An Agent-Based Financial Network Modeling

Based on Systematic Trust

An Agent-Based Financial Network Modeling

Based on Systematic Trust

By

Aghigh Farhadicheshmehmorvari, M.A.

A Thesis Submitted to the school of Graduate Studies in Partial Fulfilment of the requirements for the Degree of Master of Science in Computational Science and Engineering

Master of Science (2021)

McMaster University

Hamilton, Ontario

School of Computational Science and Engineering

TITLE: An Agent-Based Financial Network Modeling Based on Systematic Trust

AUTHOR: Aghigh Farhadicheshmehmorvari, M.A.

SUPERVISOR: Professor Matheus D. R. Grasselli

NUMBER OF PAGES:119

Abstract

In this research project, we introduced an agent-based banking system based on systematic trust. The features of the model and attributes of the agents are defined and analyzed precisely, and the results are explained. Some of this model's features include but are not limited to considering the savings system, insurance deposits, the impact of the Central Bank loans, and correlated regional shocks in a banking system. Different Scenarios are applied. The results indicate that by having the Central Bank loans in the model, the banking system experience dramatically fewer failures. Even if some correlated regional shocks occur, the system can be more stable than when the Central Bank does not exist. Moreover, the trust system establishes and forms during different financial periods based on the bank's clients' point of view about the bank's performance as an intelligent system to attract more capital for the system by providing some information for the agents to join the more prestigious banks.

Conclusively, in the early financial periods, banks need more financial supports to support the clients' deposits and to make their reputation for attracting more clients; hence the Central Bank is an essential parameter to help the banks to be more stable and supports the banks in their early stages of growth. The Central Bank loans would be significantly important in panic times, such as regional correlated preference shocks.

Acknowledgments

I would like to express my gratitude to my supervisor Prof. Matheus Grasselli, who has provided insightful guidance and valuable support with writing this thesis and has taught me many valuable lessons for researching systematic banking issues.

I would also like to thank Prof. Traian Pirvu, Prof. David Lozinski, and Prof. Benjamin M. Bolker, who are allocating time to be on my thesis examining committee.

Finally, I would like to thank my family, who has supported me and has encouraged me to continue my education in this field of science.

To my family

Contents

Table of Figures

Chapter 1

1. Introduction

This thesis investigates the adjustment and modifications of banking, mainly using a systematic trust, and has proposed a new model. For this aim, various study fields were applied, including Financial Mathematics, Economics, Management, and Psychology. Moreover, a graphic user interface layout has been programmed for this model in NetLogo.

In this thesis, the banking industry is seen as it is in reality as much as possible. The future is found to evolve out of the past as old banks are progressively adapted to meet changing problems and try to protect their reputation, their portion of the market, and protect the people's deposits and grow smoothly and provide economic stability for themselves.

It sets forth the relations that exist between the people, banks, and the central bank in a model based on systematic trust regarding investigating banks behavior in the various situations by having deposit account, saving account, providing various rates, asking for the central bank loan, and participating in the central bank insurance system.

This model also considers some attributes for people's and managers' behavior and explains some rules for controlling the banking industry by the bank managers and the central bank.

The code has provided for the model has this option to turn off or on the policies and rules and compare the results in various cases, which makes the model comprehensive as it can be used for different societies and economics for investigating the pattern of depression or growth and checking the possibility of bank failures. However, the model can be fortified with more details and options in future studies.

A banking institution is a critical part of the economy, which provides a variety of services for individuals and businesses. Due to the critical role of the banking system in the economy, and the vital role of systematic trust and brand reputation of financial institutions in selling their services to the people, it is essential to study the banking system based on systematic trust to investigate failure and success of banks and people behaviors for choosing a bank in this system. In this regard, a banking system model based on systematic trust and the individuals' decision-making process in a financial period is introduced in this research thesis, and finally, various scenarios are analyzed, and the results are discussed.

To this aim, in chapter 2, the work's literature is reviewed, and in chapter 3, the introduced model is explained. Then, in chapter 4, different scenarios are examined for the introduced model, and the results are discussed. Finally, in chapter 5, some suggestions for future research and more investigation ideas are provided.

Chapter 2

2. Literature Review

In this chapter, some of the previous studies related to the research topic are reviewed to provide more information about our work literature.

2.1. Agent-based banking system

In this research, an agent-based model is used to simulate a banking system based on systematic trust. To this aim, some literature related to the systematic banking agent-based model is reviewed in this part

An agent-based model is a computational method for simulating a process that was occurred by the interactions of autonomous agents and different variables based on a definition by Borrill and Tesfatsion (2010). Indeed, an Agent-Based Model or ABM is a modeling method to show systems as a collection of autonomous interacting entities or agents with encapsulated functionality working together and operating in a computational world.

In this definition, two things are very important in an agent-based model, first, transferring the information or data between agents and the agents' response to this information, and these acts shape a system built based on every entity that exists in the system.

Moreover, Howitt (2008) explained that agents have their own behavioral rules that can help them to act based on the rules independently from the other agents. In other words, using an agent-based model help to model an intelligent system that agents' activities formed the system.

Grasselli and Ismail (2013) worked on an agent-based model for bank formation. They introduced a simple framework of systematic banking considering a natural need in a society of individuals with heterogeneous liquidity preferences. They used 2-dimensional cellular automation and two types of assets available for investment and banking systems to implement basic insights of both the Diamond and Dybvig model, which was introduced by Diamond and Dybvig (1983) for bank formation and the model introduced by Allen and Gale (2000) for interbank links. Also, they considered liquidity preference shocks for the individuals on a periodical basis. This model provided some features like introducing some strategies for deciding to join a bank or staying in society, interbank connections, and bank failure occurrences.

The article of Grasselli and Ismail (2013) will be used in this research project to implement the bank formation process and some parts of decision making regarding joining a bank or not, bank's learning process, bank run, and bank failure.

Furthermore, some parts of this article, including but not limited to the agents' liquidity preferences, market rules like payoffs, shocks, etc. will be used as a basic framework to shape our systematic banking model, and some of these features will be developed in chapter 3 of this research project.

2.2. Systematic trust

In this section, the previous studies about systematic trust in financial systems were reviewed. Then we use these concepts in our agent-based model.

Indeed, systematic trust is a reputation that a bank obtained through its banking history by working as a successful financial institution from its clients' point of view. The word "Successful" could be defined in many ways, but in this research and for the banking system, it is considered a bank that could pay its clients on time and without help. Systematic trust is not a new concept in the banking system, and this concept existed even from the 18th century. In a book named Lombard Street written by Walter Bagehot with a new introduction by Frank C. Genovese (1962), the systematic trust in the banking industry was explained in detail for the 17th, 18th, and 19th centuries.

This is a very comprehensive book in the history of systematic trust in the banking system in which reviews the history of the banking industry and systematic trust, mainly in European countries such as England, France, and Germany.

In this book, Bagehot and Genovese mentioned systematic trust, the banking industry and bank management, bank run, and panic conditions in detail in this book. For the bank run, they mentioned that "in a panic, some bank clients ask for their deposits. If any large fraction of that money were demanded, our banking system and our industrial system too would be in great danger."

In another part of that, it was mentioned the managing system of the money; he believed that the banking system, though curious and peculiar, maybe worked safely; Also, he mentioned that "we must study it. The money will not manage itself, and Lombard street has a great deal of money to manage." Then he mentioned that "all the banks in Lombard Street (and bill brokers are for this purpose only a kind of bankers) hold much money belonging to other people on running account and on deposit. In continental language, Lombard Street is an organization of credit" then he refers to the trust system by defining credit as a sign of trust, which is the most important part of his book, and in all the chapters, he explained everything based on this concept :

"Credit means that a certain confidence is given, and a certain trust reposed. Is that trust justified? And, is that confidence wise? These are the cardinal questions. To put it more simply- credit is a set of promises to pay; will those promises be kept? Especially in banking, where the 'liabilities, or promises to pay, are so large, and the time at which to pay them, if exacted, is so short, an instant capacity to meet engagements is the cardinal excellence."

Moreover, he believes that a good currency system that indicates a powerful trust system will benefit the country, and a bad system could hurt it. This trust and credit bring a reputation for the bank that could be increased if the bank is working well, and it would be decreased if the bank needs help to pay its liabilities on time.

Bagehot (1826-1877) wrote extensively on a wide range of literary, political, and economic subjects, but his main interests lay in the broad field of political economy.

Moreover, in a study conducted by Buckley and Nixon (2009), the authors defined reputation as "what is generally said or believed about a person's or thing's character." They explained that people need to trust those with whom they deposit money. They examined the concept of reputation and its role in contemporary banking. Also, they explained the importance of reputation in banking systems.

Furthermore, another study was conducted by Babic-Hodovic et al. (2011). They investigated the effect of the banks' reputation on the customer decisions to choose a bank or not. They found out that the reputation of a bank is very significant in customer choice. They mentioned that this reputation helps customers decide "whether to buy services or not when they can not assess the quality before buying."

In this study, they investigated and explained the importance of the level of trust or reputation for the customers, more specifically when they want to use a corporation that provided services to its customer like a bank. In another part of their study, they explained that the customers' information about a bank is mainly based on trust and the bank's reputation as it is difficult to assess essential service features. Furthermore, they found out "banks' corporate reputation increases benefits in the buyer perceived value concept and when a company deals with a bank whose reputation is superior compared to the competition, fewer resources need to be allocated for maintaining and supervising the mutual relationship."

Besides, in a study conducted by Husseini et al. (2019), the author mentioned that reputation is an essential factor for banks to be the main choices of customers, and if there is any rumors such as bank going bankrupt or bank can not work well, could decrease the banks' reputation. In this case, people will rush to withdraws their deposits.

Other instances of research about this issue are Fombrun (1996), Fang (2005), Morrison and White (2010), Jana Grittersova (2014), Knell and Helmut (2015), and Lorena (2018).

Therefore, the bank's reputation or trust has a very long history, and it should be considered in the structure of the banking system. In part 2.3, the concepts of Maslow's Hierarchy of Needs and the Theory of Subjective Value are reviewed to define why people consider a bank's reputation in their decisions.

2.3. Maslow's hierarchy of needs and value

Abraham Harold Maslow (1943), a psychologist, introduced a hierarchy of needs based on behavioral studies in his paper "A Theory of Human Motivation" in Psychological Review. Maslow Introduced this theory based on universal human needs, and it shows that each person has a hierarchy of needs, including physiological, safety, social, esteem, and self-actualization needs.

Let's consider a pyramid for Maslow's hierarchy of needs. Most fundamental needs or basic needs are located at the bottom, and the psychological needs are located in the middle of the pyramid. The need for self-actualization is located at the top. Indeed, Maslow believed that people's most basic needs must be met before they become motivated to achieve higher-level needs.

For example, this theory states that humans are compelled to fulfill these physiological needs first to pursue intrinsic satisfaction on a higher level; however, it has to be mentioned that the human brain is a complex system and can parallel work on different needs. Hence, it is possible that various levels of Maslow's hierarchy can occur at the same time.

In his works, Maslow mentioned that the possibility of occurring the different levels of motivation exists at any time in the human mind. However, he mainly focused on defining the basic types of motivation and the order in which they would tend to be met.

Figure 2.1 below shows this pyramid of needs in which the first group is Basic needs, and this group has two levels, including physiological needs and safety needs, respectively. The second group is related to Psychological needs, and this group has two levels, including belongingness and love needs, and esteem needs, respectively; and the last group is for self-fulfillment needs, and this group contains self-actualization level.

Based on the theory, the first and foremost needs in each individual are physiological needs that have to be met first, then the second level, then the third level, and so on. The final level is the self-actualization level.

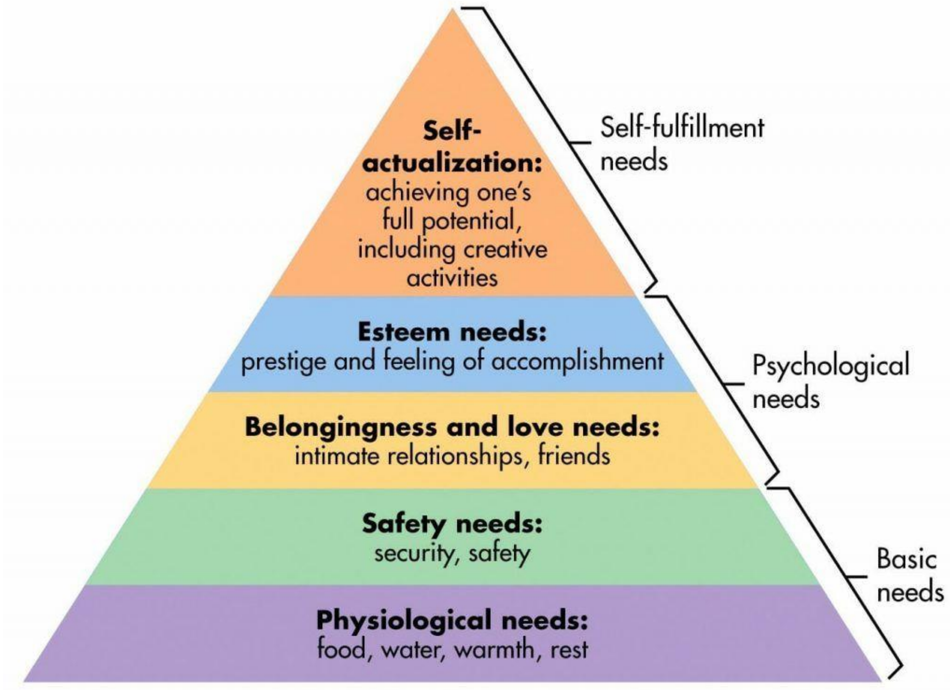

Figure 2. 1. Maslow's Hierarchy of Needs (Picture is from the website: https://www.simplypsychology.org/maslow.html)

Maslow's hierarchy of needs is only one way of finding some human personality features. There are lots of other platforms from other scientists that could be used for the modeling. However, we used this one because this is one of the most popular models that have been used for financial issues previously.

This platform is only used conceptually in our research to find some of the agents' main features in their decision-making process.

Hence, even using other psychological platforms, the same results could be taken as we considered financial issues and the hierarchies' concepts to find some of the main personality features. Furthermore, our model can be updated later for future studies by adding more personality features to that.

Many scientists in various fields of science like economics, financial management, finance, and financial system analysis use Maslow's theory in the hierarchy of needs as a platform to define various features of people in their financial decision-making.

Hence, in our model, based on Maslow's hierarchy of needs logic, which was discussed above, we defined three other attributes for this research that each of them shows one level of the hierarchy and defines the personality of each agent. Several studies have applied Maslow's hierarchy and concluded that this theory has worked well regarding the financial and banking issues, for example :

Samli and Frohlich (1993), in a study, showed that financial services should be defined based on consumer's needs to have both efficiency and effectiveness in a financial system. The authors identified and related seven individual psychological needs for banks' services to Maslow's hierarchy of needs. They demonstrated that banks could optimize their long-term profit using this method.

Moreover, Oleson, M. (2004) explored the relationship between money attitudes and Maslow's hierarchy of needs. The author found out Maslow's needs appear to be strongly related to the money attitudes of evaluation and anxiety. The article Findings supported existing literature and pointed to the importance of understanding money attitudes and level of need satisfaction among individuals and families.

Also, Yu and Fang (2009) use this method in an empirical study to demonstrate the relative impacts of product quality, service quality, and experience quality on customer perceived value and intention to shop in the future for a coffee shop market. The results of this study showed the relative importance of product, service, and experience changes over the income levels and the frequency of consumption.

As well, Cassar (2014) used this method to investigate needs in banks' newspaper advertisements, and Lee and Hanna (2015) examined associations between saving goals and saving behavior from a perspective of Maslow's Hierarchy. They found out self-actualization and retirement/security had the strongest associations with saving behavior.

Drakopoulos and Grimani (2017) studied labor earnings reductions regarding recent Great Recessions and tested the effect of pay cuts on happiness levels based on the psychological model of hierarchical needs. Also, Kautt (2018) offered suggestions to business managers for developing a scheme for financial advisor compensation using the hierarchy of needs theory.

Other scientists worked on the usage of the hierarchy of needs and financial issues like Wei (2013), Rahman et al. (2014), Taujanskaitė et al. (2015), and SITTI (2020). Finally, another important concept that is important to be noted here is the "Subjective Theory of Value."

Base on a definition by Carl Menger (1950), who was an economist in the late 19th century, "The subjective theory of value is a theory of value which advances the idea that the value of a good is not determined by any inherent property of the good, nor by the amount of labor necessary to produce the good, but instead the value is determined by the importance of an individual acting place on a good for the achievement of his desired ends."

This is not the first time that an economist mentioned this kind of value. This theory was developed by Ferdinando Galiani (1728-1787). Later in the 19th century, William Stanley Jevons, Léon Walras, and Carl Menger were the famous economists of the time who defined the modern subjective theory of value. For more information about the value theories, these sources can be studied: Bonaccorsi di Patti (2001), Lichtenstein (2017), and Roncaglia (2017).

Therefore, customers' behavior about a financial commodity would be defined based on their needs, and these needs shape the characteristics of the customers so that individuals would consider their needs to select financial services.

Hence, in this research, the concepts of Maslow's hierarchy of needs and the subjective theory of the value were used to form the decision-making value for selecting a specific bank based on people's ideas who want to join a bank.

In the next chapter, all these concepts would be modeled in an agent-based platform based on the mentioned previous studies about systematic banking, agent-based models, trust system, the hierarchy of needs, and subjective theory of value discussed in this chapter. Then, in chapter four, different scenarios using the introduced model in chapter three are examined, and the results are discussed. Finally, in chapter five, some suggestions for further research are provided, and the bibliography related to the sources that have been used in this thesis is provided in chapter six.

Chapter 3

3. Modeling

In this chapter, a financial network based on systematic trust is introduced and modeled. As well, the steps, formulas, and systematic procedures of the network are explained.

3.1. A basic financial period

In this thesis, we considered a basic financial period as a period defined by Grasselli and Ismail (2013), consisting of three steps with a preference shock between time 0 and time 1. The preference shock could change the agents' preference, or in other words, their liquidity needs.

In this model, the shocks happen in all periods, but this occurrence can be limited. Hence, the general procedure of the model is:

- Time 0
- Shocks
- Time 1
- Time 2

At time 0, each agent receives an amount as an endowment. Besides, agents have assets as a result of accumulated savings from previous periods. They have a preference as a personality's characteristic (this characteristic is the same for all periods of a scenario; however, it can be different for different scenarios), and the agents decide based on their preferences at time 0 whether they prefer to keep their endowment in a liquid style (as they think they will need their assets soon) or the agents prefer to keep it as an illiquid asset (as they think they would not need their assets soon hence they could invest it on a long term goal). Moreover, in this step, the agents must decide whether they want to stay in the market based on their previous experiences or prefer to join a bank (if there is any bank in their neighborhood).

Basically, the procedure of decision making in our model has two parts:

part 1 - The agents decide based on their previous history (7 strategies) to stay in the market or join a bank. (This part is from Grasselli and Ismail (2013) research paper.)

part 2 - If they decide to join a bank, based on their personality and various banks' features (if the agents have any options to choose), they select a bank between their options.

The complete procedures of this process are explained in detail later in this chapter in part 3.2.3.

After time 0 and before time 1, each agent receives a random shock based on their current preference, and this shock could change their liquidity preference. For example, if they preferred to have a liquid asset at time 0, now their liquidity preference change, and they could prefer to have an illiquid asset, also vice versa if they prefer to keep illiquid asset now after the shock, they could probably prefer liquid asset due to the shock. Even this is possible that the shock does not change the preference of the agent.

At time 1, the agents that changed preferences and stayed in the market should find other agents in the neighborhood from the society that had a change in their preferences and have enough assets to change their liquid and illiquid assets together with the market's short-term rate. If they could not find someone, then they were unsuccessful to fulfill their needs in that period. The agents will remember these activities in society. They use this history for the next financial period to decide whether to stay in the market or join a bank in the next period. On the other hand, those who have decided to join a bank at time 0 and now need liquid assets would satisfy their liquidity needs with the bank's short-term rates. The agents who selected a bank will continue their activity with the bank for the next financial periods as long as they are happy with the bank function and as long as the bank completes the contracts. This is a very important decision about whether they like to join the banking system or prefer to stay in the market, which is a great change in their future financial activities.

Moreover, if they decide to join the banking system, then they can choose between different banks. If something goes wrong with the banks and occurs a bank failure, the clients go back to the market for the next period. Hence, again, they decide whether they want to stay in the market or join a bank for the next financial period. The banking system and bank failure will be discussed later in this chapter.

Time 2 is the final step, and at this level, those who are patient and have decided to stay in the market would receive the market's long-term rate. As well, those who have joined a bank and are patient-client at this step would receive the bank's long-term rate.

Finally, at the end of the period, each agent decides to save some parts of their liquid assets (their total liquid assets at the end of the period) in their savings accounts and spend the rest of their earnings. This procedure will be discussed in more detail in part 3.2.4.

Each client gives its bank positive or negative points that provide a bank's reputation during the period. This reputation as a bank feature will help the other agents select between different banks if they want to join a bank. Later in this chapter, in part 3.3.3, more explanations will be provided about how systematic trust work based on the new model's structure is introduced in this research project.

This cycle is a simplified financial cycle, and we keep this 3-step style with a shock occurrence (from the Grasselli and Ismail model) for the new model. The new features of the new introduced model are the systematic trust, the agent attributes, saving system, decision-making process, bank attributes, regional shocks and regional banks, central bank and its loan system, and insurance system. Furthermore, in this research project, a platform is defined and programmed using the Netlogo in which most of the scenario features can be changed by a user. The model is programmed in a way that everyone interested in the model in the future, even if they do not have enough information about programming in NetLogo, can use the graphic user interface tab of the program and change the factors based on a specific case study and make a specific scenario to study. This model can also be expanded in the future by adding other features to the current programmed model.

Figure 3.1 shows the "Basic Financial Period" box of the programmed model in NetLogo version 6.1.1, in which the user can see the simple financial transaction procedures for a society without banks. As the image shows, every step can be checked separately to see what will happen in each step with different features of the scenario.

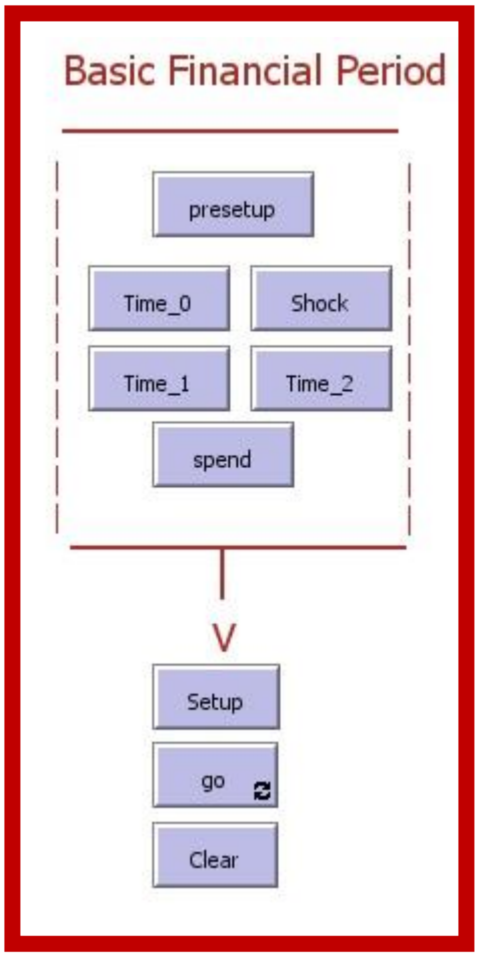

Figure 3. 1. Basic financial period box

3.2. Agents

In this part, agents' attributes - that show their personality and their tendencies - are explained, as well the preference shocks are discussed in more detail. Also, the decision-making procedures about joining a specific bank or staying in the market by the agents are explained.

