experiments. Each is composed by 100 simulations with different seeds for the pseudo-random number generation process, which involves investment and wages. The scenarios correspond to the above mentioned stages of evolution of the financial system:

- a first baseline scenario (*stage 1*) that neither includes commercial papers nor CDOs;
- a second scenario (*stage 2*) that involves commercial papers but it does not consider CDOs;
- a third scenario (*stage 3*) that includes both commercial papers and CDOs;
- a forth scenario (*stage 4*) with CDOs and no commercial papers.

Our findings are reported in Table 5. We implemented a two-sample t-Test for equal means (only on the first moments of Monte Carlo distributions) to assess whether simulation results in the second, third and forth scenarios are statistically different from the first one (*stage 1*). As to scenario 2 (*stage 2*), the test never rejects the null hypothesis except for both the Gini indexes on income and wealth inequality, the stock of loans over GDP, and the spread on NFFs' financial costs. As to scenario 3 (*stage 3*), the test never rejects the null hypothesis except for the stock of public debt over GDP, the Gini indexes, the stock of loans over GDP, the (households sector) debt-to-income ratio, and the stock of IFs' shares over GDP. Finally, in the last scenario (*stage 4*), the test always rejects the null hypothesis except for all GDP shares and the average level of NPLs.

The comparison between the first two scenarios seems to imply that the first increase in complexity - *i.e.*, the introduction of commercial papers - does not exert a major impact on the economy. Albeit mean growth not having passed the t-test, the final GDP level suggests that commercial papers might

[7] In order to get rid of the possible effects of specific initial conditions regarding the balance sheets, we assume all starting stocks but one to be zero. The only exception, namely NFFs' capital stock, is set equal to 1 as this is required to put the economy in motion.

	'STAGE 1' No Securitization No Commercial Paper	*'STAGE 2'* No Securitization Commercial Paper	*'STAGE 3'* Securitization Commercial Paper	*'STAGE 4'* Securitization No Commercial Paper
GDP growth				
- Mean	0.0245	0.0247	0.0249	0.0249
- Standard Deviation	0.0161	0.0160	0.0159	0.0159
- Skewness	-0.0544	-0.0515	-0.0411	-0.0326
- Kurtosis	2.1009	2.1017	2.1063	2.1192
GDP level*	1	1.1809	1.3511	1.4529
GDP shares				
- Consumption	0.5458	0.5460	0.5462	0.5463
- Investment	0.1268	0.1264	0.1261	0.1259
- Public Purchases	0.3275	0.3276	0.3277	0.3278
Public Debt over GDP	2.3859	2.1859	1.9964	1.8924
Gini Indexes				
- Income	0.2798	0.2844	0.2885	0.2908
- Wealth	0.7230	0.7294	0.7348	0.7378
Loan Stock over GDP	1.7236	1.6860	1.7535	1.8038
Spread (in bps) on NFF's financial costs**	143.76	126.28	143.69	153.78
Debt to Income ratio	0.9594	0.9671	0.9812	0.9906
Share Stock over GDP	0.9381	0.9525	0.9658	0.9738
Comm. Papers over GDP	0	0.4177	0.1736	0
Share of Securitized Loans	0	0	0.1707	0.2768
Non-Performing Loans***				
- Mean	0.0116	0.0113	0.0115	0.0117
- Standard Deviation	0.0020	0.0022	0.0024	0.0026
- Skewness	0.8270	0.9057	0.9610	0.9862
- Kurtosis	4.8182	5.2749	5.3817	5.5229
- Crisis Probability****	0.0190	0.0320	0.0410	0.0490

* GDP last period baseline = 1

** Difference between the average financial payments on both loans and comm. papers and the interest rate on bonds

*** Unpaid over due interests on loans

**** Number of cases for which unpaid over due interest on loans is above 5% over total cases

Table 1: Descriptive statistics comparing the various scenarios (A Two-Sample t-Test for Equal Means has been implemented to statistically assess the differences among Monte Carlo averages. See the text for the results).

have had a small positive effect on growth. What emerges manifestly is an advantage for NFFs. The measure of the financing cost, which is the spread between the interests rate NFFs need to pay on their liabilities and the interest rate paid by the government on public bonds, decreases significantly (17 base points), as can be neatly appreciated looking at the bottom right graph of Figure 1. This couples with the fall in the value of the stock of loans over GDP, which includes the debt of both households and NFFs (top left graph Figure 1).[8] These results are perfectly in line with the goal of commercial papers, thanks to which NFFs have access to a cheaper source of external finance and are able to decrease their indebtedness level. A side effect of this financial innovation is the increase in inequality as testified by the two Gini indexes on income (see Figure 1 top right graph) and wealth. This is due to the fact that only wealthier households hold IFs' shares, whose remuneration in this second stage increases, being based on a further, more lucrative asset, next to government bonds. The presence of commercial papers in the

[8]The numerous red crosses show are outliers of the distribution which correspond to crisis events.

economy therefore boosts the rentier-type source of income of the better offs, thus worsening inequality.