3.2.1. Agents' attributes

Based on previous studies that were mentioned in the literature review, including Diamond and Dybvig (1983), Allen and Gale (2000), and Grasselli and Ismail(2013), each agent could have different needs of liquidity in each period, So that, in our model, we considered the possibility of random needs of liquidity (preference) for each agent in each scenario (as explained in part 3.2.1.1) that was considered in the Grasselli and Ismail model and the possibility of changing this preference by occurrence a periodical shock (as explained in part 3.2.2).

Also, each agent can have some specific personality characteristics. These characteristics can impact their final decisions. In this part, the features of agents' personalities that are considered or introduced in our model are explained.

Figure 3.2 shows the characteristics that we considered for the personality of each agent.

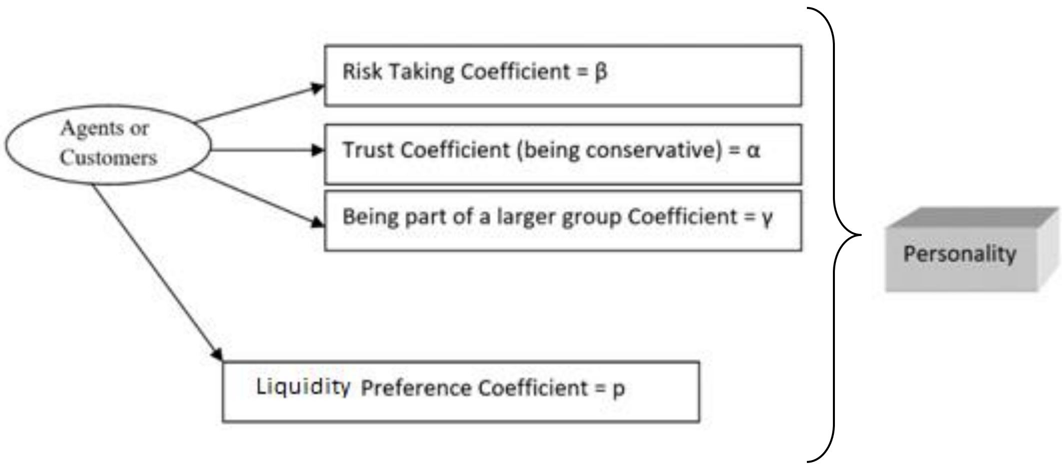

Figure 3. 2. Characteristics of each agent.

3.2.1.1. Liquidity preference of each agent

Each agent has a random preference $Pref_a$ in each scenario. The preference of agent a, is a number drawn uniformly between 0 and 1 in each scenario. If their preferences are greater than a parameter p, then the agent is patient (in our NetLogo model, we show them using blue cells). If the preference is lower than p, then the agent is impatient (in our NetLogo model, we show them using red cells).

The parameter p can be anything between 0 and 1; for example, it can be 0.5, and the programmed model in NetLogo provides a platform that users can change the parameter if they want, as shown in Figure 3.3.

Figure 3.3 shows the "Customers' Liquidity Preferences and Savings" box.

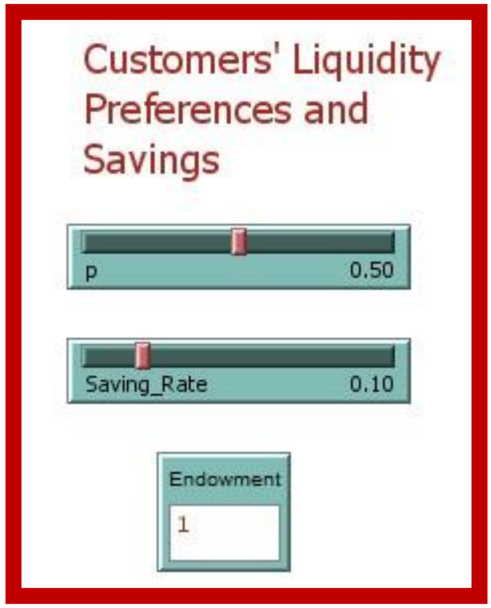

Figure 3. 3. Customers' Liquidity Preferences and Savings box

In Figure 3.3, the saving rate is a factor that indicates how much of the earnings would be saved in each period. Later in this chapter, in part 3.2.4, the saving mechanism will be discussed in more detail. Also, using this box, the user can increase or decrease the endowment amount for each scenario.

Figure 3.4 shows an example of patient agents and impatient agents of the society, which are in colors blue and red respectively (based on their preferences) in a 10 by 10 society.

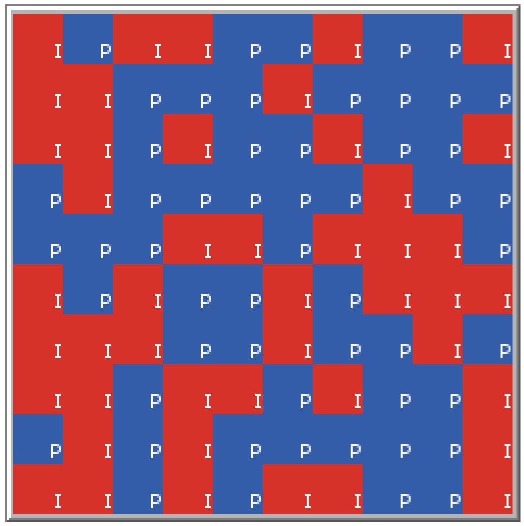

Figure 3. 4. A society with the patient and impatient agents

3.2.1.2. Agent's personality features

In our model, people do not have any concern about their basic wealth as they all receive a fixed endowment in each period. Hence, the first level of Maslow's hierarchy of needs explained in chapter 2 is not a matter in our model. However, this model can be upgraded in future studies regarding people's income situation.

Here, the first attribute is the Risk-Taking Coefficient that would be denoted as Beta. We considered the " Risk-Taking Coefficient " for the "safety level" from Maslow's hierarchy of needs diagram. Based on Maslow's concepts, this attribute is categorized in the basic needs group.

Those who have a higher tendency to take a risk want to make sure that the bank can provide liquid assets with higher rates to them if they are either patient or impatient during the financial period.

The second attribute is "Belonging Coefficient," which is defined based on the third level of Maslow's diagram concepts. This is categorized in the psychological needs, and considering the concepts of this hierarchy (explained in chapter 2), it has less importance than the previously mentioned attributes. It shows how much is important for an agent to join a bank with more clients.

The third attribute is Trust Coefficient, which is defined based on the reputation and the prestige of the bank or, in other words, how much is the ranking of the bank based on the clients' choice that shaped the reputation of the bank. This attribute is considered based on the fourth level of Maslow's diagram related to the Esteem needs and is placed in the psychological needs category. This level is related to prestige and can be defined here as each bank's reputation based on its previous performance in the banking system. Therefore, those who have a higher trust coefficient would like to put their money in a more prestigious bank with a higher reputation.

Also, the reputation shows which bank had a better performance in history, and it shows the clients could trust the bank based on its previous performance.

In this model, we only consider the first and the second categories of Maslow's model based on our financial system, and the third category, which is for the fifth level, has not been considered.

Conclusively in our model, an agent selects a bank between different banks (if they have multiple choice) based on a function of four attributes:

Agent's personality = f (p_a , α_a , β_a , γ_a)

In which p_a is the preference, α_a is the trust coefficient, β_a is a risk-taking coefficient, and γ is the belongingness coefficient of the agent "a". Each of these characteristics for each agent is a random number that is drawn uniformly between 0 and 1 in each scenario.

However, this can be different for various countries, societies, or scenarios. For example, this is possible for a specific society. The importance of the belongingness coefficient has a higher range, so this can be changed for a specific case study based on the sociology studies of that specific society. In this research project, the agents' attributes (p, α , β , γ) are fixed through different periods of a scenario; however, they can be changed based on specific case studies.

3.2.2. Agents' preference shocks

There is a shock in the agents' liquidity needs after time 0, and this shock is named preference shock, and the formula is taken from the Grasselli and Ismail (2013) research paper. Therefore, the formula for a periodical shock is:

$$pref_a^m = Pref_a + (-1)^{b_a^m} \times \frac{\varepsilon_a^m}{2}$$

In which the shock strength or ε_a is a uniformly distributed random variable on [0,1], and its direction or b_a is a Bernoulli distributed random variable on {0,1}.

$Pref_a$ is the innate preference of agent "a" and $pref_a^m$ is the new preference of the agent "a" in the period "m" after a shock occurred. We also assume that, at the end of each basic financial period, each agent's liquidity preference reverts to their innate preference, regardless of whether or not they changed during the period as the result of a shock.

In our study, the success probability has been considered as 0.5; however, it can be changed easily on the programmed model's graphic user interface using a slider named p in the "Customers Preferences and Budget" box.

Also, from the Grasselli and Ismail model, the q is:

$$q = 2p - \frac{1}{2}$$

So that, based on the definition in the Grasselli and Ismail model, agent "a" is deemed to be impatient as a result of the shock if $pref_a^m < q$, and patient otherwise.

So after the shock happens, we have these cases:

1-The liquidity preference changes after the shock :

- If the agent was patient at time 0, $pref_a > p$, but now $pref_a^m < q$:

Then agent needs liquid asset and is considered as an impatient agent:

- If they decided to stay in the market, their cell color changes to red, and they must find a neighbor that can provide liquid assets for that agent with the market rate r, provided they have enough assets to trade. If they can find the neighbor, then the agent's color changes to green, and the neighbor's color (which accepts to change its illiquid assets with liquid assets with rate r) changes its color to yellow.
- If they decided to join a bank, the bank would provide the liquid asset with the bank rate c_1.

- If the agent was impatient at time 0, $pref_a < p$ but now $pref_a^m \geq q$:

Then the agent prefers to change its liquid assets with illiquid assets and is considered as a patient agent:

- If they decided to stay in the market, then their color change to blue, and they have to find a neighbor that would like to change its illiquid assets with the agent liquid assets with the market rate r, provided they have enough assets to trade. If they could find a neighbor, then the neighbor's color (who changes its illiquid asset with the agent liquid asset) changes to green, and the agent color changes to yellow.
- If they decided to join a bank, the bank provides the liquid assets with the bank rate c_2 at the end of the financial period.

2- The liquidity need does not change after the shock:

- Then the agent's color changes to black if they stay in the market.
- The agent's color does not change if they decided to join a bank at time 0 (They have a bank's color).

Later in this chapter, in part 3.2.3, the decision-making process about joining a bank or stay in the market is explained in detail.

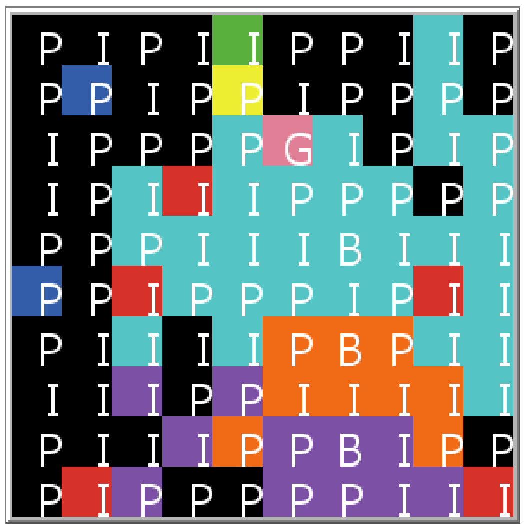

Figure 3. 5. A 10 by 10 society

Figure 3.5 shows a society with 10 by 10 agents and three banks with different colors (light blue, orange, and violet that were selected randomly) in which the colors show whether the agents have decided to join a bank (having the bank's color) or not (be a patient agent in the market with the color of dark blue or being an impatient agent in the market with the color of red) and if they decided to stay in the market whether they could find a neighbor after the shock to satisfy their liquidity needs or not (yellow and green colors). The labels "P", "I", and "B" show patient agents, impatient agents, and banks, respectively.

The label "G" is for the government or central bank, which will be discussed later in this chapter and the next chapter.

3.2.3. Decision-making process

Based on the Grasselli and Ismail model, the agents decide to join a bank or stay in the market based on seven strategies that help them use their previous market experience and decide. These strategies provide a learning process for each agent.

In the learning system, they assumed that agents have limited memory of 5 periods, according to which they try to make a prediction for the next period. Then, they endow all agents with a homogeneous set of 7 predictors as follows:

1. This period will be the same as the previous one.
2. This period will be the same as two periods ago.
3. This period will be the same as three periods ago.
4. This period will be the same as four periods ago.
5. This period will be the same as five periods ago.
6. This period will be the same as the mode of the last three periods.
7. This period will be the same as the mode of the last five periods.

Also, they explained that each strategy predicts either a neutral forecast (N), meaning that the agent will not change preferences, a good forecast (G), meaning that the agent will change preferences and find a trading partner, or a bad forecast (B), meaning that the agent will change preferences and fail to find a trading partner, in the next financial period.

Each agent starts with all seven predictors having a strength of zero. Each predictor's strength is updated during the financial period by adding one unit for each correct forecast and subtracting one for each incorrect one.

Moreover, Grasselli and Ismail (2013) defined a weighting mechanism for the agents' strategies in their paper. They explained in their work that this is a mechanism for each agent to combine his predictors and compare the payoffs obtained by not joining the bank (that is, investing directly in the two assets) against the payoff promised by the banking system base rates for the short-term and long-term contracts, according to his current state of forecasts and weighted by the strength of each of his predictors. For more details about the predictors, please review Grasselli and Ismail (2013) paper.

Hence, each agent remembers his activities in the market, and based on this mechanism, they decide whether to stay in the market for the next period or it is better to join the banking system.

In this research project, we use this mechanism, but we add another mechanism to the system that could provide an intelligent decision-making process based on the agent's characteristics when various banks have various short-term and long-term rates.

In this situation, the agents should decide about staying in the market or joining a bank based on the previous history. If they decide to join a bank, they must decide which bank is better for them to join based on their personality. So, we use the Grasselli and Ismail model as a learning mechanism for agents to decide to join the banking system or stay in the market based on their previous history. We then defined a new system of thinking and decision making for those agents who decide to join the banking system to help them choose a bank in their neighborhood based on their personality and the bank features. Therefore, they use the procedures explained below to choose the best bank that suits their personality.

First, each agent must see each bank's rates in the neighborhood, considering the agent's preference attribute as the banks could provide different rates for the short-term and long-term contracts, so the agent has to check each one individually.

When the agent has decided to join the banking system, he looks to his neighbors, that could be a bank or a bank's client. The agent can use the bank's short-term and long-term rates; this rate can be different for different banks as the bank managers can change the rates based on their Manager behavior attribute considering the base rates of the banking system (later in this chapter in the part 3.3.2, this attribute is explained in details).

If the agent is impatient, he looks at the banks' c_1 rates, which are their short-term rates, and if the agent is patient, he looks at the banks' c_2 rates, which are their long-term rates. c_1 and c_2 of each bank is a number in this range: $r < 1 < c_1 < c_2 < R$.

After that, the agent must make his final decision based on his attributes and the banks' features. For taking the final decision, we introduced the formula below. We divide the banks' reputation to the maximum possible amount of that parameter in the current period. The belongingness coefficient multiplies to the ratio of the number of the bank's clients to society's total population.

Therefore, each agent finds a ratio as a value to compare the banks in the neighborhood. This value is defined based on the concepts of the theory of the value that was explained in the previous chapter.

So, the formula is:

$$Value = \alpha \frac{Trust}{Trust_{max}} + (\beta \times rate) + \gamma \left(\frac{Clients}{Pop} \right)$$

This value is calculated for each bank in the agent's neighborhood, based on α , β , and γ attributes of the agent, and the other parameters are the banks' features. For example, the " Trust" shows the obtained Trust index or reputation of the bank by now, and $Trust_{max}$ shows the maximum amount of the Trust Index between banks of the society by now. Rate shows the banks' c_1 or c_2 rates (one of the c_1 or c_2 would be considered the rate amount based on the agents' liquidity preference). "Clients" shows the number of clients of a bank, and Pop shows society's population. Finally, the agent decides which bank in the neighborhood has the highest number of "Value" and decides which bank to join.

3.2.4. Agents' savings system

At time 2, each agent spends a portion of their current wealth (consisting of previously accumulated savings plus current endowment) and saves the remainder. However, this amount is different in various cases based on their decision to stay in the market or join a bank.

The programmed model has this option to eliminate the saving system by considering the saving rate equal to zero using the "Customers Preferences and Budget" box. For those who decide to stay in the market and not joining the banks, the available assets (or wealth) to invest or X_a^m is :

$X_a^{m,0} = E_a^m + X_a^{m-1,2}$

$X_a^{m,0}$ is the wealth of agent a in period m .

E_a^m is the agent "a" endowment in the period "m" and $X_a^{m-1,2}$ is the total wealth of the agent "a" in the previous period. Furthermore, for these agents, 3 cases can be defined:

1- Those who were patient in all steps of the financial period or those who were patient at time 0 and changed their liquidity preference after the shock but could not find a partner to trade their assets together, saving is s × R portion of their available assets (wealth) in which "s" is a coefficient of the saving rate.

In other words,

$$X_a^{m,2} = s\ (R \times X_a^{m,0})$$

As an example, if we consider $E_a^m = 1$ and the $X_a^{m-1,2} = 0$ then $X_a^{m,0} = 1 + 0 = 1$ and the saving for this agent in this period would be :

$$X_a^{m,2} = s\,R$$

2- Those who changed their liquidity preference after shock and could find a partner to change their assets save as follows. Consider two agents; if agent 1, who was impatient at time 0 and then its liquidity preference change to be patient after shock, found this chance to trade with agent 2 at time 1, who was patient at time 0, but after shock, its liquidity preference changed to impatient, then the final saving amount, provided $X_{a_1}^{m,0} \geq r\,X_{a_2}^{m,0}$, would be :

$$X_{a_1}^{m,2} = s\left(\left(R \times X_{a_2}^{m,0}\right) + \left(X_{a_1}^{m,0} - \left(r \times X_{a_2}^{m,0}\right)\right)\right)$$

$$X_{a_2}^{m,2} = s\left(r \times X_{a_2}^{m,0}\right)$$

3- For those who have been impatient in all the steps and those who have been impatient in the first step and their liquidity preference change after the shock but could not find a partner to trade their assets together, the saving is s portion of their available assets (wealth).

$$X_a^{m,2} = s \times X_a^{m,0}$$

However, for those who decide to join the banking system, the available assets (wealth) to invest or X_a^m is:

$X_a^{m,0} = E_a^m + X_a^{m-1,2}$ – Account Fee

Account fee is a fixed amount that each bank subtracts from people periodically as a service fee. This amount could also be equal to 0 in different scenarios and can be changed in the "Systematic Banking Box 1" from the programmed model's graphic user interface platform. The equations of saving for the banks' clients are different based on the banks' rates:

1- Those who were impatient at time 1, either by innate or changed preference, withdraw a portion (1-s) of their wealth and receive an interest rate c_1.

   Therefore, the available wealth at time 2 is ($s \times X_a^{m,0}$), from which they receive an interest rate c_2, that is:

$$X_a^{m,2} = c_2 (s \times X_a^{m,0})$$

2- Those who were patient at time 1 (either by innate or changed preference) save $s \times c_2$ portion of their endowment. In other words, $c_2 E_m^i$ is the total earning of the agent "i" in the period "m".

$$X_a^{m,2} = s (c_2 \times X_a^{m,0})$$

   In the programmed model, the saving rate can be changed in the graphic user interface part from the "Customer Preferences and Budget" box; the rates r and R (related to the market) can be changed from the "Market Features" box. The base rates c_1 and c_2 (related to the banking system) can be changed from the "Systematic Banking Box 1"; however, the specific bank's rates c_1 and c_2 can be different as they are determined by the bank managers using the base banking system rates and the managers' tendencies which will be explicated later in this chapter. Figure 3.6 shows the "Systematic Banking Box 1" of the programmed model.

More explanation about the features of this box will be discussed later in this chapter in parts 3.3.

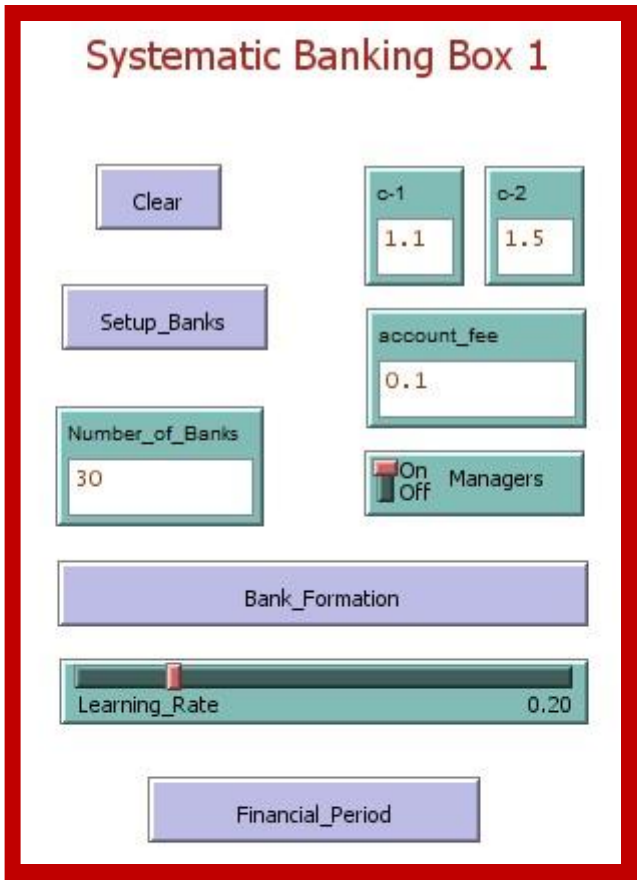

Figure 3. 6. The Systematic Banking Box 1

3.3. Banks and systematic trust

In chapter 2, the literature on systematic trust was explained. In this part, the banking system and the systematic trust related to our model are explained in detail, including bank formation, systematic trust, bank managers, and their decision about the bank rates c_1 and c_2. Also, the bank assets, including liquid assets, illiquid assets, and the learning process of investing in liquid and illiquid assets, are defined.

3.3.1. Bank formation

For banking formation, the same definitions of the Grasselli and Ismail model are used. Based on this model, at the beginning of each period, an agent is randomly chosen to decide thinking about the idea of establishing a bank or not. The agent looks around in his local neighborhood to see if any of the 8 neighbors are already bank, in which case he will not establish one. If there are no other banks in his neighborhood, the agent tries to estimate the number of patient and impatient investors amongst his immediate 9 potential clients (including himself).

Therefore W_a^m is considered as a random drawing from the set {0/9, 1/9, · · ·, 9/9} (with equal probabilities), for the agent a in the period m. W_a^m is a parameter that the agent determines whether it is feasible for him to establish a bank promising a payoff c_1 for early withdrawals and c_2 for late withdrawals, such that $r < 1 < c_1 < c_2 < R$. Indeed, W_a^m shows the agent a estimates about the ratio of impatient clients considering its 8 immediate neighbors plus the agent, which indicates a small group of 9 agents. It shows that what is the estimate of the ratio of the impatient agents of this group or, in other words, how many of the agents of this group would be impatient after a preference shock occurs in the society, for the first time (before a bank establishes) the candidate of the bank establishment consider this ratio as a random drawing from the set {0/9, 1/9, · · ·, 9/9}.

In this method, the base rates for c_1 and c_2 are given exogenously in the user's scenario (the one who defined a scenario), and they are the base rates of the banking system. The agent who is thinking about being a bank or not can invest in the liquid and illiquid assets, and consequently, he determines whether it is feasible for him to establish a bank.