A final, perhaps less expected, result regards non-performing loans (NPLs). Crisis probability, as measured by the number of cases in which unpaid interests exceed 5% of all due interest, increases sharply, passing from 0.019 to 0.0320. On top of this, the rise in skewness (from 0.83 to 0.91), coupled with the non-statistical significance of the difference between mean growths of NPLs, indicates that NPLs are much more right-skewed in scenario 2. The explanation lies in the behavior of households. Indeed, the higher remunerativeness of shares increases share holders' disposable income and their consumption with it. This leads low-income households (which are those needing loans to meet their consumption and portfolio choices) to get more indebted to keep-up with the increased average level of consumption, hence increasing the risk of default on the accumulated debt.

Moving to scenario 3 (*stage 3*), the impact of financial development appears more significant with the introduction of securitization. The final level of GDP suggests that this new financial practice may be beneficial for economic growth. Debts dynamics, however, completely differ from the previous scenario. In Section 3, we saw how securitization eases CBs' credit supply. This more than counterbalance the effects of commercial papers on total private indebtedness (i.e., the stock of loans over GDP), which not only increases with respect to the previous scenario (from 1.68 to 1.75) but it is also higher than in the baseline (1.73), as shown in Figure 1, top left graph. Also, due to the fact that commercial papers and CDOs are alternative choices in IFs portfolio allocation, the addition of CDOs leads to a significant decrease of the amount of commercial papers circulating in the economy, which fall from 42% to 17% of the GDP. A direct consequence of such financial development is the loss of commercial papers-related advantages for NFFs. Indeed, the difference in the spread between NFFs' financial costs and government bonds in scenario 3 and in the baseline is not statistically significant.

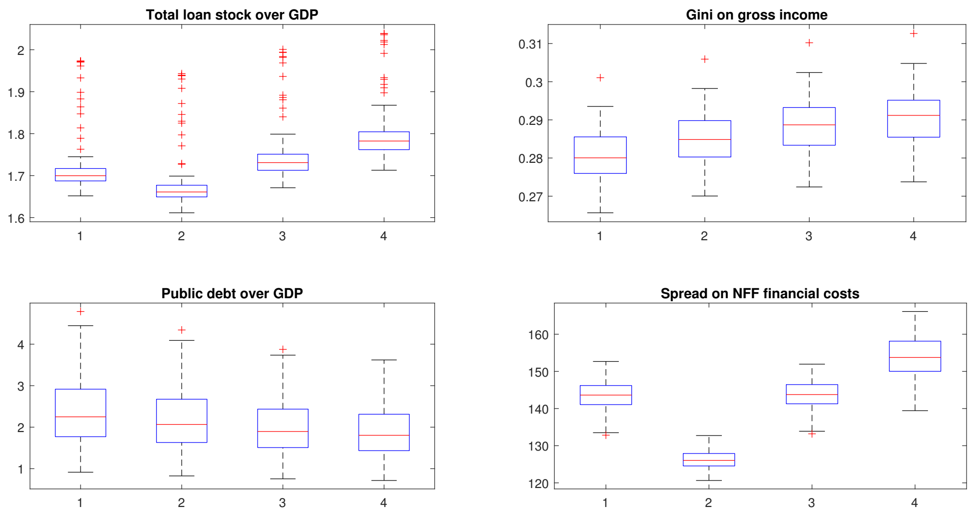

Figure 1: *Box plots for selected variables.* Top left: total private loan stock over GDP; top right: Gini index on gross households income; bottom left: public debt over GDP; bottom right: spread between the interest rate on public bonds and the weighted average interest rate that firms need to pay on their liabilities. The numbers from 1 to 4 on the horizontal axis indicate the stages.