Hence, y_a^m denotes the proportion of the assets that would be invested in the candidate's liquid asset, which is based on the ratio of the possible impatient clients. As well, the candidate considers x_a^m as the proportion of potential deposits of period m that would be invested in the illiquid based on the estimated ratio of the possible patient clients or, in other words, $1 - W_a^m$.

$$y_a^m = c_1 W_a^m$$

$$x_a^m = \frac{c2\ (1 - W_a^m)}{R}$$

Hence, based on this method, the agent will establish a bank if he can find x_a^m and y_a^m such that:

$$x_a^m + y_a^m < 1$$

Therefore, if an agent meets this condition, it can be a bank.

Finally, each bank's attributes, including the Bank Manager attribute and consequently the bank manager's decision about the new c_1 and new c_2, are defined to each of the established banks.

W_b^m will be updated periodically based on a learning rate and the real ratio of the impatient agents. The process of updating the W and the learning process will be discussed later in this chapter in part 3.3.4.

This parameter helps the banks to decide the portion of their liquid assets and their illiquid assets periodically. Moreover, more information about bank assets, liabilities, and capital will be provided in parts 3.3.5 and 3.3.6.

3.3.2. Managers' attributes

In the banking industry, bank managers and their decisions about proposed rates are very important. In this thesis, the manager's role in banking has been defined by an attribute named manager behavior or MB. This is a random number for each manager, which is determined in a specific domain.

There are c_1 and c_2 rates for short-term and long-term contracts, respectively which c_2 is greater than c_1. If Δ is considered the difference between c_2 and c_1, then we have:

$\Delta = c_2 - c_1$

Managers' behaviors impact the c_2 and c_1 of each bank; in other words, they can change the rates, but they have to consider the base rates.

Also, we know that $r < 1 < c_1 < c_2 < R$, in which R is the payoff of the illiquid asset if held until time 2 and r is its liquidation price if sold at time 1. So, the range of the random number for manager behavior should consider the rates 1 and R as the minimum and maximum boundary as well.

Manager behavior noted as MB, so for the new rates, we should consider these boundaries:

Manager behavior noted as MB, so for the new rates, we should consider these boundaries:

$$\Delta = c_2 - c_1$$

$$\text{threshold} = \delta = 0.05$$

$0 \leq MB \times \Delta \leq R - 1 - \delta$ Therefore, $0 \leq MB \leq \frac{R - 1 - \delta}{\Delta}$

Hence: $\Delta_{new} = MB \times \Delta$

So, this is the range of manager behavior, and it changes the rates based on the following conditions. If κ defined as:

$$\kappa = | \Delta_{new} - \Delta |$$

Then, the c1 and c2 rates are based on one of the conditions defined below:

1 - if $\Delta_{new} > \Delta$, then, two cases could happen :

- First case: when $c1 - \kappa > 1 + \delta$ then :

  $c_{1\ new} = c_1 - \kappa$ and $c_{2\ new} = c_2$

- Second case: when $c_1 - \kappa < 1 + \delta$ then :

  $c_{1\ new} = 1 + \delta$ and $c_{2\ new} = c_2 + (\kappa - (c_1 - 1 - \delta))$

2 - if $\Delta_{new} < \Delta$, then :

$c_{1\ new} = c_1 + \kappa$ and $c_{2\ new} = c_2$

3- if $\Delta_{\text{new}} = \Delta$, then :

$c_{1\ new} = c_1$ and $c_{2\ new} = c_2$

3.3.3. Systematic trust for a simple period

Systematic trust in this model is defined based on customer satisfaction and the clients' positive or negative points to the banking system that provides each bank's reputation. If the banks work successfully without asking for help from other sources like the Central bank, the bank's clients give the bank positive points, and as long as they have more happy clients, they would receive more points, which shape the bank's reputation based on the clients' ideas. Thus, the trust index in a systematic way is:

$$Trust_b^{m+1} = Trust_b^m + (k_1 \times nsc_b^m) - (k_2 \times nnsc_b^m)$$

nsc_b^m is the number of happy clients of bank b in the period m, and $nnsc_b^m$ is the number of not happy clients (or frustrated clients) of bank b in the period m. Also, k_1 and k_2 here are coefficients for showing how much stronger is the positive and the negative effect of having happy clients and not happy ones in the system, respectively.

Usually, k_2 could be greater than equal to k_1 as when the banks working successfully; it means that the bank is doing its job, and it will not be that much surprising if an institution works its duties correctly; however, when people heard a bank needs help to do its duties then it is not acceptable at all and in other words in the positive effect people earns something that they supposed to receive but in the negative effect clients lose something that they deserve to have. For different scenarios, these numbers can be changed easily in the model codes; here, as an example, we considered $k_1 = 1$ and $k_2 = 10$.

Here we considered that there is no previous history about the banking system, so the society has neither negative nor positive history about the banks when the banks start their job, and the bank trust index starts from 0. In this model, when a bank needs borrowing from the central bank, its clients would give the bank negative points, and if the bank works well without any help, the clients give the bank positive points.

These points can be given either at times 1 or 2 based on the clients' ideas. Furthermore, when the bank failure occurred, the bank received negative points from its clients.

3.3.4. Bank capital and learning rate

At the end of each period, banks should decide and estimate the portions they want to allocate to the liquid assets and the illiquid assets for the next period based on their current period performance. They have to update their previous estimate by a learning rate base on their current period results. Therefore, they update their estimate of the ratio of their impatient clients periodically. As it was mentioned previously in the bank formation in part 3.3.1, they have an estimate about the ratio of their impatient clients for the period m named W_b^m. Based on the Grasselli and Ismail model, if we name the real ratio of impatient clients as $\overline{W}_b^m$ then:

If $W_b^m > \bar{W}_b^m$ then the bank had an overestimating of the portion of the impatient clients that might lead to a shortage of liquid assets to satisfy the needs of impatient clients at time 1, and vice versa if $W_b^m < \bar{W}_b^m$ then the bank had an underestimating of the portion of the impatient clients, and in this case, it might lead to a shortage of illiquid assets to satisfy the needs of patient clients at time 2, and if $W_b^m = \bar{W}_b^m$ The bank has allocated the right ratio of its assets to the liquid and illiquid assets, which is the ideal situation of allocating assets for each bank. Each bank has to try to be in this position to invest the correct portion of its assets in short-term (liquid assets) and long-term (illiquid assets) contracts. To this aim, they use a learning rate to update their knowledge to estimate W_b^m as precisely as possible. Based on Grasselli and Ismail model, the banks update their knowledge using an Exponential Moving Average model with a constant smoothing factor ω :

$$W_b^m = W_b^{m-1} + \omega \; (\bar{W}_b^{m-1} - \; W_b^{m-1} \;)$$

In which $0 \; \leq \; \omega \; \leq 1$ and denotes the speed of adaption or learning rate.

3.3.5. Reviewing basic banking activity

In this part, an example is provided regarding a basic banking activity when there is no saving or account fee in the system.

$$x_b^m = \frac{c2\ (1 - W_b^m)}{R}$$

$y_b^m = c_1 \, W_b^m$

x_b^m denotes the amount that bank b considers to invest in illiquid assets based on the estimated ratio of patient clients of period m, which is $(1 - W_b^m)$ and y_b^m denotes the amount that bank b considers to invest in liquid assets based on the estimated ratio of impatient clients of period m, which is W_b^m.

Consequently, as we mentioned in part 3.3.4, at the end of each financial period, the estimate of impatient clients would be updated based on the learning rate ω and the real ratio of the impatient clients of the period; hence, the amount of investment on the liquid and illiquid assets for the next period, would be updated based on the new estimate of W_b^m periodically.

$W_b^m = W_b^{m-1} + \omega \ (\overline{W}_b^{m-1} - \ W_b^{m-1})$

Moreover, as in this example, there is no saving and account fee in the banking system, the wealth of each agent in period m and time 0 is equal to their endowment in that period. Hence, the wealth of agent a in period m is equal to his endowment in period m:

$X_a^{m,0} = \ E_a^m$

Therefore, agents' wealth changed at time 1 or time 2 based on their liquidity preference.

If the agent is impatient at time 1 and 2, then its wealth is equal to :

$X_a^{m,1} = \ 0$

$X_a^{m,2} = \ 0$

And, if the agent is patient at time 1 and 2, then its wealth is equal to :

$\mathrm{X}_a^{m,1} = c_1 \mathrm{X}_a^{m,0}$

$\mathrm{X}_a^{m,2} = 0$

Now, have a look at banks' assets and liabilities during a basic financial period in this system.

1- Assets:

$$\mathrm{A}_b^{m,0} = \mathrm{A}_{b_L}^{m-1,2} + \mathrm{A}_{b_I}^{m-1,2} + \sum_{a:all} \mathrm{X}_a^{m,0}$$

In which, $\mathrm{A}_{b_L}^{m-1,2}$ and $\mathrm{A}_{b_I}^{m-1,2}$ respectively denote the value of liquid assets and the value of illiquid assets of bank b in the last step (time 2) of the previous period.

Also $\sum_1^n \mathrm{X}_a^{m,0}$ indicated the value of the bank clients' deposits (in period m).

Now each bank is reallocating their assets to the liquid assets and illiquid assets based on the estimated ratio of the impatient and patient clients, calculated using the learning process of W (explained in part 3.3.4).

$$\mathrm{A}_{b_L}^{m,0} = (1 - x_b^m)\ \mathrm{A}_b^{m,0}$$

$$\mathrm{A}_{b_I}^{m,0} = x_b^m\ \mathrm{A}_b^{m,0}$$

Consequently, in this system of banking, the liquid assets and illiquid assets at time 1 are :

$$A_{b_L}^{m,1} = \left[A_{b_L}^{m,0} - c_1 \sum_{a:impatient} X_a^{m,0} \right]^+$$

$$A_{b_I}^{m,1} = \frac{1+R}{2} \left[A_{b_I}^{m,0} - \left(\frac{1}{r} \left[c_1 \sum_{a:impatient} X_a^{m,0} - A_{b_L}^{m,0} \right]^+ \right) \right]^+$$

Here the first expression corresponds to the remaining liquid assets after paying for the withdraws of impatient agents, whereas the second expression shows the book value of the remaining units of the illiquid asset after some of it is liquidated if needed to pay for withdraws of impatient agents.

Furthermore, in the last step or time 2, the liquid assets and illiquid assets are :

$$A_{b_L}^{m,2} = \left[A_{b_L}^{m,1} - \left[c_2 \sum_{a:impatient} X_a^{m,0} - \frac{2R}{1+R} A_{b_I}^{m,1} \right]^+ \right]^+$$

$$A_{b_I}^{m,2} = \left[\frac{2R}{1+R} A_{b_I}^{m,1} - c_2 \sum_{a:patient} X_a^{m,0} \right]^+$$

Here the second expression corresponds to the value of the remaining illiquid assets at time 2 after paying for withdraws of patient clients, whereas the first expression indicates the remaining value of the liquid asset after some of it is used to pay for withdraws of patient clients if needed.

2- Liabilities (Debts):

$$\mathrm{D}_b^{m,0} = \sum_{a:all} \mathrm{X}_a^{m,0}$$

$$\mathrm{D}_b^{m,1} = c_1\, \mathrm{D}_b^{m,0} - c_1 \sum_{a:impatient} \mathrm{X}_a^{m,0} = \sum_{a:all} \mathrm{X}_a^{m,1}$$

$$\mathrm{D}_b^{m,2} = 0 = \sum_{a:all} \mathrm{X}_a^{m,2}$$

3- Capital:

$$\mathrm{C}_b^{m,t} = \mathrm{A}_b^{m,t} - \mathrm{D}_b^{m,t}$$

In which t = 0,1,2 and denotes the time.

These are changes in assets and Liabilities during a basic financial period. Now, in the examples below, some cases are reviewed. In all cases, in period 1 and time 0, there are 1000 agents, and each one has an endowment equal to 1 ($\sum_1^{1000} \mathrm{X}_a^{1,0} = 1000$). $c_1 = 1.1$, $c_2 = 1.5$, R=2, r =0.8, and in all cases estimated W is equal to 0.5 (there is no account fee or accumulated saving in these cases). Figure 3.7 is a situation that in a 50 by 50 society, there is a bank with 1000 clients.

Hence,

$$x_b^0 = \frac{1.5 \times 0.5}{2} = 0.375$$

And,

$$y_b^0 = 1 - x_b^0 = 0.625$$

Therefore:

$$\mathrm{A}_b^{0,0} = 1000$$

$$\mathrm{A}_{b_L}^{0,0} = (1 - x_b^0)\ \mathrm{A}_b^{0,0} = 625$$

$$\mathrm{A}_{b_I}^{0,0} = x_b^0\ \mathrm{A}_b^{0,0} = 375$$

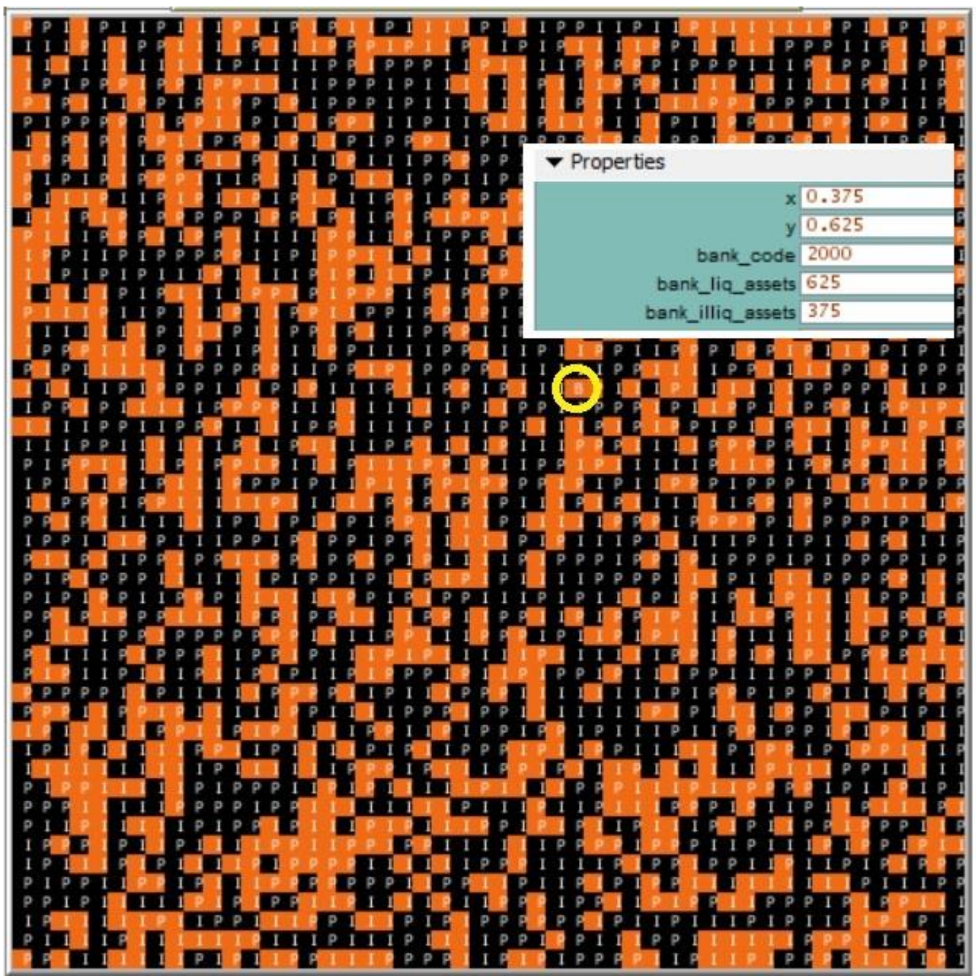

Figure 3. 7. A bank with 1000 clients in a 50 by 50 society

Case 1- If $\overline{W}$ (or real ratio of impatient clients) = W (or the estimated ratio of the impatient clients) = 0.5, then at time 1, the assets, deposits, and capital are :

$$\mathrm{A}_{b_L}^{0,1} = 625 - 550 = 75$$

$$\mathrm{A}_{b_I}^{0,1} = 1.5 \times 375 = 562.5$$

$$\mathrm{D}_{b}^{0,1} = 550$$

$$\mathrm{C}_{b}^{0,1} = 87.5$$

Figure 3.8 shows the number of units of the bank's liquid and illiquid assets extracted from the bank properties for time 1 (for Case 1). So, the value (as per the formula above is 562.5.

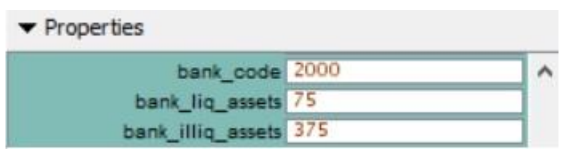

Figure 3. 8. Bank's liquid and illiquid assets (Case 1)

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are :

$$\mathrm{A}_{b_L}^{0,2} = 75$$

$$\mathrm{A}_{b_I}^{0,2} = 2(375) - 750 = 0$$

$$\mathrm{D}_{b}^{0,2} = 0$$

$$\mathrm{C}_{b}^{0,2} = 75$$

Figure 3.9 shows the bank's capital at the end of the period extracted from the bank properties (for Case 1).

Figure 3. 9. Bank's capital at the end of the period (Case 1)

Case 2- If $\overline{W}$ = 0.4 < W , then at time 1 the assets, deposits and capital are :

$$\mathrm{A}_{b_L}^{0,1} = 625 - 440 = 185$$

$$\mathrm{A}_{b_I}^{0,1} = 1.5 \times 375 = 526.5$$

$$\mathrm{D}_{b}^{0,1} = 660$$

$$\mathrm{C}_{b}^{0,1} = 87.5$$

Figure 3.10 shows the number of units of the bank's liquid and illiquid assets extracted from the bank properties for time 1 (for Case 2).

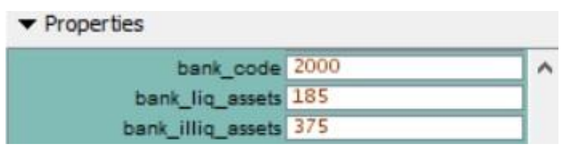

Figure 3. 10. Bank's liquid and illiquid assets (Case 2)

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are :

$$\mathrm{A}_{b_L}^{0,2} = 35$$

$$\mathrm{A}_{b_I}^{0,2} = 2(375) - 900 = [-150]^{+} = 0$$

$$\mathrm{D}_{b}^{0,2} = 0$$

$$\mathrm{C}_{b}^{0,2} = 35$$

Figure 3.11 shows the bank's capital at the end of the period extracted from the bank properties (for Case 2).

Figure 3. 11. Bank's capital at the end of the period (Case 2)

Case 3- If $\overline{W} = 0.3 < W$, then at time 1 the assets, deposits and capital are :

$$A_{b_L}^{0,1} = 625 - 330 = 295$$

$$A_{b_I}^{0,1} = 1.5 \times 375 = 562.5$$

$$D_b^{0,1} = 770$$

$$C_b^{0,1} = 87.5$$

Figure 3.12 shows the number of units of the bank's liquid and illiquid assets extracted from the bank properties for time 1 (for Case 3).

Figure 3. 12. Bank's liquid and illiquid assets (Case 3)

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are :

$$A_{b_L}^{0,2} = [295 - 300]^{+} = 0$$

$$A_{b_I}^{0,2} = [2(375) - 1050]^+ = [-300]^+ = 0$$

$$D_b^{0,2} = 0$$

$$C_b^{0,2} = 0$$

Figure 3.13 shows the bank's capital at the end of the period extracted from the bank properties (for Case 3).

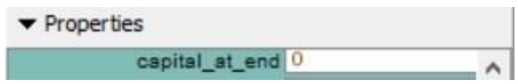

Figure 3. 13. Bank's capital at the end of the period (Case 3)

The debt amount is 1050, and the value of the assets is 1045; hence, 1045 divided between the patient agents so that :

$$\frac{1045}{700} = 1.49$$

As 1.49 still greater than c_1, the bank can continue its business, and the clients do not leave the bank.

Figure 3.14 indicates a patient client's final assets based on Case 3, which is equal to 1.49.

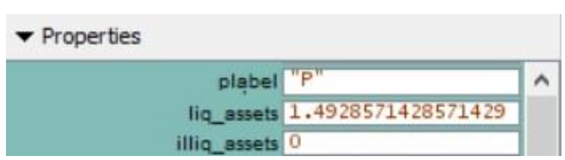

Figure 3. 14. Final liquid assets of a patient client (Case 3)

Case 4- If $\overline{W}$ = 0.55 > W , then at time 1 the assets, deposits and capital are :

$$A_{b_L}^{0,1} = 625 - 605 = 20$$

$$A_{b_I}^{0,1} = 1.5 \times 375 = 562.5$$

$$D_b^{0,1} = 495$$

$$C_b^{0,1} = 87.5$$

Figure 3.15 shows the number of units of the bank's liquid and illiquid assets extracted from the bank properties for time 1 (for Case 4).

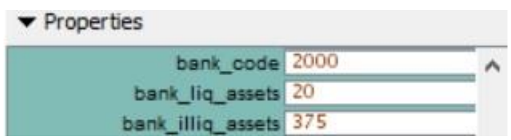

Figure 3. 15. Bank's liquid and illiquid assets (Case 4)

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are :

$$A_{b_L}^{0,2} = 20$$

$$A_{b_I}^{0,2} = 2(375) - 675 = [+75]$$

$$D_b^{0,2} = 0$$

$$C_b^{0,2} = 95$$

Figure 3.16 indicates the bank's capital at the end of the financial period extracted from the bank properties (Case 4).

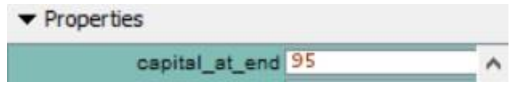

Figure 3. 16. Bank's capital at the end of the period (case 4)

Case 5- If $\overline{W}$ = 0.6 > W , then at time 1 the assets, deposits and capital are :

$$A_{b_L}^{0,1} = [625 - 660]^{+} = 0$$

$$A_{b_I}^{0,1} = \left(1.5 \times (375 - \frac{35}{0.8})\right) = 1.5 \times 331.25 = 496.875$$

$$D_b^{0,1} = 440$$

$$C_b^{0,1} = 56.875$$

Figure 3.17 shows the number of units of the bank's liquid and illiquid assets extracted from the bank properties for time 1 (Case 5).

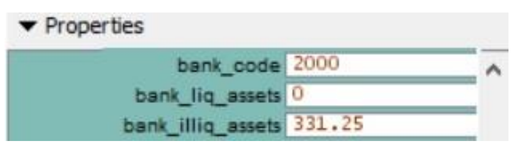

Figure 3. 17. Bank's liquid and illiquid assets (Case 5)

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are :

$$A_{b_L}^{0,2} = 0$$

$$A_{b_I}^{0,2} = 2(331.25) - 600 = 62.5$$

$$D_b^{0,2} = 0$$

$$C_b^{0,2} = 62.5$$

Figure 3.18 indicates the bank's capital at the end of the financial period extracted from the bank properties (Case 5).

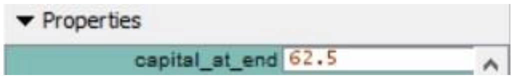

Figure 3. 18. Bank's capital at the end of the period (Case 5)

Case 6- If $\overline{W}$ = 0.65 > W , then at time 1 the assets, deposits and capital are :

$$A_{b_L}^{0,1} = [625 - 715]^{+} = 0$$

$$A_{b_I}^{0,1} = \left(1.5 \times (375 - \frac{90}{0.8})\right) = 1.5 \times 262.5 = 393.75$$

$$D_b^{0,1} = 385$$

$$C_b^{0,1} = 8.75$$

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are :

$$A_{b_L}^{0,2} = 0$$

$$A_{b_I}^{0,2} = 2(262.5) - 525 = 0$$

$$D_b^{0,2} = 0$$

$$C_b^{0,2} = 0$$

Figure 3.19 indicates the bank's capital at the end of the financial period extracted from the bank properties (Case 6).