As required by macro-accounting (sectoral balances) relations, in our closed economy a rise in the private level of indebtedness implies a reduction in public indebtedness. The ratio of public debt over GDP decreases from 2.39 in the baseline scenario to 2.00 in scenario 3 (see bottom left graph, Figure 1).

On top of having an impact on the credit market, the introduction of CDOs also affects the financial market. Indeed, CDOs represent an additional high-yield asset in IFs' portfolios. Accordingly, IFs' shares become even more remunerative, so that the stock of IFs' shares held by households rises, with respect to GDP, from 0.94 to 0.96. The increasing degree of financialization of the economies goes hand-in-hand with rising crisis probability, which further increases from 0.032 in scenario 2 to 0.041 in scenario 3. So does the skewness of NPLs. This finds a double explanation in this scenario. On the one hand, CDOs increase the remunerativeness of IFs' shares', so that the dynamics already observed in scenario 2 gets even more pronounced. On the other hand, securitization makes credit creation easier, so that even less 'creditworthy' borrowers may now get access to CBs loans. Last but not least, in the third stage of financial evolution, a reinforcing dynamics kicks in. When households start defaulting, the remunerativeness of CDOs falls and this may hamper the ability of other households to meet their financial obligations, as they see their financial income decreased. This two-sided effects of securitization, one linked to borrower and the other to financial investors, explains also the rise in inequality. More households get indebted and have a further monetary outflows, as they need to meet their financial commitments. This is mirrored by an increase in the financial inflow for share holders, which see their rentier-type income increase.

Moving to the last scenario (*stage 4*), all results are qualitative coherent with the second stage of financial development but increase in magnitude. Securitization, which passes from 17% to 28% of banks loans, has a positive effect on growth and decreases public indebtedness. This comes at the expenses of an increase in income and wealth inequality, and a rise of private indebtedness, as portrayed in Figure 1. Most importantly the probability of a crisis to occur peaks (0.049). The causal links (as exemplified by the rise in the skewness) are the same as in the previous scenarios.

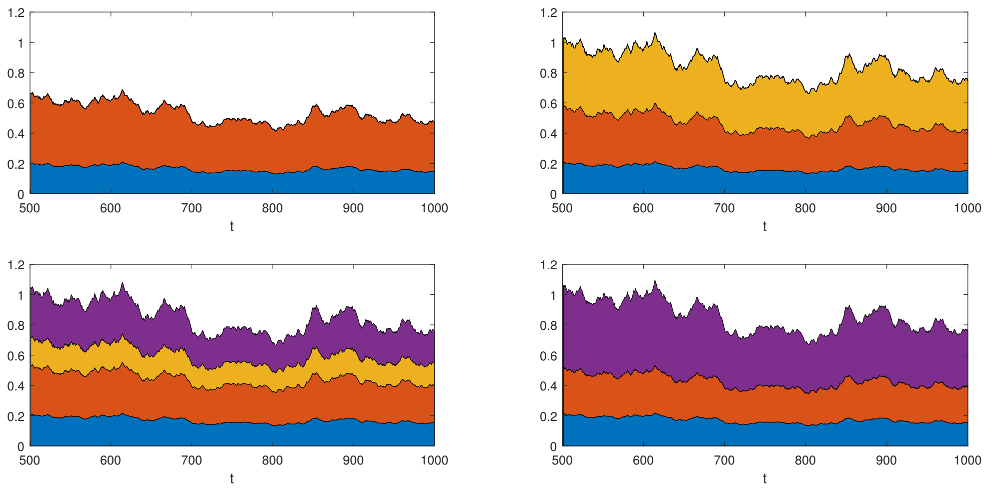

Figure 2: *IFs' balance sheet composition over GDP*. The *area plot* shows how the composition of IFs' balance sheet (*blue* for deposits; *orange* for government bonds; *yellow* for commercial papers; *purple* for CDOs) changes in the four stages, top left being *Stage 1*, top right *Stage 2*, bottom left *Stage 3*, bottom right *Stage 4*.

The impacts of higher degrees of financial complexity (with respect to the baseline), both in positive (e.g. growth) and negative (e.g. crisis probability) terms, increase in each of the four stages and have their acme in the economy whose financial system specialises on more complex financial products (stage 4). Indeed, what seems to matter the most for our results is the composition of IFs' balance sheet, as portrayed in Figure 2. The higher the quota of CDOs in the financial system, the stronger the simulation results. A larger presence of more complex financial instruments like CDOs (Figure 2, bottom right) has a greater effect than a higher level of variety of financial products (bottom left). Our results, therefore, can be considered more in line with the second of the two dimensions of financial complexity mentioned in Section 2. The increase in financial products' complexity exerts stronger effects than the increase in the variety of assets traded in the financial systems. This is not only with respect of *stage 2*, which presents the same level of variety in financial products, but also with respect to *stage 3*, which is the one with the highest variety, or we may say, widest *(financial) production space*.

Finally, our results question the view of higher degrees of financial developments having plain positive impacts on the economy (Levine, 1997). On the one hand, the capacity of higher degrees of financial complexity of fostering growth thanks to finance-led consumption, as described by Boyer (2010), is confirmed by the model. The same holds true for the rise of credit associated with CDOs. On the other hand, however, just as described by Boyer (2010) himself and Russo et al. (2016), a system in which high levels of consumption are sustained by the rising indebtedness of households, in the context of increasingly unequal economies, is bound to be prone to financial fragility. To better appreciate under this perspective the results of our simulations, it is important to keep in mind that some features of our model mitigate the effects of a crisis. Indeed, we assume the aggregate sectors not to go bankrupt. Nonetheless, the economic system with CDOs and without commercial papers is the one experiencing not only the highest growth but also the most severe and frequent crises.

6 Concluding remarks

Since the end of the 1970s, financial systems have gone through structural changes often leading financial actors to depart from their traditional role as support institutions of real-side economic activity. The spread of financial engineering and the proliferation of complex financial products represent glaring outcomes of these changes. In this paper, we proposed an AB-SFC macro model aimed at studying how increasing financial complexity may affect economic growth and macroeconomic stability. Differently from the literature on product complexity *à la* Hidalgo and Hausmann (2009), financial complexity does not seem to be always related to better economic performances. Indeed, simulation results show that more complex financial systems may well result in higher economic growth rates but at the cost of more macroeconomic instability, thus making the system more crisis-prone. Moreover, while Hartmann et al. (2017) find that more economic complexity tends to reduce inequality, financial complexity rather works the other way around. However, this is not surprising giving that growing inequality boosts the creation of bank (credit-)money through the loans provided to households and NFFs that, at the same time, constitute the raw material used in the securitization process for the production of new structured financial products eventually sold to rentiers. Accordingly, financial payments on bank loans, typically coming from low-to-middle income households, feed rich households who invested in high-return financial products provided by financial intermediaries, resulting in higher economic growth (because of a wealth-effect for the rich and a stable or even rising consumption for the poor despite declining real incomes) but also in a more unequal and financial unstable economic system.

Yet, in order to assess the relationship between financial complexity and macroeconomic performance, we need to clarify in which way we are measuring complexity. The model we proposed features four stages that we can relate to the composition of the shares that investment funds (IFs) sell to (rich) households. In the first stage, namely the baseline scenario, shares only include government bonds, thus resulting in a relatively low yield. In the second stage, we introduce commercial papers that make the returns on shares increase. The third stage adds CDOs and the remuneration of IFs' share rises even more. The forth stage only considers CDOs, while commercial paper are absent, resulting in the highest returns on share. While one could be tempted to consider that the third stage is the more financially complex, due to a larger number of financial products being implicitly included in the IFs' shares, an alternative interpretation is that the complexity of the financial system mainly depends on the complexity of certain financial products (incorporating more knowledge and capabilities), and their degree of diffusion in the financial system. Given that CDOs, namely the most complex financial products in our simulated economy, are more widespread in the forth than in the third stage, the former should be considered the most complex case among the four involved in our analysis.

While measuring complexity based on the varieties of financial products could result in a non-linear relationship between financial complexity and economic growth, taking into account the complexity of certain products may lead to a different interpretation according to which increasing financial complexity makes the economy grow faster (whereas becoming more crisis-prone). Which one is the correct way to measure financial complexity? Based on simulation results, we are inclined to think that what matters most is the role played by more complex financial products like CDOs (as in the forth stage of our simulation analysis), and then that as financial complexity increases we should expect more economic growth as well as more inequality and financial instability. Although we do not have a definitive answer, we hope that our findings may stimulate a debate on measuring financial complexity, thus opening the field to new theoretical and empirical contributions in this area of investigation.

Appendix A: Matrices

In this appendix we include the balance sheet and the transaction matrix of the economy. *Stage 4* is obtained setting to zero all variables related to commercial papers.