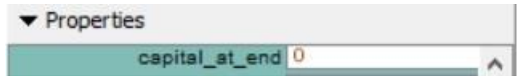

Figure 3. 19. Bank's capital at the end of the period (Case 6)

Case 7- If $\overline{W} = 0.7 >$ W , then at time 1, the assets, deposits and capital are :

$$A_{b_L}^{0,1} = [625 - 770]^{+} = 0$$

$$A_{b_I}^{0,1} = \left(1.5 \times (375 - \frac{145}{0.8})\right) = 1.5 \times 193.75 = 290.625$$

$$D_b^{0,1} = 330$$

$$C_b^{0,1} = [-39.375]$$

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are :

$$A_{b_L}^{0,2} = 0$$

$$A_{b_I}^{0,2} = [2(193.75) - 450]^{+} = [-62.5]^{+} = 0$$

$$D_b^{0,2} = 0$$

$$C_b^{0,2} = 0$$

Figure 3.20 indicates the bank's capital at the end of the financial period extracted from the bank properties (Case 7).

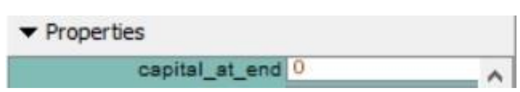

Figure 3. 20. Bank's capital at the end of the period (Case 7)

The debt amount is 450, and the value of the assets is 387.5; hence, 387.5 divided between the patient agents, so that :

$\frac{387.5}{300} = 1.29$

As 1.29 still greater than c_1, the bank can continue its business, and the clients do not leave the bank. Figure 3.21 indicates the final assets of a patient client based on Case 7, which is equal to 1.29.

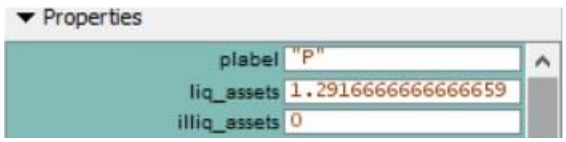

Figure 3. 21. Final liquid assets of a patient client (Case 7)

Case 8- If $\overline{W} = 0.8 > W$, then at time 1 the assets, deposits and capital are :

$$A_{b_L}^{0,1} = [625 - 880]^{+} = 0$$

$$A_{b_I}^{0,1} = \left(1.5 \times (375 - \frac{255}{0.8})\right) = 1.5 \times 56.25 = 84.375$$

$$D_b^{0,1} = 220$$

$$C_b^{0,1} = [-135.625]$$

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are :

$$A_{b_L}^{0,2} = 0$$

$$A_{b_I}^{0,2} = [2(56.25) - 300]^{+} = [-187.5]^{+} = 0$$

$$D_b^{0,2} = 0$$

$$C_b^{0,2} = [-187.5]$$

The debt amount is 300, and the value of the assets is 112.5; hence, 112.5 divided between the patient agents, so that :

$\frac{112.5}{200} = 0.56$

As 0.56 is lower than c_1, the bank fails, and each patient agent receives 0.56 and leaves the bank. Figure 3.22 indicates the final assets of a patient client based on Case 8, which is equal to 0.56.

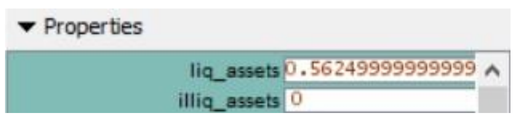

Figure 3. 22. Final liquid assets of a patient client (Case 8)

3.3.6. Reviewing the banking system in the presence of savings

In this part, an example is provided regarding a banking system with a saving presence in the agents' wealth. In this system, each agent's wealth in period m and time 0 is equal to their endowment in this period plus their accumulated saving from the previous period. Hence:

$$X_a^{m,0} = E_a^m + X_a^{m-1,2}$$

The banking system could also consider some amount as account fee as in this research, "a" denotes the account fee, which is a fixed fee for all the banking system.

Therefore, agents' wealth changed at time 1 or time 2 based on their liquidity preference. If the agent is impatient at time 1 and 2, then its wealth is equal to :

$$\mathrm{X}_a^{m,1} = c_1 \, s \, (\mathrm{X}_a^{m,0} - a)$$

$$\mathrm{X}_a^{m,2} = c_2 \, s \, (\mathrm{X}_a^{m,0} - a)$$

In which "a" is account fee and "s" is saving rate. If the agent is patient at time 1 and 2, then its wealth is equal to :

$$\mathrm{X}_a^{m,1} = c_1 \, (\mathrm{X}_a^{m,0} - a)$$

$$\mathrm{X}_a^{m,2} = c_2 \, s \, (\mathrm{X}_a^{m,0} - a)$$

Now, have a look at banks' assets and liabilities during a basic financial period in this system.

1- Assets:

$$\mathrm{A}_b^{m,0} = \mathrm{A}_{b_L}^{m-1,2} + \mathrm{A}_{b_I}^{m-1,2} + \left(\sum_{a:\, all_m} (\, \mathrm{X}_a^{m,0} - a) - \sum_{a:\, all_{m-1}} \mathrm{X}_a^{m-1,2} \right)$$

The number of clients in period m can be different from the number of clients in period m-1 because of clients joining and leaving the bank.

Each bank reallocated their assets to the liquid assets and illiquid assets based on the estimated ratio of the impatient and patient clients that was calculated using the learning process of W (explained in part 3.3.4).

$$\mathrm{A}_{b_L}^{m,0} = (1 - x_b^m)\ \mathrm{A}_b^{m,0}$$

$$\mathrm{A}_{b_I}^{m,0} = x_b^m\ \mathrm{A}_b^{m,0}$$

Consequently, in this system of banking, the liquid and illiquid assets at time 1 are :

$$\mathrm{A}_{b_L}^{m,1} = \left[\mathrm{A}_{b_L}^{m,0} - c_1(1-s) \sum_{a:impatient} (\mathrm{X}_a^{m,0} - a) \right]^+$$

$$\mathrm{A}_{b_I}^{m,1} = \frac{1+R}{2} \left[\mathrm{A}_{b_I}^{m,0} - \left(\frac{1}{r} \left[c_1(1-s) \sum_{a:impatient} (\mathrm{X}_a^{m,0} - a) - \mathrm{A}_{b_L}^{m,0} \right]^+ \right) \right]^+$$

And, at time 2, the liquid assets and illiquid assets are :

$$\mathrm{A}_{b_L}^{m,2} = \left[\mathrm{A}_{b_L}^{m,1} - \left[c_2(1-s) \sum_{a:patient} (\mathrm{X}_a^{m,0} - a) - \frac{2R}{1+R}\ \mathrm{A}_{b_I}^{m,1} \right]^+ \right]^+$$

$$\mathrm{A}_{b_I}^{m,2} = \left[\frac{2R}{1+R}\ \mathrm{A}_{b_I}^{m,1} - c_2(1-s) \sum_{a:patient} (\mathrm{X}_a^{m,0} - a) \right]^+$$

2- Liabilities (Debts):

$$D_b^{m,0} = \sum_{a:all} (X_a^{m,0} - a)$$

$$D_b^{m,1} = c_1 \, D_b^{m,0} - c_1 \; (1 - s) \sum_{a:impatient} (X_a^{m,0} - a) = \sum_{all} X_a^{m,1}$$

$$D_b^{m,2} = c_2 \, s \sum_{a:all} (X_a^{m,0} - a) = \sum_{a:\, all} X_a^{m,2}$$

3- Capital:

$$C_b^{m,t} = A_b^{m,t} - D_b^{m,t}$$

In which t = 0,1,2 and denotes the time.

These are changes in Assets and Liabilities during a basic financial period. Now, in the example below, three financial periods of a bank are reviewed. In the example, in period 1 and time 0, there are 1000 agents, and each one has an endowment equal to 1 ($\sum_1^{1000} X_a^{1,0}$ = 1000). c_1 = 1.1 , c_2 = 1.5, R=2, r =0.8, s = 0.1, a=0.01 , and estimated W is considered as equal to 0.5 for all periods. In this example again a 50 by 50 society has considered like part 3.3.5 (Figure 3.7) and this society has a bank with 1000 clients.

Hence,

$$x_b^0 = \frac{1.5 \times 0.5}{2} = 0.375$$

And,

$$y_b^0 = 1 - x_b^0 = 0.625$$

Therefore:

$$\mathrm{A}_b^{0,0} = 1000$$

$$\mathrm{A}_{b_L}^{0,0} = (1 - x_b^0)\ \mathrm{A}_b^{0,0} = 625$$

$$\mathrm{A}_{b_I}^{0,0} = x_b^0\ \mathrm{A}_b^{0,0} = 375$$

So that the deposits are the total wealth of the agents and as in period 0 of this example the saving is equal to 0, and the account fee is 0.01, then the deposit at time 0 is :

$$\mathrm{X}_a^{m,0} = \mathrm{E}_a^m + \mathrm{X}_a^{m-1,2} - a = 1 + 0 - 0.01 = 0.99$$

$$\mathrm{D}_b^{0,0} = 1000 \times 0.99 = 990$$

The bank account fee is considered in the bank's capital:

$$\mathrm{C}_b^{0,0} = 0.01 \times 1000 = 10$$

If $\overline{W}$ (or real ratio of impatient clients) = W (or the estimated ratio of the impatient clients) = 0.5, therefore the total wealth of impatient clients and patient clients can be calculated as:

The total wealth of impatient clients: $990 \times 0.5 = 495$

Total wealth of patient clients :990 – 495 = 495

Then at time 1, the assets, deposits, and capital are :

$$A_{b_L}^{0,1} = 625 - (1.1 \times 0.9 \times\ 495)\ = 134.95$$

$$A_{b_I}^{0,1} = 1.5\ \times 375 = 562.5$$

$$D_b^{0,1} = 598.95$$

$$C_b^{0,1} = 98.50$$

Figure 3.23 shows the units of the bank's liquid and illiquid assets extracted from the bank properties for time 1.

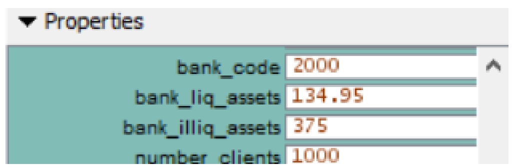

Figure 3. 23. Units of bank's liquid and illiquid assets at time 0 (first financial period)

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are :

$$A_{b_L}^{0,2} = 134.95$$

$$A_{b_I}^{0,2} = 2(375) - (1.5 \times 0.9 \times\ 495) = 750 - 668.25 = 81.75$$

$$D_b^{0,2} = (1.5 \times 0.1 \times\ 0.99)\ \times\ 1000 =\ 0.1485\ \times\ 1000 =\ 148.5$$

Figure 3.24 shows the saving amount of a bank client in the first financial period.

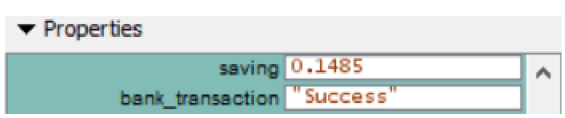

Figure 3. 24. Saving amount of a bank client in the first financial period

So, the bank's capital in the first financial period is:

$$C_b^{0,2} = 68.2$$

Figure 3.25 shows the bank's capital at the end of the period extracted from the bank properties.

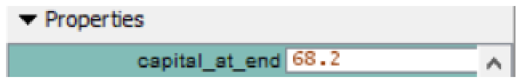

Figure 3. 25. Bank's capital at the end of the first period

Now, in the second financial period, at time 0, the assets, deposits, and capital are:

$$A_b^{1,0} = 216.70 + 1000 = 1216.70$$

$$D_b^{1,0} = 1138.5$$

$$C_b^{1,0} = 78.20$$

If $\overline{W}$ (or real ratio of impatient clients) = W (or the estimated ratio of the impatient clients) = 0.5, therefore the total wealth of impatient clients and patient clients can be calculated as:

The total wealth of impatient clients: 1138.5 × 0.5 $= 569.25$

Total wealth of patient clients: 1138.5 – 569.25 = 569.25

Consequently:

$$A_{b_L}^{1,0} = 760.4375$$

$$A_{b_I}^{1,0} = 456.2625$$

Figure 3.26 shows the units of the bank's liquid and illiquid assets at time 0 of the second financial period.

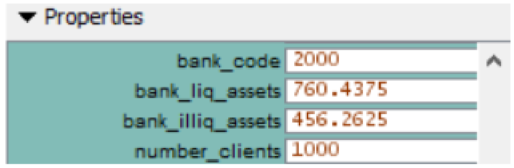

Figure 3. 26. Units of bank's liquid and illiquid assets at time 0 (second financial period)

Then at time 1, the assets, deposits, and capital are:

$$A_{b_L}^{1,1} = 760.4375 - (1.1 \times 0.9 \times 569.25) = 196.88$$

$$A_{b_I}^{1,1} = 1.5 \times 456.2625 = 684.39375$$

$$D_b^{1,1} = (1.1 \times 569.25) + (0.1 \times 1.1 \times 569.25) = 688.7925$$

$$C_b^{1,1} = 192.48125$$

Figure 3.27 shows units of the bank's liquid and illiquid assets extracted from the bank properties for time 1.

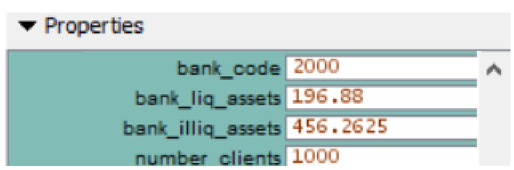

Figure 3. 27. Units of the bank's liquid and illiquid assets in the second financial period

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are:

$$A_{b_L}^{2,2} = 196.88$$

$$A_{b_I}^{2,2} = (2 \times 456.2625) - (1.5 \times 0.9 \times 569.25) = 912.525 - 768.4875 = 144.0375$$

$$D_b^{2,2} = (1.5 \times 0.1 \times 1.1385) \times 1000 = 0.170775 \times 1000 = 170.775$$

Figure 3.28 shows the saving amount of a bank client in the second financial period.

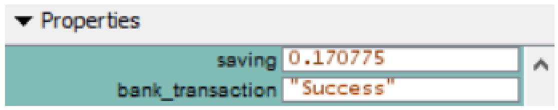

Figure 3. 28. Saving amount of a bank client in the second financial period

$$C_b^{2,2} = 340.9175 - 170.775 = 170.1425$$

Figure 3.29 shows the bank's capital at the end of the second financial period extracted from the bank properties.

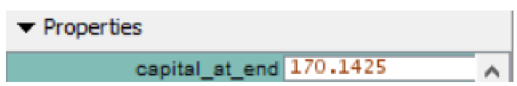

Figure 3. 29. Bank's capital at the end of the second financial period.

Now, in the third financial period, if the actual proportion of the impatient value is 0.8, but the estimated one was 0.5, then at time 0, the assets, deposits, and capital are:

$$A_b^{1,0} = 340.9175 + 1000 = 1340.9175$$

$$D_b^{1,0} = 1160.775$$

$$C_b^{1,0} = 180.1425$$

If $\overline{W}$ (or real ratio of impatient clients) = 0.8, therefore the total wealth of impatient clients and patient clients can be calculated as:

The total wealth of impatient clients: $1160.775 \times 0.8 = 928.62$

Total wealth of patient clients: 1160.775 – 928.62 = 232.155

Consequently, an estimated portion of impatient clients was calculated as 0.5:

$$\mathrm{A}_{b_L}^{1,0} = (1 - 0.375)\ 1340.9175 = 838.0734375$$

$$\mathrm{A}_{b_I}^{1,0} = 502.8440625$$

Figure 3.30 shows the bank's liquid and illiquid assets units at time 0 of the third financial period.

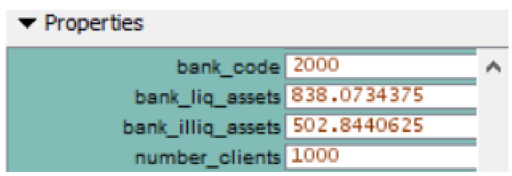

Figure 3. 30. Units of bank's liquid and illiquid assets at time 0 (third financial period)

Then at time 1, the assets, deposits, and capital are:

$$\mathrm{A}_{b_L}^{1,1} = 838.0734375 - (1.1 \times 0.9 \times\ 928.62)\ = [-81.2603625]^{+}$$

$$\mathrm{A}_{b_I}^{1,1} = \left(1.5\ \times (502.8440625 - \frac{81.2603625}{0.8})\right) = 1.5\ \times 401.268609375$$

$$= 601.9029140625$$

$$\mathrm{D}_{b}^{1,1} = (1.1\ \times 232.155) + (0.1 \times 1.1 \times\ 928.62) =\ 255.3705 +\ 102.1482$$

$$=\ 357.5187$$

$C_b^{1,1} = 244.3842140625$

Figure 3.31 shows units of the bank's liquid and illiquid assets extracted from the bank properties for time 1.

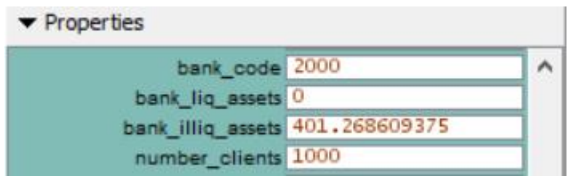

Figure 3. 31. Units of the bank's liquid and illiquid assets at time 0 (third financial period)

Consequently, at time 2 or the last step, the assets, debts (or liabilities), and capital are:

$$A_{b_L}^{2,2} = 0$$

$$A_{b_I}^{2,2} = (2 \times 401.268609375) - (1.5 \times 0.9 \times\ 232.155)$$

$$= 802.53721875 - 313.40925 = 489.12796875$$

$$D_b^{2,2} = 1.5 \times 0.1 \times\ 1160.775 \ = \ 174.11625$$

$$C_b^{2,2} = 489.12796875 - 174.11625 = 315.01171875$$

Figure 3.32 shows the bank's capital at the end of the third financial period extracted from the bank properties.

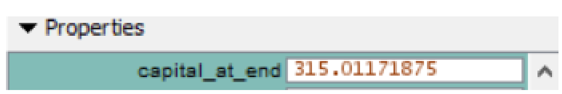

Figure 3. 32. Bank's capital at the end of the third financial period.

3.4. Deposit insurance

We now introduce deposit insurance in the form of an insurance fee that is paid by banks to the central regulator, which then guarantees the deposits of clients in the case of bank failure. This insurance fee is not deducted from the bank's clients, and it is only deducted from the bank's total assets at time 0 based on the number of clients of the banks in that period.

The insurance system helps to rescue the clients' assets as much as possible in the bank failure condition, and in other words, this system helps the clients avoid losing all their assets in the bank failure. Each bank has a different number of clients that they could have a different amount of wealth. Each bank has to pay a fixed fee (indicated exogenously by the user) for the clients' assets that they received periodically.

Therefore:

$$\mathrm{A}_{b}^{m,0} = \mathrm{A}_{b_L}^{m-1,2} + \mathrm{A}_{b_I}^{m-1,2} + \left(\sum_{a:\, all_m} (\mathrm{X}_a^{m,0} - a) - \sum_{a:\, all_{m-1}} \mathrm{X}_a^{m-1,2} \right) - \left[(Insurance\ Rate) \times \sum_{a:\, all_m} (\mathrm{X}_a^{m,0} - a) \right]$$

When bank failure occurred, the total insurance will be divided between clients to cover all or some of their deposited assets. The insurance system working parallel during systematic banking and collect insurance from each bank periodically.

Suppose the "Frustrated Clients" can not receive the full deposited amount from the banks' assets or the insurance system. In that case, they lose some parts of their deposits, and it impacted the overall wealth of the society.

3.5. Borrowing from the Central Bank

In this study, banks can apply for receiving a loan from the Central bank; each bank must meet the eligibility conditions to be able to borrow from the Central Bank.

If banks do not have any debt to the central bank and need liquidity at time 1, and if they can pay at least a percentage of their liabilities themselves, for example, 75% of their liabilities, and they only have a few percentage liquidity shortages (considering both their liquid assets and the value of their illiquid assets), they are eligible to request for borrowing liquid assets from the Central Bank. However, if they have a previous debt to the central bank and have a liquidity shortage at time 1, they can not apply for a new loan as long as their debt is not zero and the bank failure occurs.

Indeed, when they borrow from the Central bank to pay their debts, the bank still continues its business, and clients do not leave the bank, but they consider negative points for the bank performance. In this case, the banks at time 1 could keep their illiquid assets and only use their liquid assets plus their received loans from the Central Bank to cover their liquidity shortage in this step.

They must then pay their loan amount to the Central bank in decided portions periodically considering the payment duration and the Central Bank interest rate.

Therefore, banks try to pay their clients using different resources. The resources that the banks can use in this model are listed in order below:

1-Bank's liquid assets

2- Borrowing from the Central Bank: Banks must be in a condition that they could be eligible to use the central bank loan option. Eligibility condition depends on the below factors:

- ❑ If a Central bank exists
- ❑ If the bank does not have a debt to the Central Bank
- ❑ If the bank is at time 1
- ❑ If the bank can pay a percentage of its liabilities (like at least 75%)

3- Bank's illiquid assets: if the banks are not eligible for the loan, they must liquidate their illiquid assets with a rate as low as "r" to cover their liquidity shortage at time 1

If the banks are eligible to receive a loan, they could keep their illiquid assets and cover their liquid shortage by borrowing from the Central Bank. If they need liquid assets at time 1, their Loan amount is:

$$Loan_b = (CBLI + 1)\left[\left(c_1^b \sum_{a=impatient} (\mathrm{X}_a^{m,0} - a) \right) - \mathrm{A}_{b_L}^{m,1}\right]$$

CBLI is the Central Bank Loan Interest's rate.

$Loan_b$ shows the amount that bank "B" is borrowing from the central bank.

$A_{b_L}^{m,1}$ is the amount of liquid assets at time 1. c_1^b and c_2^b are the short-term and long-term contracts' rates from the bank "b", respectively.

Therefore, the periodical debt is :

$$debt_b = \frac{Loan_b}{RD}$$

RD is repayment duration and indicates the number of periods that each bank should pay its debt.

Consequently, the bank's total assets updated periodically at time 0 based on this debt until the bank's loan amount goes to zero:

$$A_b^{m,0} = A_{b_L}^{m-1,2} + A_{b_I}^{m-1,2} + \left(\sum_{a:\, all_m} (X_a^{m,0} - a) - \sum_{a:\, all_{m-1}} X_a^{m-1,2} \right) - \left[(Insurance\ Rate) \times \sum_{a:\, all_m} (X_a^{m,0} - a) \right] - debt_b$$

Hence,

$$Loan_b^{m,0} = Loan_b^{m-1,0} - debt_b$$

The banks can not apply for a loan when they are in the last step of the financial period or time 2, because it shows they had not a satisfactory performance in the financial period and can not continue their business as a bank so that the bank failure occurs.

The "Central Bank" box, shown in Figure 3.33, is the graphic user interface of the programmed model and let the user turn on the Central Bank features for the system and set the loan properties for the loan system.