	Households	Banks	SPV (stage 3)	IF	Firms	Gov	Total
Deposits	$+D_H$	$-D$	$+D_{IF}$	$+D_{SPV}$	$+D_F$		0
Capital					$+K$		$+K$
Shares	$+Sh$			$-Sh$			0
Bonds		$+B_B$		$+B_{IF}$		$-B$	0
Loans	$-L_H$	$+(1-z)L$	$+zL$		$-L_F$		0
Stage 2: a new asset (commercial *papers*) is included; SPV is still not included in this scenario							
Papers				$+CP$	$-CP$		0
Stage 3: a further asset (Derivatives) and a new sector (SPV) add to the model							
Derivatives			$-CDO$	$+CDO$			0

Table 2: Aggregate Balance Sheet (Initial Situation)

	Households	Banks		SPV(Stage 3)		IF		Firms		Govt.	Σ
		CA	KA	CA	KA	CA	KA	CA	KA		
TRANSACTIONS											
Consumption	$-C$	0	0	0	0	0	0	$+C$	0	0	0
Publ. Exp.	0	0	0	0	0	0	0	$+G$	0	$-G$	0
Investment	0	0	0	0	0	0	0	$+I$	$-I$	0	0
Wages	$+W$	0	0	0	0	0	0	$-W$	0		0
Taxes	$-T_H$	0	0	0	0	0	0	$-T_F$	0	$+T$	0
Int. on Loans	$-r_h Lht-1$	$+r(1-z)L$	0	$+rzL$	0	0	0	$-r_f Lf_{t-1}$	0	0	0
Return on Shares	$+RSH$	0	0	0		$-RSH$	0	0	0	0	0
Int. on Bonds	0	$+RB_B$	0	0	0	$+RB_{IF}$	0	0	0	$-RB$	0
Dividends	0	$-Div_B$	0	0	0	$+Div_B$	0	0	0	0	0
Stage 2											
Return on papers	0	0	0		0	$+r_{cp}CP$	0	$-r_{cp}CP$	0	0	0
Stage 3											
Return on Deriv.	0	0	0	$-fCDO$	0	$+fCDO$	0	0	0	0	0
Saving and Profits	$+\Pi_H$	0	0	0	0	$-\Pi_{IF}$	$+\Pi_{IF}$	$-\Pi_F$	$+\Pi_F$	0	0
Δ STOCKS											
Deposits	$-\Delta D_H$	0	$+\Delta D$	0	0	0	$-\Delta D_{IF}$	0	$-\Delta D_F$	0	0
Loans	$+\Delta L_H$	0	$-\Delta(1-z)L$	0	$-\Delta zL$	0	0	0	$+\Delta L_F$	0	0
Shares	$-\Delta Sh$	0	0	0	0	0	$+\Delta Sh$	0	0	0	0
Bonds		0	$-\Delta B_B$	0	0	0	$-\Delta B_{IF}$	0	0	$+\Delta B$	0
Stage 2											
Papers	0	0	0	0	0	0	$-\Delta CP$	0	$-\Delta CP$	0	0
Stage 3											
Derivatives	0	0	0	0	$+\Delta CDO$	0	$-\Delta CDO$	0	0	0	0
Total	0	0	0	0	0	0	0	0	0	0	0

Table 3: Aggregate Transaction Flow Matrix

Appendix B: Equations

Hereafter, we present the list of equations. The scenario *Stage 4* is obtained setting to zero all variables related to commercial papers.

Commercial Banks

$$E[r^h_{i,t}] = i^B_{t-1} + \iota i^B_{t-1}\frac{Lh_{i,t-1} + \Delta Lh^*_{i,t}}{yn_{i,t}} \tag{1}$$

$$\text{if } m^*_{i,t} < \psi_t \text{ and } \Delta Lh_{i,t} = \Delta Lh^*_{i,t} \text{ then } r^h_{i,t} = E[r^h_{i,t}] \tag{2}$$

$$E[r^f_t] = r^f_t = i^B_{t-1} + \iota i^B_{t-1}\frac{Lf_{t-1} + \Delta Lf^*_t}{Pf_t} \tag{3}$$

$$mh^*_{i,t} = E[r^h_{i,t}]\frac{Lh_{i,t-1} + \Delta Lh^*_{i,t}}{yd_{i,t}} \tag{4}$$