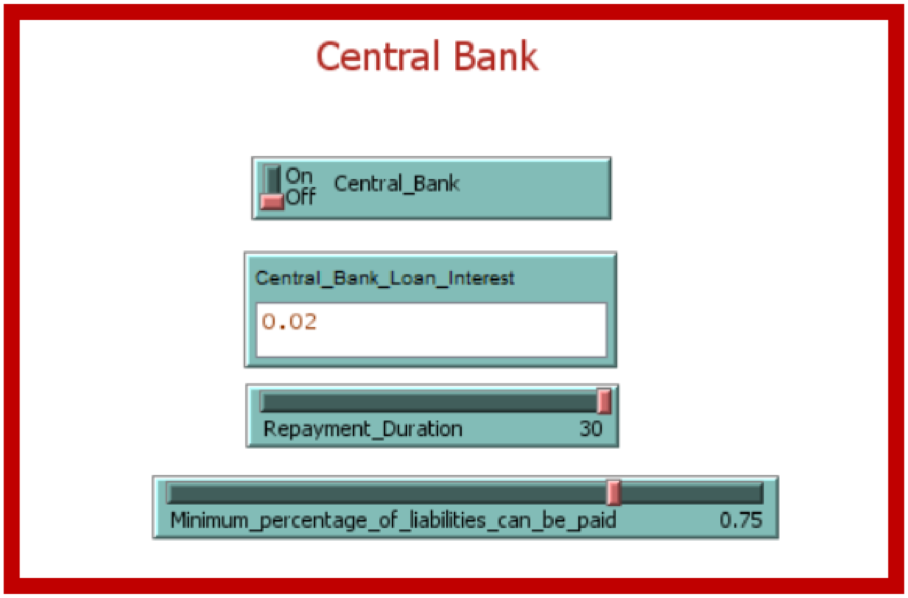

Figure 3. 33. The Central Bank propertied box of the programmed model

In this image, as an example, when the central bank exists in the system, the government (or Central Bank) fixed-rate interest applied to the central bank loans is 0.02 or 2%, and the repayment duration is 30 periods.

3.6. Correlated preference shocks

Except for the individuals' preference shock, which is different for each agent and happens in each period, in this model, we consider a powerful correlated shock as well (correlated preference shocks), that changes all the agents' preference numbers equally in specific periods.

The idea of the correlated shocks previously applied in the Grasselli and Ismail model. These phenomena updated in our model by making it more interactive as the user can define various positive and negative shocks at the same time, and there is a feature name intensity for each shock that the user can change it exogenously either for all society or for a specific part of the society (using the programmed regional correlated shock controller box of our model).

This shock can be considered as a specific growth era or a specific panic era. Based on the programmed model, this shock can be repeated cyclically in some specific periods, or as well it can occur only once. Our model considered these shocks as bad news and the good news that indicate negative shocks and positive shocks, respectively.

Furthermore, these shocks' intensity can easily be determined in the programmed model in the "Shock Properties" box, as shown in Figure 3.34. This box can be used for implementing various positive and negative shocks in the different scenarios to consider a possibility of huge liquidation at time 1 or a huge tendency to be patient in a financial period, or both together in some specific case studies based on various scenarios.

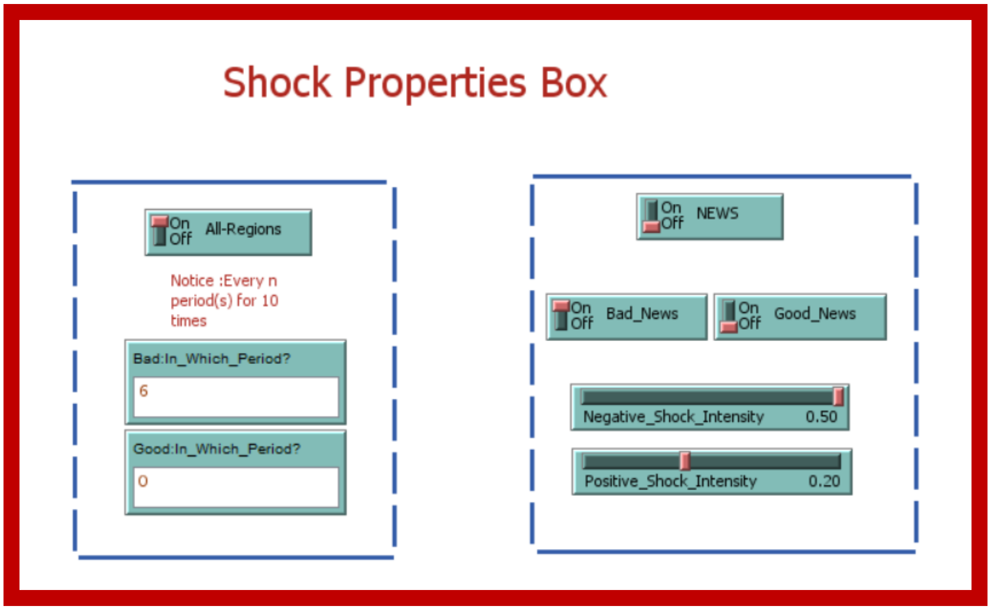

Figure 3. 34. Shock properties box that is used for changing the features of the correlated shocks

From the periodically individual shock, we have $pref_a^m$, now if we consider another correlated shock too, then:

1- The new preference after the correlated positive shock (or good news) occurrence is:

$$pref_a^{m\_new} = pref_a^m + PSI$$

in which PSI is the correlated positive shock intensity.

2- The new preference after the correlated negative shock (or bad news) occurrence is:

$$pref_a^{m\_new} = pref_a^m - NSI$$

in which NSI is the correlated negative shock intensity.

3- The new preference after the correlated negative and positive shocks happened together is:

$$pref_a^{m\_new} = pref_a^m - NSI + PSI$$

In our study, PSI and NSI are considered as exogenous numbers that are drawn uniformly between 0 and 1 in each scenario

Again, $pref_a^{m\_new}$ should be compared with the probability, as mentioned previously in part 3.2.2, due to determining the liquidity preference of the agents after the correlated shock(s) occurred. The negative and positive shocks could completely impact the agents' preferences if they have a significant intensity.

3.7. Regional activities

In our financial agent-based model, we considered this option that some of the activities can be done regionally, including banking formation and correlated shocks. There are some properties in the programmed model for all these activities that the user can change them.

The properties for regional banking are in the "Systematic Banking Box 2" part. In this box, the user can divide society into four regions and decide how many banks should be established in each region. Figure 3.35 shows the elements of this box. As well, the user can determine the size of each region. Also, some of the other features like c_1 and c_1 base rates, the bank managers' existence in the system, and the amount of the account fee should be determined from the "Systematic Banking Box 1" part from the programmed model's graphic user interface.

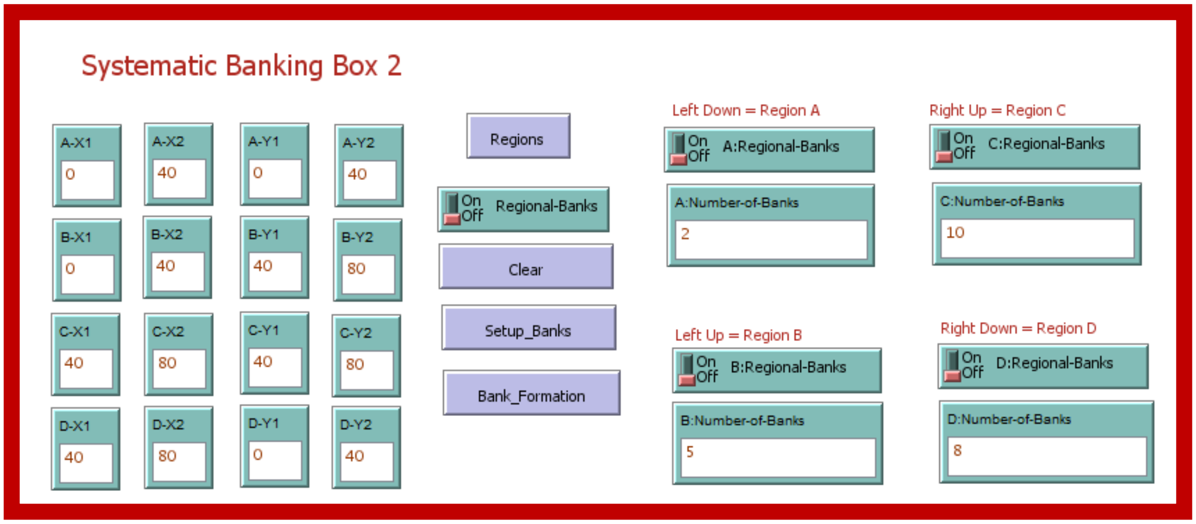

Figure 3. 35. The Systematic Banking Box 2 of the programmed model

Another regional activity is the regional shocks. Using the shock properties box designed for the correlated shocks and is shown in figure 3.36, the user can determine where and when the shocks happen.

Moreover, the user can apply both positive and negative shocks (even simultaneously) in various regions as panic elements or growth elements.

This feature of the programmed model makes the program suitable for lots of various case studies and scenarios with different situations.

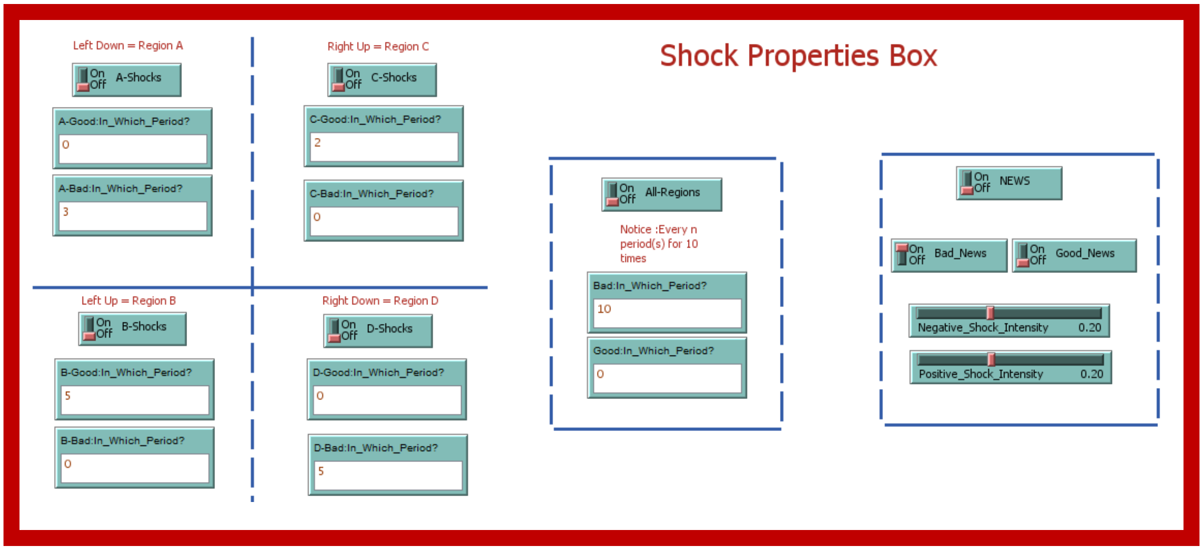

Figure 3. 36. The "Shock Properties Box" of the programmed model

3.8. Run a scenario for various societies

There is a box in the programmed model's graphic user interface that allows users to check a specific scenario based on the selected features, which were explained in this chapter, for different societies.

The user can fix a scenario and repeat that scenario for a society (number of financial periods) using the icon "Run-Scenario", or the user can run the scenario for different societies (for example, 500 societies that each of them has experienced 100 financial periods) using the icon "Repeat-for-Societies" from the "Various Societies" box.

Figure 3.37. shows the "Various Scenarios" box of the programmed model; for example, in Figure 3.37, the banking system of a scenario repeated for 5 different societies that each of them experienced 100 financial periods.

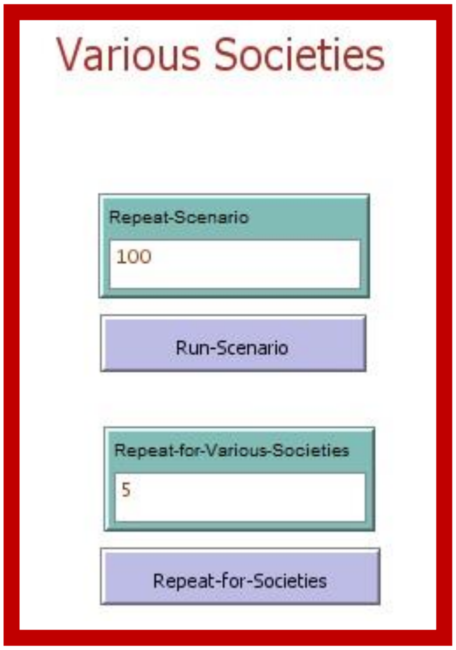

Figure 3. 37. The "Various Scenarios" box of the programmed model.

In the next chapter, some usage of these properties will be explained in various scenarios, and each of the scenarios is analyzed and explained in detail, and some graphs and diagrams of the results will be provided.

One of the outstanding features of the graphic user interface of the introduced Agent-based programmed model is that lots of variables and features can be easily changed by the user who would like to use this model for a specific scenario analysis or a case study even with no knowledge of a programming language.

In other words, the graphic user interface of the model is properly designed to make the model usable for those who are interested in conducting some case studies with various scenarios related to this topic using the introduced model of this research project.

Chapter 4

4. Numerical Experiments

In this chapter, the introduced model is used for some scenario analysis, including checking the model when the central bank and insurance are not in the system and when they are in the system. As well the existence of correlated preference shocks is examined in some scenarios.

To this aim, a 80 by 80 society is considered, and 100 financial periods are simulated for different scenarios. The base rates considered as $R = 2$, $r = 0.5$, $c_1 = 1.1$, and $c_2 = 1.5$. Also, for the scenarios, some savings for the agents are considered based on the definition explained in chapter 3, part 3.2.4, and the saving rate is considered equal to 0.1. At the first financial period, the scenario has 40 established banks (based on the bank formation procedures explained in chapter 3), and the aim is to see how many of these banks could successfully survive through 100 financial periods in different scenarios.

Moreover, an account fee as a services fee of the banks to the customer equal to 0.01 is considered for the scenarios. As well, the system learning rate that was explained in chapter 3, part 3.3.4, is considered equal to 0.1. These numbers can be easily changed in the programmed model based on different case studies and scenarios for further future studies.

The scenarios start to establish 40 banks based on the bank formation explanations provided in chapter 3, part 3.3.1. Hence, the society is divided into 4 equal regions, and 10 banks are located in each region, and then during the 100 financial periods, it would be found out how many banks could continue their business and how many bank failures occurred. Then, all other results about the scenario are analyzed in detail.

Here, c_1 and c_2 are considered the base numbers, and they can be changed based on managers' behavior, as discussed in the previous chapter in part 3.3.2. Furthermore, the society is divided into 4 regions that each region has 10 banks (in total, 40 banks for the society) to analyze the market more accurately in the case of regional correlated preference shocks. Figure 4.1 shows the regions of a society divided into 4 regions A, B, C, and D.

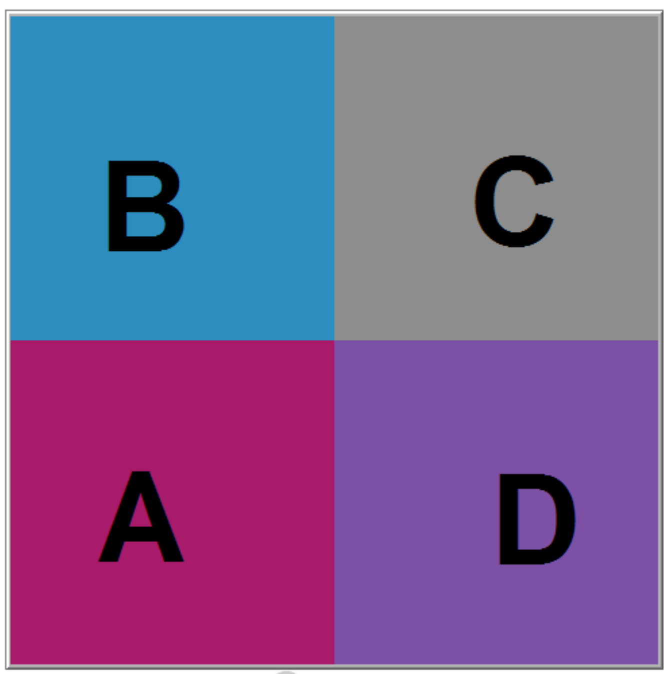

Figure 4. 1. Four regions of a society

4.1. The model without Central Bank and insurance

In this part, the model is considered without the presence of the central bank loans and the insurance system. First, the model is checked for the scenario when the correlated preference shocks do not exist in the model, and then the model is checked for the scenario when the correlated preference shocks occur in the system in some specific periods. In the following parts, the scenarios are analyzed and explained in detail.

4.1.1 The system without correlated preference shocks

In this part, the model is used for a scenario that there is a simple systematic trust banking in a society. In this scenario, there are no correlated preference shocks, Central Bank, and Insurance.

Bank's reputation is increased and decreased by the clients' ideas about the bank's function during the financial periods. In this system, people find out sooner, maybe before a huge banking failure in the system, which bank is weaker and which one is wealthier reputationally or more trustable, and consequently could satisfy their clients most specifically when they need liquidity, based on the banks' trust index. Figures 4.2 and 4.3 provide the result of the scenario for one society es as an instance.

Figure 4.2 shows a society with the features explained above. It shows that 15 banks could continue their business successfully through 100 financial periods, and each of them could successfully achieve a portion of the market. Some of them could absorb more clients and be more successful in attracting new clients and, consequently, having a better reputation.

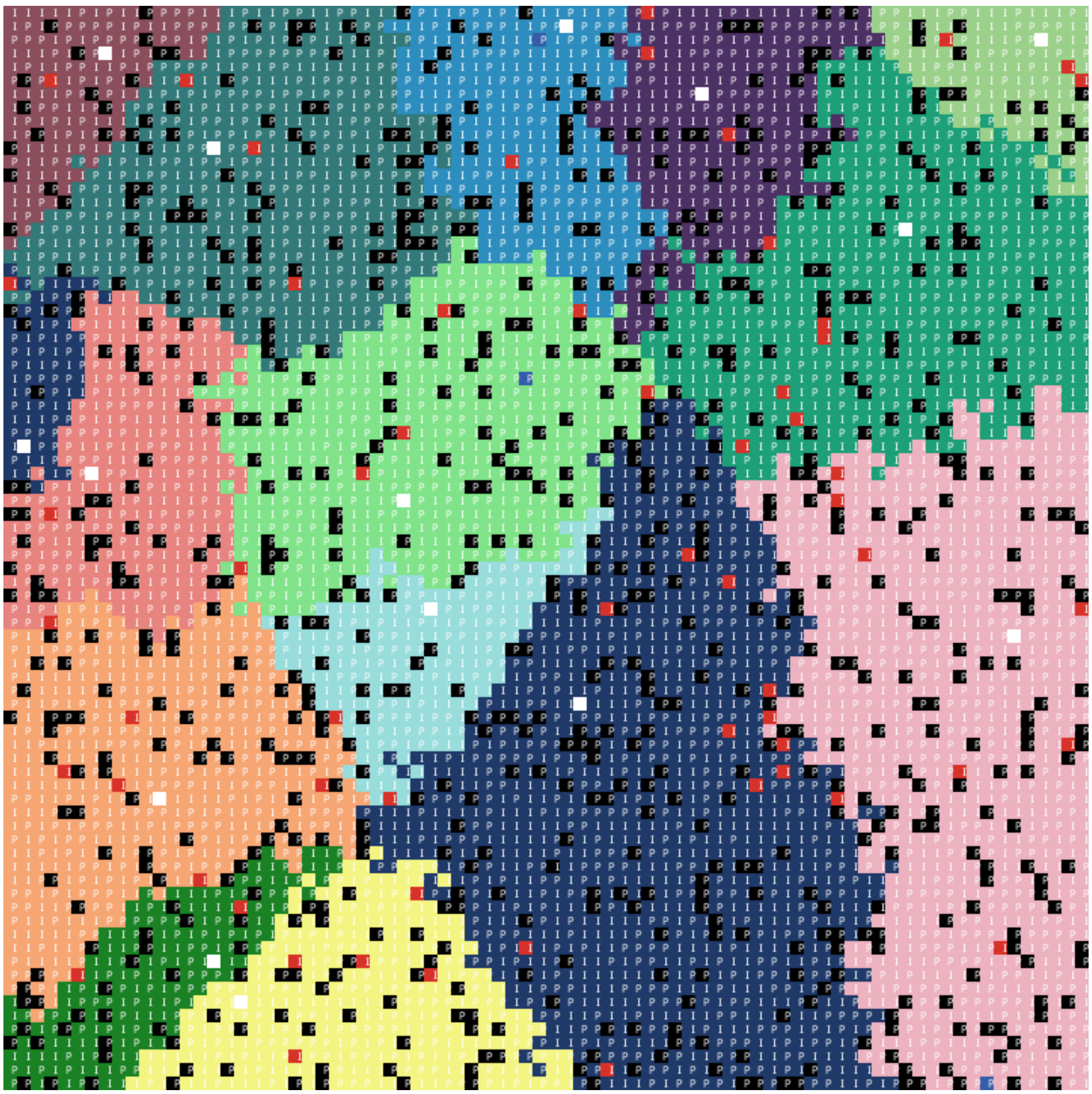

Figure 4. 2. Banks activity after 100 financial periods in a society without Central Bank and insurance

In figure 4.2, each bank's clients are shown with a specific color; the colors are selected randomly. In this figure, the banks are shown in white among their clients to have a better presentation.

In Figure 4.3, more details about the example are provided. In this figure, each line belongs to a bank, and the horizontal axis shows the number of periods. As can be seen, in this society, there are no frustrated clients after period 10, and trust is increased during the periods for the successful banks. Also, the banks learning process that is shown in the "Learning (W – W_bar)" chart of the figure indicates that the banks could update their information and their estimation about the ratio of their impatient and patient clients very well, and this help to work and to estimate their liquidity needs in step 2 or time 0 of the financial period as accurately as possible. In this example, the highest number of clients is for the bank with the dark blue color (with 984 clients) and the bank with the pink color (with 817 clients). These two banks could successfully attract approximately one-fourth of the market, and the rest of the market is divided between the 13 banks. The figure shows that from 10 banks of each region, 4 banks in region A, 5 banks in region B, 4 banks in region C, and 2 banks in region D could continue their business and find some portion of the market through 100 financial periods.

Based on the results of this instance, 25 banks could not continue their business, and the worst failure happened in period 10 with 145 frustrated clients. After this period, the frustrated clients of the society decreased to zero, and there are no frustrated clients in the banking system since then (based on the "Frustrated Clients" chart of Figure 4.3.

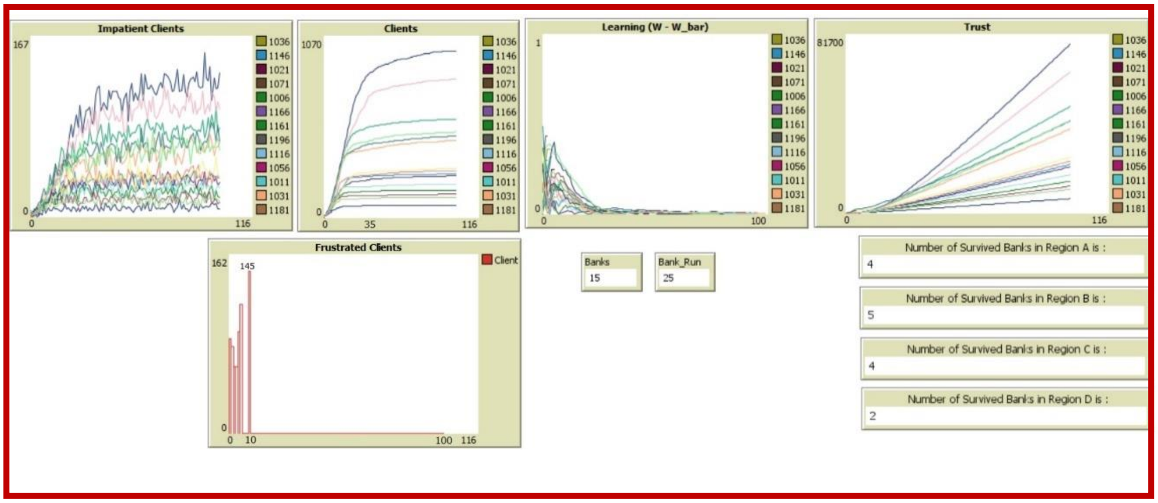

Figure 4. 3. The results of the banks' activities in the defined society through 100 financial periods

Besides, the same thing can be seen in the Client diagrams of each bank too (that shows the number of clients of each bank through 100 financial periods). The "Clients" chart of the figure indicated that after period 35, the banks found their customers and stabled their portion of the market.