$$mf^*_{i,t} = E[r^f_{i,t}]\frac{Lf_{i,t-1} + \Delta Lf^*_{i,t}}{Pf_t} \tag{5}$$

$$\psi_t = max\left(\bar{\psi}, \quad \bar{\psi} + \omega(k_{t-1} - \overline{k})\right) \tag{6}$$

$$k_{B,t} = \frac{B_{B,t}}{[L_t + B_{B,t}]} \tag{7}$$

$$k_{B,t,STAGE3} = \frac{B_{B,t}}{[(1 - z_t)L_t + B_{B,t}]} \tag{8}$$

$$B_{B,t} = GD_t - B_{IF,t} \tag{9}$$

$$RL^h_{B,t}t = \sum_{i=1}^{N}(1 - z_{t-1})[r^h_{i,t-1}\widetilde{Lh_{i,t-1}}] \tag{10}$$

$$RL^f_{B,t} = (1 - z_{t-1})[r^f_{t-1}Lf_{t-1}] \tag{11}$$

$$RB_{B,t} = i^B_{t-1}B_{B,t-1} \tag{12}$$

$$\Pi_{B,t} = RL^h_{B,t} + RL^f_{B,t} + RB_{B,t} \tag{13}$$

Stage 3

$$CDO_{if,t} = z_t\sum_{i=1}^{N} Lh_{i,t} + z_t Lf_t \tag{14}$$

$$z_t = min(1, \frac{CDO_{IF}}{L_t}) \tag{15}$$

$$r^{cdo}_t = \frac{z_t[(\sum_{i=1}^{N} r^h_{i,t-1}\widetilde{Lh_{i,t-1}}) + r^f_{t-1}Lf_{t-1}]}{CDO_{if,t-1}} \tag{16}$$

Investment Funds

$$
\begin{aligned}
D_{IF,t} &= \sigma SH_t && (17)\\
q^b_{if,t} &= q^b_{if,t-1}(1-\beta[(r^{cdo}_t - i^B_t) - (r^{cdo}_{t-1} - i^B_{t-1})] && (18)\\
B^D_{IF,t} &= q^b_{if,t} SH_t(1-\sigma) && (19)\\
CDO^D_{IF,t} &= SH_t(1-\sigma) - B_{IF,t} && (20)\\
CDO_{IF,t} &= min(z_t L_t, CDO^D_{IF,t}) && (21)\\
RCDO_{IF,t} &= r^{cdo}_{t-1} CDO && (22)\\
RB_{IF,t} &= i^B_{t-1} B_{IF,t-1} && (23)\\
RSH_t &= RCDO_{IF,t} + RB_{IF,t} && (24)\\
rsh_{i,t} &= RSH \frac{sh_{i,t-1}}{SH_{t-1}} && (25)\\
q^b_{if,t} &= min\big\{0.1, q^b_{if,t-1}[1-\beta(i^B_{t-1} - i^B_t)] && (26)\\
D_{IF,t} &= (1-q^b_{if,t})SH && (27)\\
D_{IF,t} &= \sigma SH_t && (28)\\
B^D_{IF,t} &= q^b_{if,t} SH_t(1-\sigma) && (29)
\end{aligned}
$$

stage 2

$$
\begin{aligned}
q^b_{if,t} &= min\big\{0.1, q^b_{if,t-1}[1-\beta[(r_{cp} - i^B_t) - (r_{cp,t-1} - i^B_{t-1})]\big\} && (30)\\
CP^D_{IF,t} &= SH_t - D_{IF,t} - B^D_{IF,t} && (31)
\end{aligned}
$$

stage 3

$$
\begin{aligned}
q^b_{if,t} &= min\big\{0.1, q^b_{if,t-1}[1-\beta[(rr - i^B_t) - (rr - i^B_{t-1})]\big\} && (32)\\
CP^D_{IF,t} &= SH_t - D_{IF,t} - B^D_{IF,t} && (33)\\
CDO^D_{if,t} &= (SH - D_{IF,t} -) min\big\{0.1, q^b_{if,t-1}[1-\beta[(rr - i^B_t) - (rr_{t-1} - i^B_{t-1})]\big\} && (34)\\
RA^D_{IF,t} &= SH_t - D_{IF,t} - B^D_{IF,t} && (35)\\
CDO^D &= RA^D * \frac{r^{cdo}_t}{r^{cdo}_t + r^{cp}_t} && (36)
\end{aligned}
$$