Indeed, the figure indicates that the banking system of the society, which is working based on the trust system, is getting stable gradually thorough 100 financial periods, and this system lead agents to consider more stable banks to join based on the previous history of the banks' activities from the clients' point of view and this trust system can be mentioned as the banks' main spiritual assets that gained from the clients' experiences and shows the banks successful history over 100 financial periods.

Hence, the defined scenario is repeated for 100 financial periods. Then it is repeated for 500 different societies that each society is 80 by 80 (6400 agents in total), and the results are shown in Figure 4.4. The running time for such a simulation in a system with corei5 and SSD500 is between 2.5 to 3 hours.

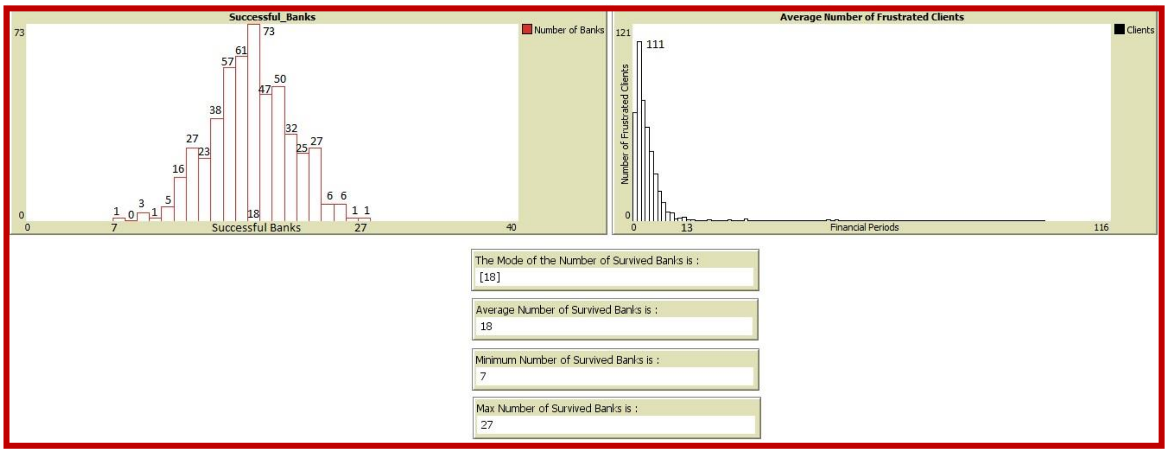

Figure 4. 4. The scenario's average number of successful banks and the average number of frustrated clients for 500 different societies

Figure 4.4. Shows the average number of successful banks for the defined scenario over 100 financial periods and considering the 500 different societies. The horizontal axis shows the number of banks as bids of the histogram. Each histogram shows how many times these number of banks could survive in different societies (over 100 financial periods).

Considering all the societies, the results indicate that the average number of survived banks is 18, and the minimum number and the maximum number of successful banks considering the societies are 7 and 27, respectively. As well, the mode of the number of survived banks is 18. Based on the Successful Banks chart of the figure, this can be found out that in 386 societies (out of 500) greater and equal to 16 banks have survived and successfully continue their business, which is equal to 77.2 % of the cases and in 148 societies more than 20 banks could survive or in other words in 29.6% of cases, more than half of the total banks (20 out of 40) could continue their business successfully.

Also, the average number of frustrated clients for the defined scenario over 100 financial periods and for 500 different societies can be seen in figure 4.4. The horizontal axis shows the number of periods, and each histogram shows the total number of frustrated clients for each society (over 100 financial periods).

From the "Average number of frustrated clients" chart, it is found out that after period 2, the percentage of Frustrated clients dramatically decreases. After period 13, there are approximately no frustrated clients in the system for all societies (except a few times that the system experience very few frustrated clients). This is because the trust system formed well by that period, and the clients have enough information to select the better banks based on the banks' previous customers' satisfaction points. Consequently, they can know which bank had a better performance during previous financial periods. This is very important as the clients select the more stable banks regarding the banks' previous function and avoid selecting the banks with poor functionality. Indeed, the trust system led the clients to detect stronger banks among their choices, and this led the system to be wealthier as the stronger banks detected sooner, and these banks could increase the system's total capital. This issue was examined based on the average capital of the 500 different societies over 100 financial periods, which is shown in figure 4.5.

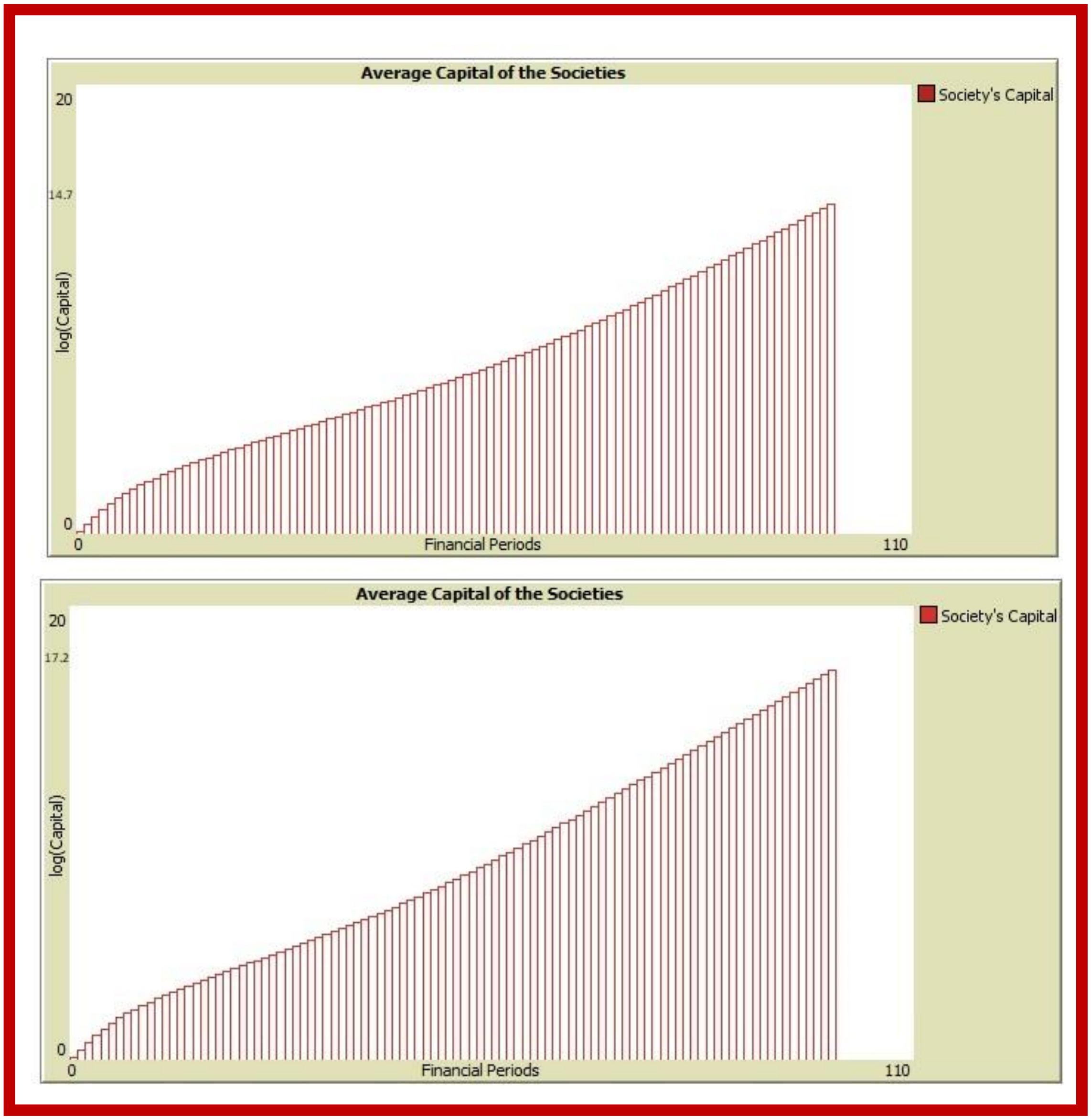

Figure 4. 5. The average capital of the 500 different societies over 100 financial periods

In Figure 4.5, the upper graph shows the average capital of the 500 different societies over 100 financial periods when the trust system is not considered in the banking system. The agents only decide based on their own experience of being in the market (based on the 7 strategies that were explained previously in chapter 3 in part 3.2.3). Furthermore, the lower graph shows the average capital of the 500 different societies over 100 financial periods when the trust system is considered for the system and the agents decide based on the 7 strategies to join a bank and then select a bank based on the specific characteristics of agents and banks' features that were explained in chapter 3. The results indicate that when a trust system exists, the societies' average capital is dramatically higher than the time it is not considered in the banking system. The logarithm of the average capital of the societies (vertical axis) over 100 financial periods (horizontal axis) shows that when the trust system is considered for the societies, the average capital at 100^{th} period is about 17.2 and when it is not considered for the societies the average capital at 100^{th} period is about 14.7.

Therefore, this is critical to consider systematic trust as an important characteristic of the banking system as it has a vital role in the system's average capital. Indeed, this impact could be happening because of the agents' awareness of the banks' previous performance (from the customer satisfaction point of view). Hence the agents would consider the better banks (among their choices) to work with; then their wealth is increased more proficiently that this leads to having a wealthier society and more trustable banks as based on the natural selection, the more reputable banks selected and could attract more clients than the banks with lower trust. Indeed, the trust system's main impact is changing each bank's clients' distribution as the clients prefer to work with a more reputable bank.

Furthermore, in this system, banks update their information periodically and learn about their patient and impatient clients' possible ratios based on their history. Hence, this learning process helps them to decide better about their liquidity needs in the middle of a financial period, and it helps them to act better regarding keeping their illiquid assets as much as possible by the time that they can liquidate the illiquid assets with the maximum possible rate (time 2 of a financial period).

Moreover, the saving system could increase society's total wealth and provide a more realistic condition for the banking system. The account fee that is received periodically provides a good source of income for the banks to increase their responsivity in keeping the clients' assets.

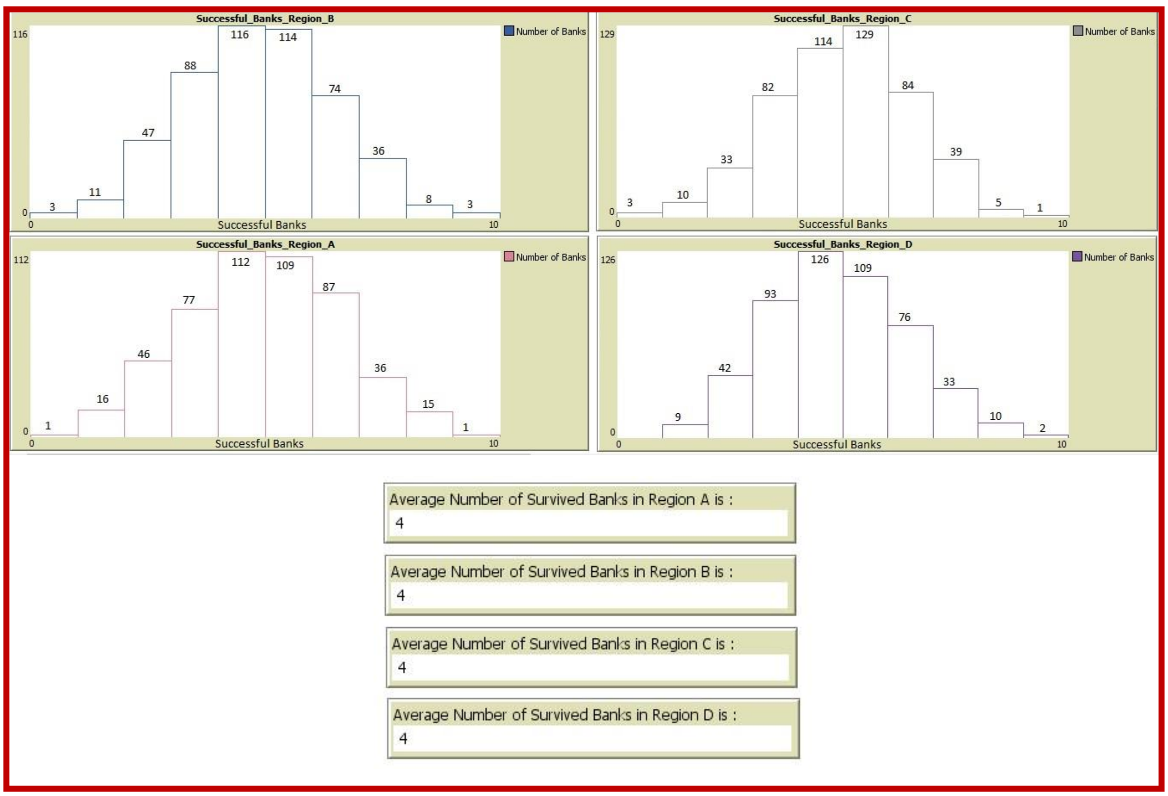

Figure 4. 6. The scenario's regional average number of successful banks for 500 different societies

Figure 4.6 provides more details about the average survived banks regionally through 100 financial periods for 500 societies. The results indicate that, in each of the regions A, B, C, and D, 4 banks could survive (on average); therefore, the distribution of the survived banks in these four regions is similar. Also, it shows that the regions are homogenous, and there is no difference between them. Later, in part 4.1.2, you could see how the correlated preference shocks change the banks' distribution between the shocked regions.

4.1.2. With regionally correlated preference shocks

In this part, the correlated preference shocks occur regionally, or it is better to say that they occur in some specific regions, to find out the impact of these shocks in the ability of the system to overcome that and to see what are the impact of these shock in the final results (considering the scenario through 100 financial periods and for 500 different societies). To this aim, the correlated preference shocks will occur in two of the regions. The correlated preference shocks will occur every 10 periods in regions A and C; however, the shocks will not occur in the two other parts (B and D). The correlated preference shocks in this new scenario have high intensity.

Figure 4.7 shows the average number of successful banks and the average number of frustrated clients through 100 financial periods for 500 different societies when there are regional correlated preference shocks in the scenario. Figure 4.9 shows the regional average number of successful banks through 100 financial periods for 500 different societies considering the regional shocks.

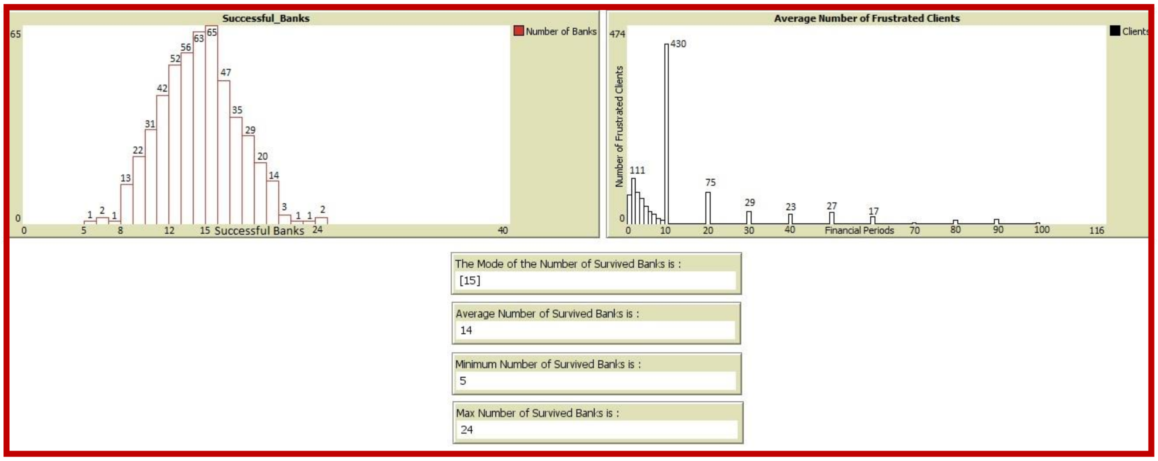

Figure 4. 7. The scenario's average number of successful banks and the average number of frustrated clients for 500 different societies, considering the regional correlated preference shocks

Based on the information provided in the "Successful Banks" chart of figure 4.7, considering all societies, the results indicate that the average number of successful banks is 14. The minimum number and the maximum number of successful banks are 5 and 24, respectively. As well, the mode of the number of survived banks is 15. These numbers are slightly lower (10% lower average) than the results of a scenario when the correlated preference shocks did not exist in the societies. In the case without the occurrences of the correlated preference shocks and considering 500 different societies, on average18 banks (45% of the banks), could successfully keep their business during 100 financial periods; however, after the shocks occurred, this number decreased to 14 (35% of the banks). The results could indicate that although the shocks could impact the banking system, the system has enough stability to overcome these shocks, and only a few more bank failures occurred in the system (10% more failure in the banking system). Later, in part 4.2.2, you would see how the system decreases these failures using a defined loan system.

Also, the "Average Number of Frustrated Clients" chart of figure 4.7 shows the average number of frustrated clients for the defined scenario over 100 financial periods and for 500 different societies. The horizontal axis shows the number of periods, and each histogram shows the average number of frustrated clients for the societies in the n^{th} period (over 100 financial periods). The results indicate that the system experienced some bank failures in the periods that shock occurred; however, after the 10^{th} period (the period that first correlated shock occurred), this amount decreased gradually, and after the 60^{th} period, this amount even decreased more.

Hence, it can be found out that the system is trying to learn the procedures and the banks trying to overcome experiencing a failure based on this learning system; as well because the trust system formed well by the 60^{th} period, the clients have good information, based on the points that the banks received from their customer by that period, to select the most stable banks between their possible choices. When the correlated trust occurs in a banking system, the trust index needs more time to be shaped to have the customers' experiences for the shocked periods.

Indeed, in this system, agents try to choose wealthier and more stable banks based on the available information about the banks' reputation. Besides, from the "Average Number of Frustrated Clients" chart of figure 4.7, it can be said that the worst bank failure happened in period 10 with an average of about 430 frustrated clients; this period is the first period that the shocks occurred in the system, since then on the banking system try to handle the shocks.

The average capital of the 500 different societies over 100 financial periods is shown in figure 4.8. In this figure, the regional correlated preference shocks occur in the system, the upper graph shows the average capital of the 500 different societies over 100 financial periods when the trust system is not considered in the banking system, and the agents only decide based on their own experience of being in the market (based on the 7 strategies that were explained previously in chapter 3 in part 3.2.3). Furthermore, the lower graph shows the average capital of the 500 different societies over 100 financial periods when the trust system is considered for the system and the agents decide based on the 7 strategies to join a bank and then select a bank based on the specific characteristics of agents and banks' features that were explained in chapter 3. The results indicate that by occurring the correlated preference shocks in the system, the scenario with the trust system has a significantly higher average capital of the societies than the time the trust system is not considered in the banking system. In this case, the logarithm of the average capital of the societies (vertical axis) over 100 financial periods (horizontal axis) shows that when the trust system is considered for the societies, the average capital at 100th period is about 18.6 and when it is not considered for the societies the average capital at 100th period is about 15.2. So that, even by occurrences of the correlated preference shocks, the systematic trust has a vital role on the average capital of the banking system, and the systematic trust should be considered as an important feature of the banking system.

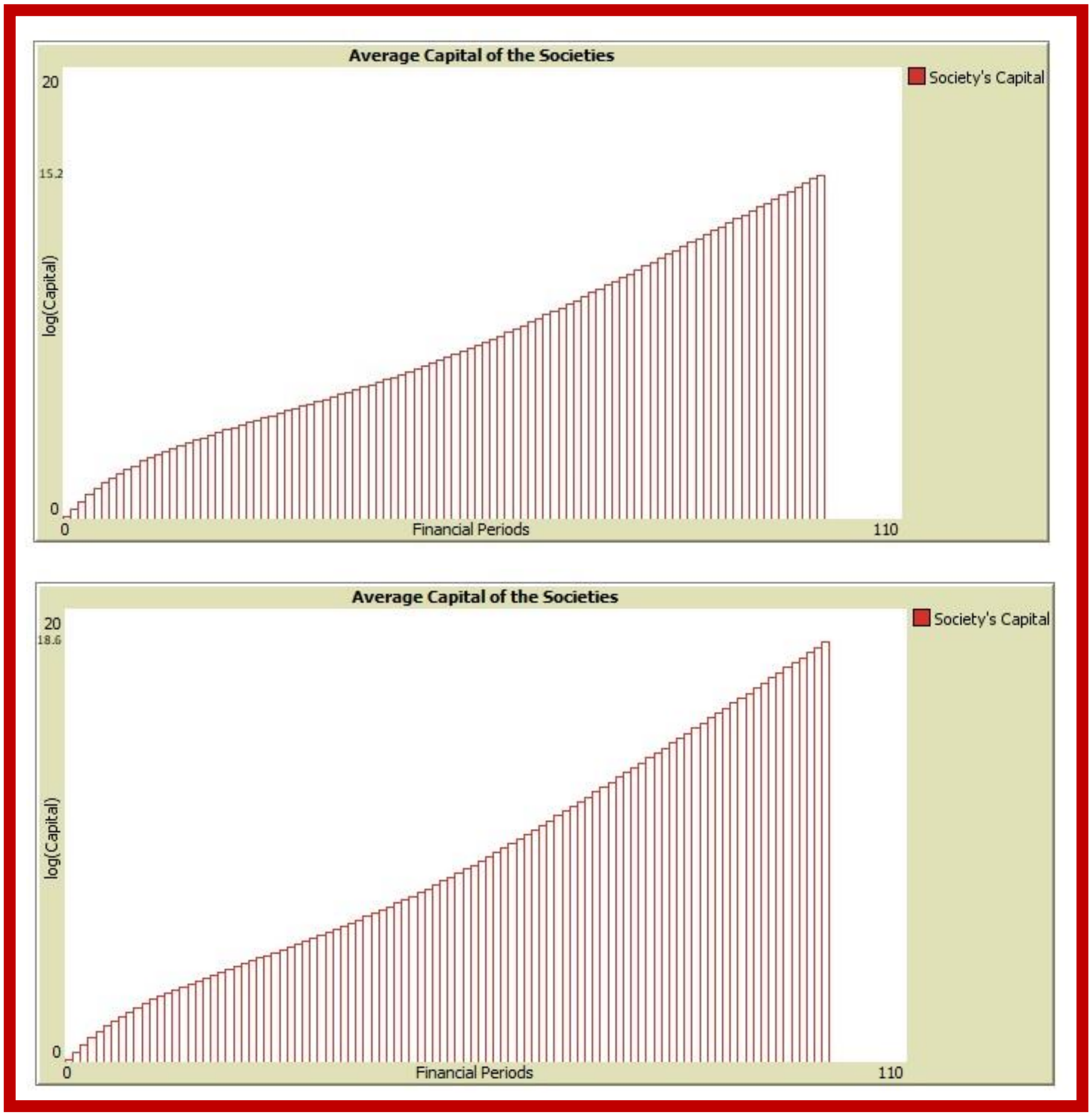

Figure 4. 8. The average capital of the 500 different societies over 100 financial periods (with the existence of regional correlated preference shocks)

Figure 4.9 below shows that the regional impacts of the correlated preference shock on the banking system. Based on the results, these shocks did not have a significant impact on the final results.