Special Purpose Vehicles

$$
z_t \sum_{i=1}^{N} Lh_{i,t} + z_t Lf_t = CDO_{if,t} \tag{37}
$$

$$
z_t = min(1, \frac{CDO_{IF}}{L_t}) \tag{38}
$$

$$
r^{cdo}_t = \frac{z_t[(\sum_{i=1}^{N} r^h_{i,t-1} \widetilde{Lh_{i,t-1}}) + r^f_{t-1} Lf_{t-1}]}{CDO_{if,t-1}} \tag{39}
$$

Households

$$yd_{i,t} = w_{i,t} - tax^w_{i,t} + rsh_{i,t} - r^h_{i,t-1}\widetilde{Lh}_{i,t-1} \tag{40}$$

$$tax^w_{i,t} = \tau^w_j w_{i,t} \begin{cases} \text{if } w_{i,t} < \hat{w}_t & \Longrightarrow tax^w = \tau^w_1 * w_{i,t} \\ \text{if } w_{i,t} \geq \hat{w}_t & \Longrightarrow tax^w = \tau^w_1 * \hat{w} + \tau^w_2 * (w_{i,t} - \hat{w}_t) \end{cases} \tag{41}$$

$$c^*_{i,t} = c_y yd_{i,t} + c_n \bar{c}_{t-1} \tag{42}$$

$$s^*_{i,t} = yd_{i,t} - c^*_{i,t} \tag{43}$$

$$Dh^*_{i,t} = \eta WH_{i,t-1} \tag{44}$$

$$\Delta Dh^*_{i,t} = Dh^* - Dh_{i,t-1} \tag{45}$$

$$Sh^*_{i,t} = Sh_{i,t-1}[1 + \sigma(\frac{rsh_{i,t-1}}{Sh_{i,t-1}} - i^B_{i,t-1})] \tag{46}$$

$$\Delta Sh^*_{i,t} = Sh^*_{i,t} - Sh_{i,t-1} \tag{47}$$

$$\Delta Lh^*_{i,t} = \Delta Dh^*_{i,t} + \Delta Sh^*_{i,t} - s^*_{i,t} \tag{48}$$

$$\text{if } m^*_{i,t} < \psi_t \Longrightarrow \begin{cases} \Delta Lh_{i,t} = & \Delta Lh^*_{i,t} \\ \Delta Sh_{i,t} = & \Delta Sh^*_{i,t} \\ \Delta Dh_{i,t} = & \Delta Dh^*_{i,t} \\ c_{i,t} = & c^*_{i,t} \end{cases} \tag{49}$$

$$\text{if } m^*_{i,t} > \psi_t \Rightarrow Lh_{i,t} = 0 \Rightarrow \begin{cases} \text{if } s^*_{i,t} > \Delta Dh^*_{i,t} \Rightarrow \begin{cases} \Delta Sh_{i,t} > 0 \\ \Delta Sh_{i,t} = s^*_{i,t} - \Delta Dh^*_{i,t} \\ \Delta Dh_{i,t} = \Delta Dh^*_{i,t} \\ c_{i,t} = c^*_{i,t} \end{cases} \\ \text{if } s^*_{i,t} < \Delta Dh^*_{i,t} \text{ and } s^*_{i,t} + Sh_{i,t-1} > \Delta Dh^*_{i,t} \Rightarrow \begin{cases} \Delta Sh_{i,t} < 0 \\ \Delta Sh_{i,t} = s^*_{i,t} - \Delta Dh^*_{i,t} \\ \Delta Dh_{i,t} = \Delta Dh^*_{i,t} \\ c_{i,t} = c^*_{i,t} \end{cases} \\ \text{if } s^*_{i,t} + Sh_{i,t-1} < \Delta Dh^*_{i,t} \text{ and } s^*_{i,t} + Sh_{i,t-1} > 0 \Rightarrow \begin{cases} Sh_{i,t} = 0 \\ \Delta Sh_{i,t} = -Sh_{i,t-1} \\ \Delta Dh_{i,t} > 0 \\ \Delta Dh_{i,t} = s^*_{i,t} + Sh_{i,t-1} \\ c_{i,t} = c^*_{i,t} \end{cases} \\ \text{if } s^*_{i,t} + Sh_{i,t-1} < 0 \text{ and } s^*_{i,t} + Sh_{i,t-1} + Dh_{i,t-1} > 0 \Rightarrow \begin{cases} Sh_{i,t} = 0 \\ \Delta Sh_{i,t} = -Sh_{i,t-1} \\ \Delta Dh_{i,t} < 0 \\ \Delta Dh_{i,t} = s^*_{i,t} + Sh_{i,t-1} \\ c_{i,t} = c^*_{i,t} \end{cases} \\ \text{if } s^*_{i,t} + Sh_{i,t-1} + Dh_{i,t-1} < 0 \Rightarrow \begin{cases} Sh_{i,t} = 0 \\ \Delta Sh_{i,t} = -Sh_{i,t-1} \\ Dh_{i,t} = 0 \\ \Delta Dh_{i,t} = -Dh_{i,t-1} \\ c_{i,t} \geq \tilde{c} \\ c_{i,t} = yd_{i,t} + Sh_{i,t-1} + Dh_{i,t-1} \end{cases} \end{cases} \tag{50}$$