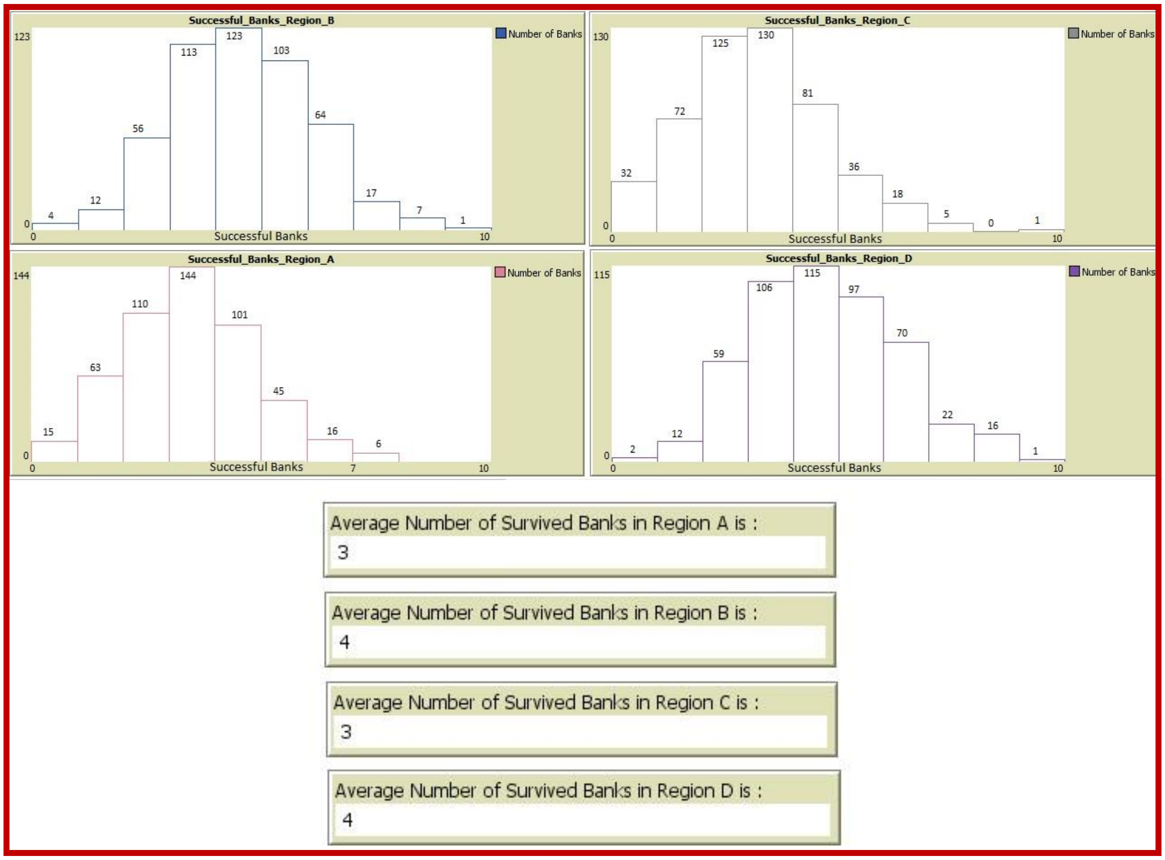

Figure 4. 9. The scenario's regional average number of successful banks for 500 different societies, considering the regional correlated preference shocks

In figure 4.6, the results indicate that, in each of the regions A, B, C, and D, 4 banks could survive on average; however, in figure 4.9, the results indicate that these numbers are 3, 4, 3, and 4 for the regions A, B, C, and D, respectively. Therefore, regarding the issue that the correlated preference shocks occurred in regions A and C, the number of banks in regions A and C experienced a slight decrease (1 more failure in each of them), and on average, there are no more failures in the regions B and D. Hence, these shocks only slightly impacted the bank activities of the shocked regions.

4.2. The system with Central Bank and insurance

In this part, the Central Bank and Insurance system are added to the banking system, and the results are explained in detail. As well, the scenario is examined when the regionally correlated preference shocks occurred. Finally, the results of this scenario (with the Central Bank and Insurance system) are compared to the case that there is no Central Bank and Insurance system in the banking system discussed in part 4.1.

4.2.1. Without correlated preference shock

In this part, the previous scenario features are used, but this time some other features related to the presence of the Central bank and Insurance system are considered too. The Central bank provides loans for the banks to support them when they need liquidity in time 1 (based on some conditions explained in chapter 3 part 3.5). The Insurance system (that was explained in chapter 3, part 3.4) helps the banks support their clients' deposits in failure occurrences as much as possible that is beneficial for society's total wealth and their possible future investments in the banking system.

First, the defined scenario is examined for a society during 100 financial periods, and the results are provided in figures 4.10 and 4.11. The scenario is then examined for 500 different societies, and the results are provided in figures 4.12 and 4.13. In this part, the fixed amount of the insurance that each bank should pay it based on their clients' assets is set to 0.006 of the unit, and if a bank receives a loan, it should be paid in 20 financial periods considering the Central Bank loan Interest of 0.01. The banks can be eligible to ask for a loan if they have enough capital to pay at least 75% of their dept to the clients (in time 1). More information about the Central Bank loan system was provided in chapter 3, part 3.5.

Figure 4.10 shows a society with the features explained above. Figure 4.11 shows that using the applied features explained above, 37 banks could continue their business successfully through 100 financial periods in this society, and each of them could successfully achieve a portion of the market. Some of them could absorb more clients and be more successful in attracting new clients and, consequently, having a better reputation. Only 3 bank failures occurred in this example.

Indeed, 92.5% of the banks could continue their business successfully by the end of the 100th financial period. The worst number of frustrated clients is about 202 in the 16th financial period; also, there are no frustrated clients after this period. Hence, the loan system helps to significantly decrease the number of frustrated clients through the 100 periods

Moreover, the Central Bank supports the banks' liquidity as much as possible, and it helps the banks to overcome their liquidity needs shortages in time 1. Hence, the banks have more chance to continue their business and stabilize their business mostly in the first periods of their business that they probably face a shortage regarding the issue that they need more time to complete their learning process.

Besides, the "Clients" and "Insurance" charts of figure 4.11 indicate that after a few periods (about 15 periods), the banks could find their portion of the market, and their business will be stable.

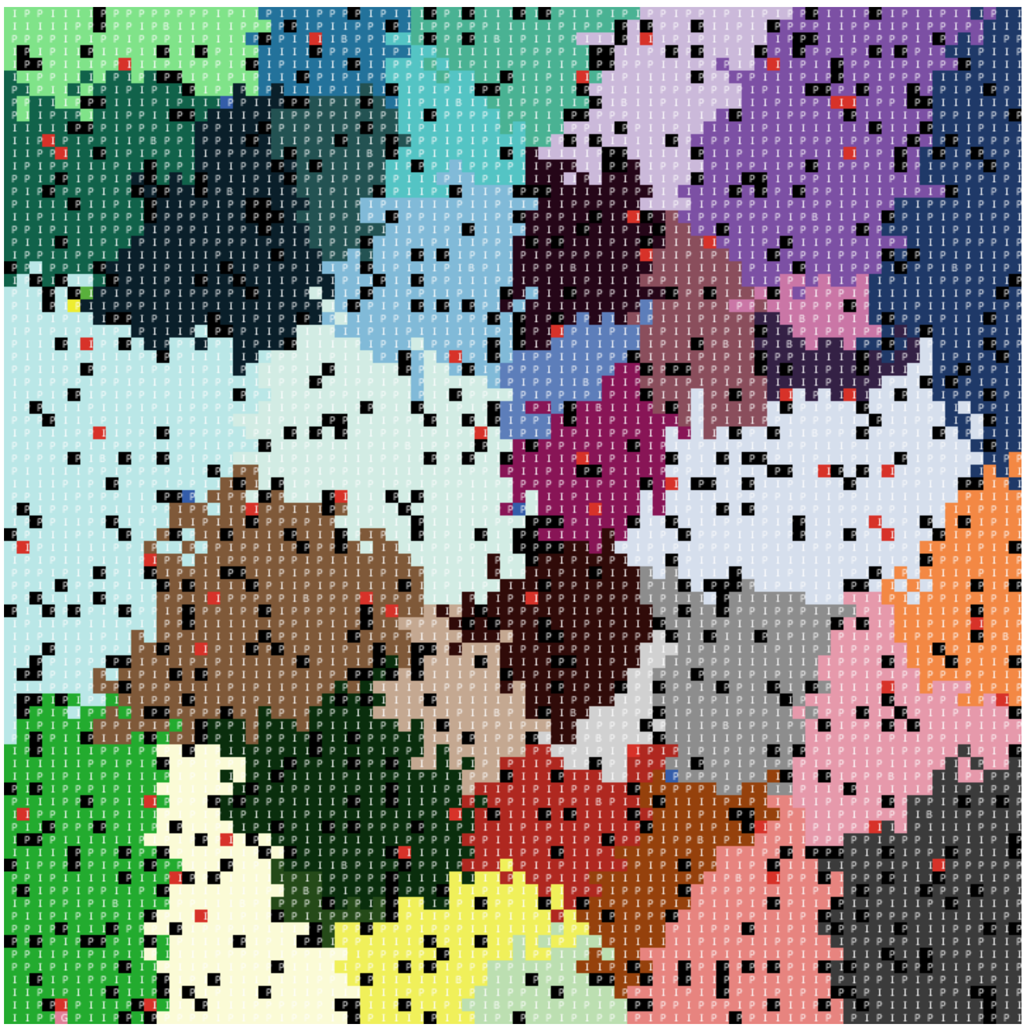

Figure 4. 10. Banks' portion of the market after 100 financial periods in a society with Central Bank and insurance

Indeed, when the banks start their business in the first period and start absorbing new clients, their business is risky, and there could be more chance of bank failure regarding their lack of enough capital and they have to continue their business for a while to be able to reach a stable condition in the market. In this regard, the Central Bank loans could support them in going further in their business and providing this chance for them to have an extra resource (considering some conditions explained in chapter 3 part 3.5) to overcome its liquidity needs shortages. Also, during the 100 financial periods, the banks could use this option to keep their clients and continue their business; however, the bank can receive negative points from its clients regarding using this source.

During financial periods, some of the banks could face a failure in their business, and consequently, they must leave the market; on the other hand, some of them could work better and find their place in the market and absorb more clients and attract their trust. In this way, the insurance system, as much as possible, helps the clients to receive their deposited assets back, and it could be beneficial for the overall wealth of the society.

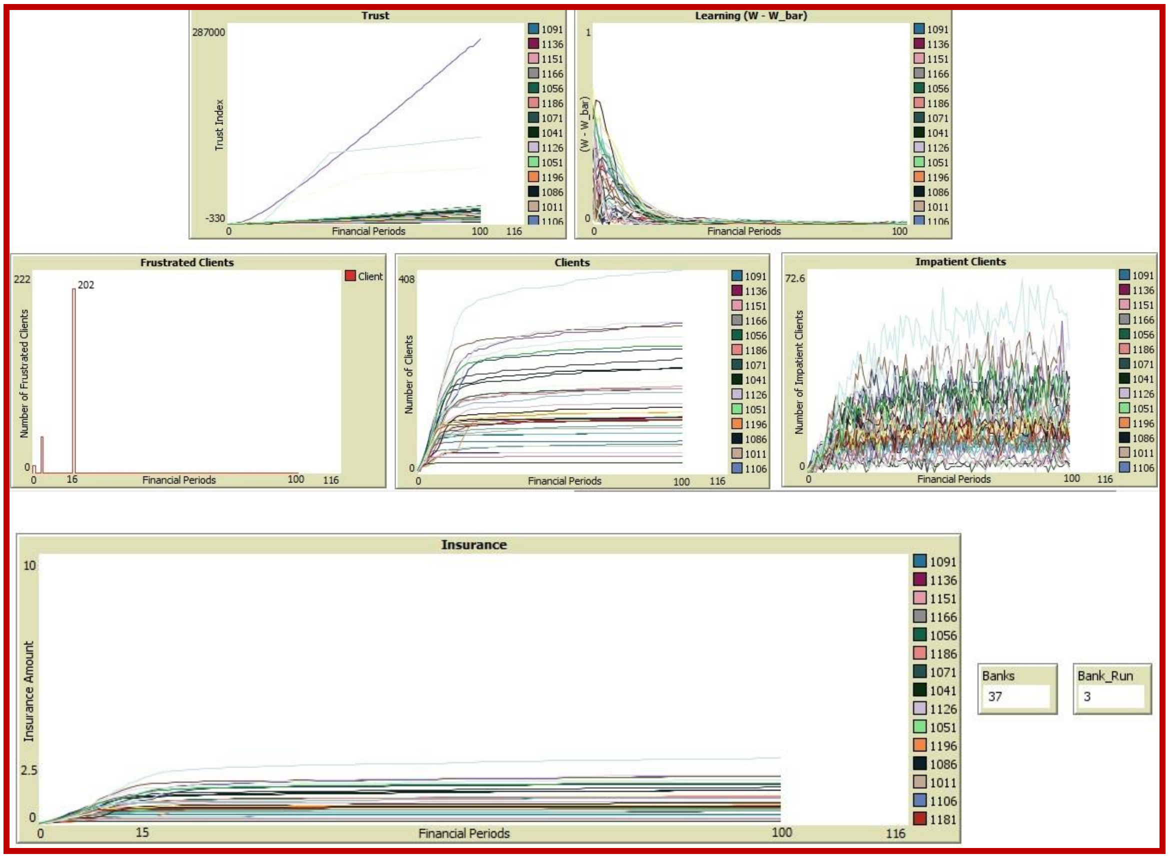

Figure 4. 11. The results of the banks' activities in the defined society through 100 financial periods (considering the existence of the Central Bank and insurance)

Figure 4.11 shows that the trust index of each successful bank is increased during the periods; also, the banks learning process that is shown in the "Learning (W – W_bar)" chart of the figure indicates that the banks could update their information and their estimation about the ratio of their impatient and patient clients very well. This helps to work and estimate their possible liquidity needs of time 1 of the financial period as accurately as possible. In this example, the highest number of clients is for the bank with a light blue color (408 clients). Because more banks had the chance to grow in this system, it could be said that the market divided more appropriately between the banks.

The defined scenario is repeated for 100 financial periods, and then it is repeated for 500 different societies that each society is 80 by 80 (6400 agents in total), and the results are shown in Figure 4.12.

Considering all the societies, the results indicate that the average number of survived banks in this scenario is 35. The minimum number and the maximum number of successful banks considering the societies are 28 and 40, respectively. As well, the modes of the number of survived banks are 35 and 36. The average number of frustrated clients for the defined scenario over 100 financial periods of 500 different societies can be seen in this figure. In the "Average Number of Frustrated Clients" chart, the horizontal axis shows the number of periods, and each histogram shows the average of the total number of frustrated clients for each society (over 100 financial periods).

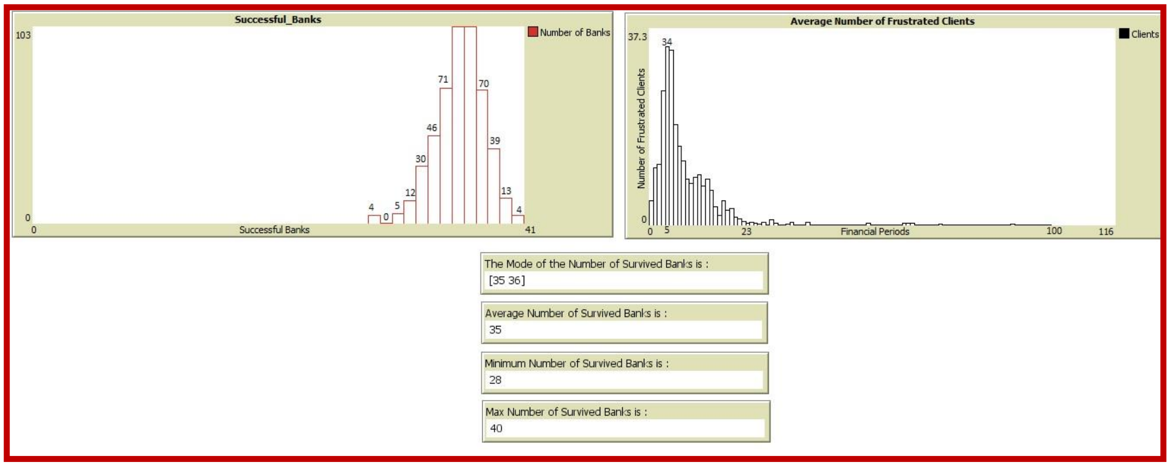

Figure 4. 12. The scenario's average number of successful banks and the average number of frustrated clients for 500 different societies (considering the existence of the Central Bank and insurance)

From the "Average number of frustrated clients" chart of figure 4.12, it is found out that after period 5, the number of frustrated clients is gradually decreased, and there are approximately no frustrated clients after the 31st financial period in the system for all societies (except a few times that the system experience a few frustrated clients). This is because the trust system formed well by that period, and the clients have enough information to select the better banks based on the banks' previous customers satisfaction points; consequently, they can know which bank had a better performance during previous financial periods. This is very important as the clients select the more stable banks regarding the banks' previous function and avoid selecting the banks with poor functionality.

Furthermore, in this system, banks update their information periodically and learn about their patient and impatient clients' possible ratios based on their history. Hence, this learning process helps them to decide better about their liquidity needs in the middle of a financial period, and it helps them to act better regarding keeping their illiquid assets as much as possible by the time that they can liquidate the illiquid assets with the maximum possible rate (time 2 of a financial period).

Moreover, the saving system could increase society's total wealth and provide a more realistic condition for the banking system. The account fee that is received periodically provides a good source of income for the banks to increase their responsivity in keeping the clients' assets. Also, the Central Bank loans help the banks to have a better performance in keeping their customers, and the insurance system helps to save the wealth of agents in a failure occasion. All these things together help the banking system work well for different societies with the same scenario. On average, 35 banks (out of 40 banks), which is 87.5% of all banks, in the system work successfully based on this scenario. This result is dramatically higher (42.5% higher) than when the Central Bank was not in the society that explained in the previous part (4.1.1).

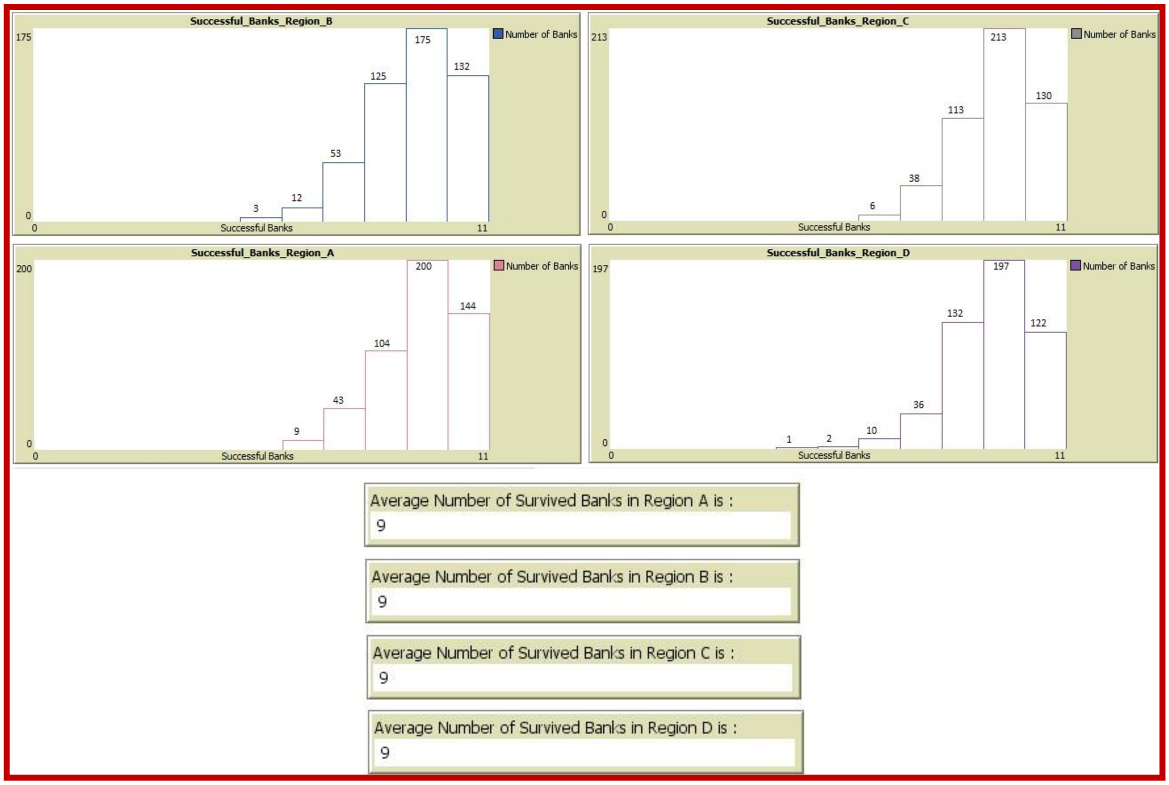

Figure 4. 13. The scenario's regional average number of successful banks for 500 different societies (considering the existence of the Central Bank and insurance)

Figure 4.13 provides more details about the average survived banks regionally through 100 financial periods for 500 societies. The results indicate that, in each of the regions A, B, C, and D, 9 banks could survive on average, and this is a very good result in comparison to the time that there was no Central Bank support, as only explained in part 4.1 that on average, only 4 banks could survive in each of the regions. This information would be beneficial to compare the results of the scenarios with and without correlated regional shocks.

Therefore, a scenario with the existence of the Central bank loans and Insurance system has resulted that:

1-In this scenario, Central Bank loans helped the banks in the first periods to absorb more clients and to be able to support their clients better, respectively.

2- In the 500 times repetitions of the scenario with the mentioned features, more banks could continue their business success than when we have no central bank in the system.

3- The market is divided between the banks more efficiently, and more banks continue their business so that there are more successful competitors in the market, which means people have more choices.

4- The insurance system secures the wealth of society as much as possible.

4.2.2. With regionally correlated preference shocks

In this part, the correlated preference shocks occur regionally; in other words, they occur in some specific regions. To this aim, every 10 periods, the system experience a correlated shock in regions A and C. The results of these shocks for 500 different societies are provided in figures 4.14 and 4.15.

The results indicate that the system works well, and these correlated regional shocks do not cause a significant change in the banking system compared to the time that the Central bank does not exist in the societies (scenario of part 4.2.1). However, the results show that the existence of the Central Bank loans and Insurance system, on average, helps the banking system ignore the correlated shocks. Consequently, the system could continue its cycle without any new systematic failure caused by the correlated shocks.

Figure 4.14 shows that, on average, 35 banks could successfully continue their business for 500 different societies, and the mode of the number of survived banks is 34. In part 4.1.2, we saw that on average, 14 banks could survive, which is 35% of the total banks who start their business, and this could show that the chance of having a successful business could approximately increase 100% with the existence of the Central Bank loans and Insurance system in the banking system.

The maximum and the minimum numbers of survived banks of this scenario for 500 different societies are 26 and 40, respectively. The results could indicate that the system has enough stability to overcome the impacts of the correlated shocks.