Firms

$$C_t = \sum_{i=1}^{N} c_{i,t} \tag{51}$$

$$I_t = \gamma_1 \frac{\Pi_{t-1}}{Y_{t-1}} + \gamma_2 u_{t-1} + \gamma_3 Zt \tag{52}$$

$$Z_t = \gamma_4 Z_{t-1} + U(0, 0.1) \tag{53}$$

$$K_t = (1-\delta) K_{t-1} + I \tag{54}$$

$$Y_t = C_t + I_t + G_t \tag{55}$$

$$\Pi_{F,t} = C_t + I_t + G_t - W_t \tag{56}$$

$$\pi_t = \frac{\Pi_{F,t}}{Y_t} \tag{57}$$

$$D_{f,t} = \eta K_t \tag{58}$$

$$Pf_t = (1-\tau_3)\Pi_{F,t} - RL_{f,t} \tag{59}$$

$$\Delta Lf_t = I + \Delta D_{f,t} - Pf_t \tag{60}$$

$$\tag{61}$$

Stage 2 and 3

$$\Delta CP_{f,t} = \chi(I + \Delta D_{f,t} - Pf_t) \tag{62}$$

$$\Delta Lf_t = I + \Delta D_{f,t} - Pf_t - \Delta CP_{f,t} \tag{63}$$

$$r^{cp} = (1-\mu) r^f_{t-1} + \text{\o} \frac{CP^S_{f,t-1} - CP^D_{if,t-1}}{CP^S_{f,t-1} + CP^D_{if,t-1}} \tag{64}$$

Government

$$T_t = \tau_3 \Pi_{F,t} + \sum_{i=1}^{N} \tau^w_j w_{i,t} \tag{65}$$

$$G_t = \xi C_{t-1} \tag{66}$$

$$GDS_t = r^b_{t-1} GD_{t-1} \tag{67}$$

$$\Delta GD_t = G_t - T_t + GDS_t \tag{68}$$

$$GD_t = GD_{t-1} + \Delta GD_t \tag{69}$$

$$i^B_t = i^B_{t-1}[1 + \alpha(\frac{B_{B,t}}{GD_t} - \frac{B_{B,t-1}}{GD_{t-1}})] \tag{70}$$

Appendix C: Parameters

Symbol	*Description*	*Baseline*
T	Number of periods	1000
N	Number of households	1000
τ_1	Lower tax rate on income	0.2
τ_2	Higher tax rate on income	0.4
τ_3	Tax rate on profit	0.5
γ_1	Profit share weight (investment function)	0.2
γ_2	Capacity utilization weight (investment function)	0.01
γ_3	Animal spirit weight (investment function)	0.1
γ_4	Weight of the autoregressive component (investment function)	0.9
η	Precautionary deposits	0.2
β	Weight of CDO/Bond spread in IF portfolio allocation	10
σ	Sensitivity to return on share/base rate spread (household portfolio choice)	1
ϕ	Speed of adjustment in public bonds' bids	0.01
ω	Sensitivity to distance from desired share of bonds (banks credit rationing)	0.3
ι	Sensitiveness to the debt service ratio (interest rate setting)	1
ϵ	Tolerance in recursive processes (bonds and return on share determination)	0.1
$\bar{k}$	Desired share of bonds in banks' portfolio	0.4
c_y	Propensity to consume out of income	0.8
δ	Capital depreciation rate	0.03
λ_1	Wage bill's determination out of capital	0.15
ξ	Public purchases' determination out of capital	0.6
θ	Log-standard deviation (wage distribution)	0.5
c_{sub}	Subsistence consumption	0.25
c_n	'Socially determined' consumption	0.2

Table 4: Parameter setting

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