Also, the "Average Number of Frustrated Clients" chart of figure 4.14 shows the average number of frustrated clients for the defined scenario over 100 financial periods and for 500 different societies. The horizontal axis shows the number of periods, and each histogram shows the average number of frustrated clients for the societies in the n^{th} period (over 100 financial periods). The results indicate that the system experienced considerably fewer frustrated clients than when the Central Bank does not exist in the system (part 4.1.2. After the 40th period and approximately the frustrated clients go to zero, the system finds its stability. The results indicate that the Central Bank loans helped the banking system overcome the correlated shocks' impacts as much as possible.

Hence, it can be found out that the system is trying to learn the procedures and the banks trying to overcome experiencing a failure based on this learning system; as well because the trust system formed well by the 40th period, the clients have good information, based on the points that the banks received from their customer by that period, to select the most stable banks between their possible choices. When the correlated shocks occur in a banking system, the trust index would need more time to be shaped to have the customers' experiences for the shocked periods.

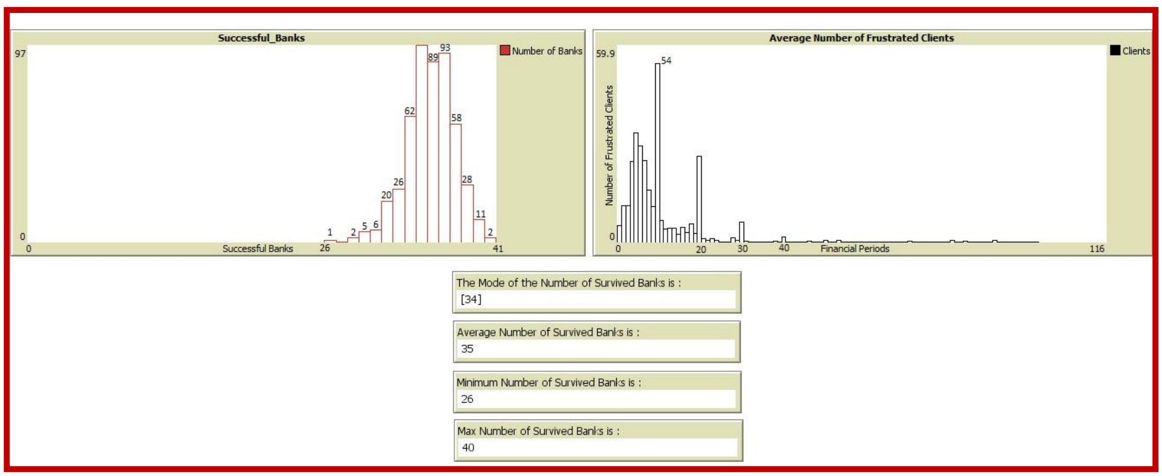

Figure 4. 14. The scenario's average number of successful banks and the average number of frustrated clients for 500 different societies, considering the regional correlated preference shocks (considering the existence of the Central Bank and Insurance)

As an extra cost, the insurance system leads the weaker banks to be omitted sooner, and on average, this helps the agents know the weaker banks sooner. The highest number of frustrated clients was 430 in part 4.1.2, which decreased to 54 in Figure 4.14.

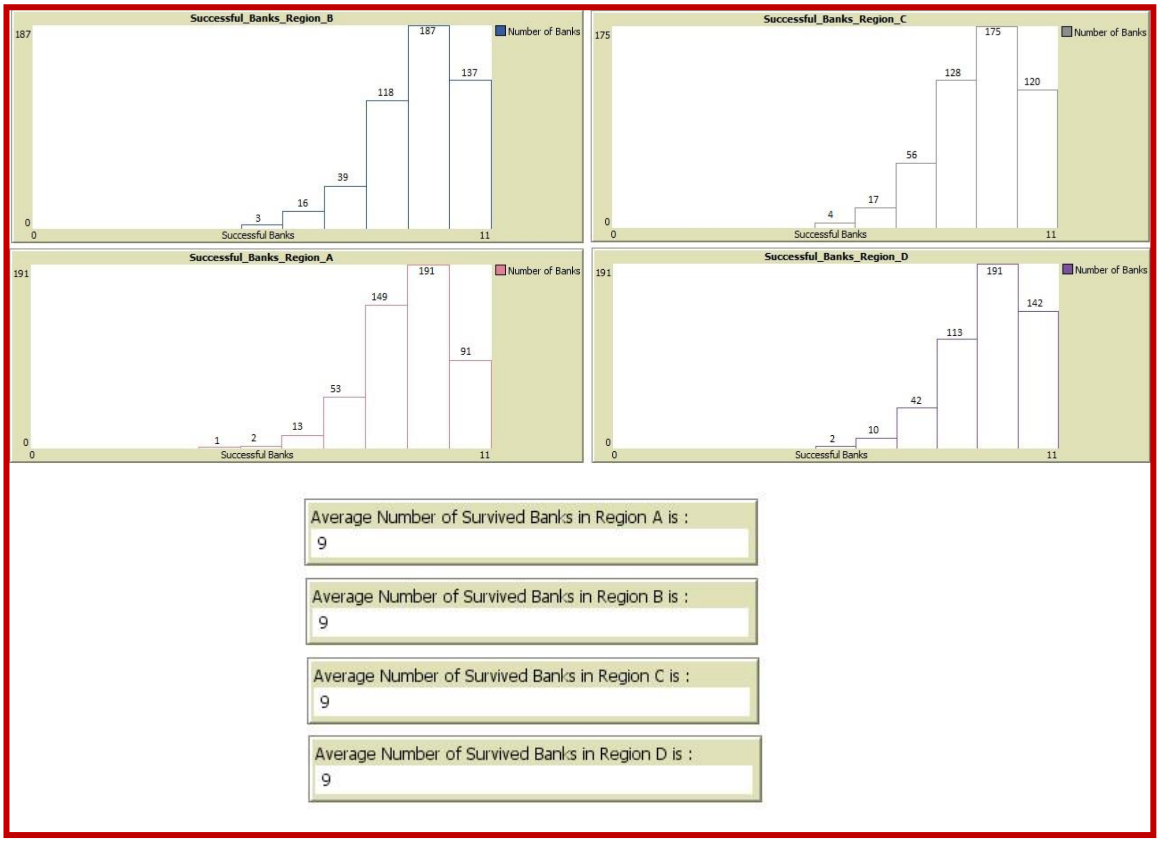

Figure 4. 15. The scenario's regional average number of successful banks for 500 different societies, considering the regional correlated preference shocks (considering the existence of the Central Bank and Insurance)

The average number of banks in various regions is provided in Figure 4.14. Based on the results, these shocks did not impact the final results as, on average, for 500 different societies, each region has 9 banks.

All in all, the results show that the Central Bank helps the banks in a difficult economic situation by giving them loans; hence, the banks use the loan system to support their clients to keep them satisfied as much as possible.

In our programmed model, all these diagrams can be exported in an excel file, and the information on the activity of a specific bank can be analyzed individually for various case studies.

4.3. Different bank rates

In this part, the different crates and their impact are examined in a banking system based on systematic trust. In this part, a simple banking system (without Central Bank loans and Insurance system) based on the trust system would be considered.

4.3.1. Lower c_2 base rate

If we consider lower c rates like the base rates: $c_1 = 1.1$ and $c_2 = 1.3$, then the banks could have more profit at the end of each period. However, the rates will be changed a bit based on the managers' behaviors, but still, the range of the c_1 and c_2 are lower than the previous examples. For example, in a simple model, if we consider these rates, then more banks can continue their business successfully, and there would be fewer frustrated clients in the system because the system has wealthier banks in comparison to the time that the c_2

is greater and is near to the market rate R. Figure 4.16 show the result of this scenario for 500 different societies.

In figure 4.16, considering all the societies, on average from period 17, approximately there are no frustrated clients, as well, there are 27 successful banks; however, they may have lower clients than the ones explained in the previous parts with higher c_2. In this scenario, the banks work under less risky conditions, and they could have more capital regarding their rates as by decreasing the bank rates, the risk decreases in the banking system. Consequently, more banks can satisfy their clients, and instead of having a significant portion of the market, they try to keep their current clients satisfy as much as possible. In this figure, the average number of successful banks and the mode is 28, which is 70% of the total banks who start their business in the first financial period. This amount was 45% for the model with $c_2 = 1.5$, which shows lowering the rate in this scenario, 25% increases the chances of the banks to be successful.

Figure 4.16 shows that the maximum and the minimum number of successful banks in the 500 different societies is 36 and 16, respectively, which are dramatically higher than the scenario explained in part 4.1.1. Also, on average, the highest number of frustrated clients for the banks is 62 in the 2^{nd} period and is significantly lower than the one explained in part 4.1.1. After the second period, the average number of frustrated clients dramatically decreases, and it goes to zero. All in all, in this scenario, banks and clients are in a less risky condition.

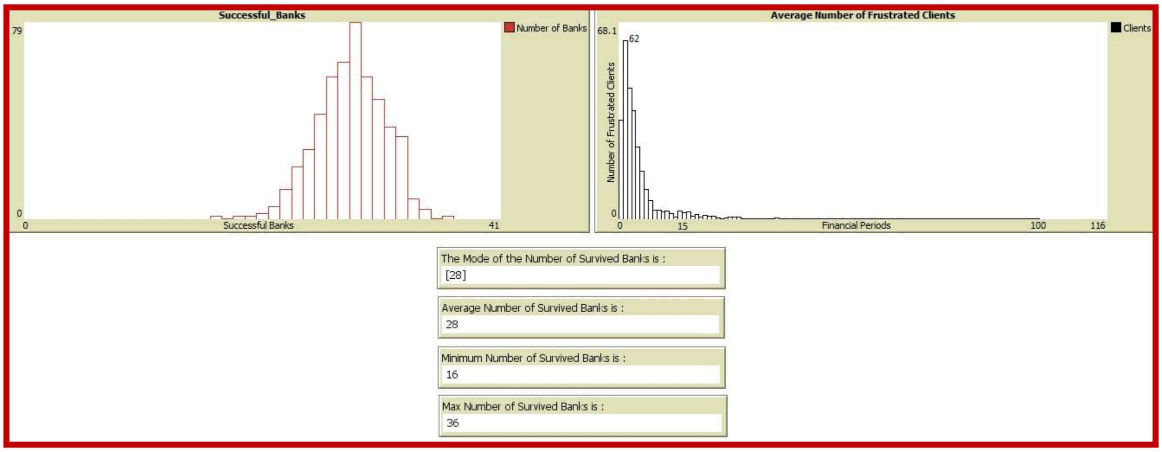

Figure 4. 16. The scenario's average number of successful banks and the average number of frustrated clients for 500 different societies with the banking base rates c_1=1.1 and c_2=1.3

4.3.2. Higher c_1 and c_2 base rates

Now, if we consider higher rates for a scenario (for example, the base rates c_1 = 1.3 and c_2=1.7), then we could either have no banks at the end of period 100 or oligopoly conditions, as well the chance of monopoly occurrences is dramatically increased as the results show in the Figure 4.17. Based on the figure, the maximum and the minimum number of banks for the 500 different societies are 6 and 0, respectively.

Besides, based on the figure, the successful banks' mode for 500 different societies for this scenario is 1, and the average number of successful banks is 2. Hence, on average, 2 banks could continue their business successfully, and each of them could have a huge number of clients.

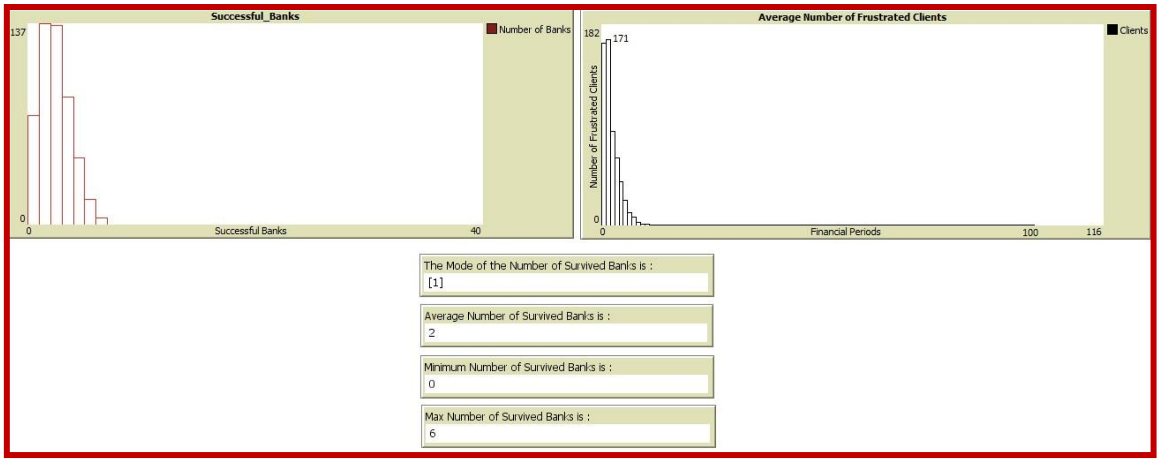

Figure 4. 17. The scenario's average number of successful banks and the average number of frustrated clients for 500 different societies with the banking base rates c_1=1.3 and c_2=1.7

However, after period 11, there are no frustrated clients in the system, but by that time, most of the banks experienced a failure and could not continue their business. This condition put the market in a risky condition. Regarding the vast number of agents of a bank, the chance of a catastrophic failure in the banking system by occurring a shock is increased dramatically.

All in All, by providing lower rates, the banks could have fewer clients compared to the time the banks provide higher rates but will be in a less risky condition. So that, as long as banks could provide enough profit per customer, they can increase the rates due to absorbing more clients. However, they have to avoid considering very high rates as it could lead them to a bank failure, and it is a very risky condition for both the bank and their clients.

Chapter 5

5. Conclusion and recommendations for future research directions

In this research project, a new agent-based model based on systematic trust was introduced. The model was explained conceptually and mathematically, and the results were discussed and analyzed.

As a brief review, in chapter 2, some literature, including but not limited to systematic banking and the process of people decision making in selecting a product or service based on their needs, was reviewed. To this aim, Maslow's hierarchy of needs was reviewed.

In chapter 3, the details of the introduced model, different attributed in selecting a bank, the saving system, the Central Bank loans, and the Insurance system were explained.

In chapter 4, some scenarios were applied based on the introduced model. The scenarios such as a banking system with or without Central Bank and Insurance system and their stability when the regional correlated preference shocks occurred in the system, the scenarios for comparing the banking system situation when the bank rates are high and when the bank rates are low, also the scenarios to compare the impact of systematic trust on the average of the total capital of the banks per financial periods.

The results of these scenarios were analyzed and discussed in chapter 4, and some results were concluded that explained in chapter 4.

Conclusively, the main findings are:

1- The existence of systematic trust in the clients' decision-making process leads the banking system (on average) to have a higher total capital at the end of each financial period compared to the time clients select a bank to join by chance and without evaluating the bank features based on their individual needs.

2- The regional correlated preference shocks cause higher bank failure.

3- The Central Bank loans help the system overcome the correlated preference shocks. On average, the results indicated that when the banks have the financial support of the Central Bank, the correlated shocks will not cause more bank failure in the system.

4- By considering very high rates, the banking system placed in a higher risk condition; hence, the bank failures increased, and the possibility of monopoly or oligopoly situations is increased dramatically. However, by lowering the bank rates, the banking system experiences a lower risk condition, and the banks can continue their business with more stability, and the system would be safer for both the banks and their clients.

So that, this research project aimed to introduce a more realistic model for a banking system that considers some extra attributes for the banking system and the people behavior and the impact of these features in the decision making and final performance of the system in the agent-based space.

However, this research project provided a more realistic model for systematic banking by considering behavioral features and extra attributes for the Agent-Based system, it can be improved in the future. Other features can be added to the system to make it even more realistic and expand the system by adding more details in various parts of the model.

Indeed, the model can be improved from different perspectives like policy-making, economics, behavioral finance, and management. Below, some suggestions for expanding the model are provided:

First of all, there could be some improvements to the agents' attributes. In the current model, people do not have any concern about receiving their income periodically (as all of them receive a fixed endowment in each period); hence, the first level of Maslow's hierarchy of needs is not a matter in the introduced model. However, this issue can be upgraded in future studies regarding people's income situation.

Besides, in this model, we do not consider any attributes for level five of Maslow's hierarchy of needs, which is "Self-Actualization." Hence the introduced model can be expanded in this way.

Furthermore, it is possible to consider an investment account for the banks to invest in various international projects to receive some profit from this activity as well.

Moreover, the model's decision-making process can be expanded by considering more features for the system and the agents based on management, psychology, and Behavioral Finance. Also, the possibility of receiving loans from the banks by agents to spend on housing or other expenditure issues can be considered in future studies.

All in all, those interested in the introduced model can use the introduced model as a base model. By changing some parts of the codes or some parts of the defined features, they can make the model suitable for simulating a specific case or analyzing a specific phenomenon in systematic banking, systematics shocks, systematic failures, or systematic trust.

Chapter 6

6. Bibliography

Allen, Franklin, and Douglas Gale. "Financial Contagion." *Journal of Political Economy* 108, no. 1 (2000): 1–33. https://doi.org/10.1086/262109.

Babić-Hodović, Vesna, Eldin Mehić, and Maja Arslanagić. "Influence of Banks' Corporate Reputation on Organizational Buyers Perceived Value." *Procedia -Social and Behavioral Sciences* 24 (2011): 351–60. https://doi.org/10.1016/j.sbspro.2011.09.063.

Bagehot, Walter, and Frank C. Genovese (1962), *Lombard Street*. Homewood, IL: Irwin, 1962.

Borrill, Paul L., and Leigh, Tesfatsion. "Agent-Based Modeling: The Right Mathematics for the Social Sciences?" *The Elgar Companion to Recent Economic Methodology*, July 2010. https://doi.org/10.4337/9780857938077.00018.

Buckley, Ross P, and Justen Nixon. "The Role of Reputation in Banking." *Journal of Banking and Finance Law and Practice*, 20 (2009): 37–50.

Cassar, Graziana. "Investigating Needs in Banks' Newspaper Advertisements on The Sunday Times of Malta in 2002 and 2012," (2014). http://search.ebscohost.com.libaccess.lib.mcmaster.ca/login.aspx?direct=true&db=edsbas&AN=edsbas.FBC5E99A&site=eds-live&scope=site.

Diamond, Douglas W., and Philip H. Dybvig "Bank Runs, Deposit Insurance, and Liquidity." *Journal of Political Economy* 91, no. 3 (1983): 401–19. https://doi.org/10.1086/261155.

Drakopoulos, Stavros, and Katerina. Grimani, "Labor Earnings Reductions, Happiness Levels and Needs Hierarchy." *International Journal of Wellbeing* 7, no. 1 (2017): 23–39. https://doi.org/10.5502/ijw.v7i1.540.

Fang, Lily Hua. "Investment Bank Reputation and the Price and Quality of Underwriting Services." *The Journal of Finance* 60, no. 6 (2005): 2729–61. https://doi.org/10.1111/j.1540-6261.2005.00815.x.

Fombrun, Charles J. *Reputation: Realizing Value from the Corporate Image*. Boston, MA: Harvard Business School Press, 1996.

Grasselli, Matheus R., and Omneia R. H. Ismail. "An Agent-Based Computational Model for Bank Formation and Interbank Networks." *Handbook on Systemic Risk*, 2013, 401–31. https://doi.org/10.1017/cbo9781139151184.021.

Grittersová, Jana. "Transfer of Reputation: Multinational Banks and Perceived Creditworthiness of Transition Countries." *Review of International Political Economy* 21, no. 4 (2014): 878–912. https://doi.org/10.1080/09692290.2013.848373.

Howitt, Peter. "Macroeconomics with Intelligent Autonomous Agents." In *Macroeconomics in the Small and the Large: Essays on Microfoundations, Macroeconomic Applications and Economic History in Honor of Axel Leijonhufvud*, edited by Axel Leijonhufvud, 157–77. Edited by Roger E. A. Farmer. Cheltenham, U.K. and Northampton, Mass.: Elgar, 2008. http://search.ebscohost.com.libaccess.lib.mcmaster.ca/login.aspx?direct=true&db=eoh&AN=1084734&site=eds-live&scope=site.

Husseini, Saleh Ali, Soo-Fen Fam, and Samer Ali Al-shami. "The Relationship Between Knowledge Management And Malaysian Digital Banking Reputation ." *Opcion-Faculty of Technology Management& Technopreneurship, Universiti Teknikal Malaysia Melaka* 35 (2019): 2899–2921.

Knell, Markus, and Stix. Helmut, "Trust in Banks during Normal and Crisis Times-Evidence from Survey Data." *Economica* 82 (2015): 995–1020. https://doi.org/10.1111/ecca.12162.

Lee, Jae Min, and Sherman D. Hanna. "Savings Goals and Saving Behavior From a Perspective of Maslow's Hierarchy of Needs." *Journal of Financial Counseling and Planning* 26, no. 2 (2015): 129–47. https://doi.org/10.1891/1052-3073.26.2.129.

LICHTENSTEIN, PETER M. *Introduction to Post-Keynesian and Marxian Theories of Value and Price*. ROUTLEDGE, 1983.

Lorena, Antonio. "The Relation between Corporate Social Responsibility and Bank Reputation: A Review and Roadmap." *European Journal of Economics and Business Studies* 4, no. 2 (2018): 7–19. https://doi.org/10.2478/ejes-2018-0034.

Maslow, A. H. "A Theory of Human Motivation." *Psychological Review* 50, no. 4 (1943): 370–96. https://doi.org/10.1037/h0054346.

Menger, Carl. *Principles of Economics*. Glencoe, IL: publisher not identified, 1950.

Morrison, Alan D., and Lucy White. "Reputational Contagion and Optimal Regulatory Forbearance." *Journal of Financial Economics* 110, no. 3 (2013): 642–58. https://doi.org/10.1016/j.jfineco.2013.08.011.

Oleson, Mark. "Exploring the Relationship between Money Attitudes and Maslow's Hierarchy of Needs." *International Journal of Consumer Studies* 28, no. 1 (2004): 83–92. https://doi.org/10.1111/j.1470-6431.2004.00338.x.

Patti, Emilia B. Di. "Francesco Ferrara and Subjective Value Theory." *History of Political Economy* 33, no. 2 (2001): 315–44. https://doi.org/10.1215/00182702-33-2-315.

Rahman, Hasebur, and Sheikh M. Nurullah. "Motivational Need Hierarchy of Employees in Public and Private Commercial Banks." *Central European Business Review* 3, no. 2 (2014): 44–53. https://doi.org/10.18267/j.cebr.84.

Roncaglia, Alessandro. *A Brief History of Economic Thought*. Cambridge: Cambridge University Press, 2017.

Samli, A. Coskun, and Cheryl J. Frohlich. "Consumer Friendly Financial Services: Combining Efficiency and Effectiveness." *Journal of Business and Psychology* 8, no. 2 (1993): 145–62. https://doi.org/10.1007/bf02230382.

SITTI AISYAH. "Legal Protection of Household Credit Guarantee against Pension of Civil Servants in the Concept of Welfare State." *Awang Long Law Review 2(2) 71-78*, (2020). doi:10.5281/zenodo.3902128.

Taujanskaitė, K., Milčius, E., & Rutkauskas, A.. "Integrated cross-disciplinary approach to household expenditure management". (2015)

Wei, Guiling. "From 'Double Pyramid' Thoughts to Corporate Social Responsibility for Enterprise Employees." *Journal of Management and Strategy* 4, no. 1 (2013). https://doi.org/10.5430/jms.v4n1p108.

Yu, Hueiju, and Wenchang Fang. "Relative Impacts from Product Quality, Service Quality, and Experience Quality on Customer Perceived Value and Intention to Shop for the Coffee Shop Market." *Total Quality Management & Business Excellence* 20, no. 11 (2009): 1273–85. https://doi.org/10.1080/14783360802351587.