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„Modelling of systemic risk“

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1 Introduction

During and in the aftermath of the financial crisis 2008 was one thing omnipresent, systemic risk. In this thesis we wanted to model systemic risk and how it works in different network structures. As basis for our description of a financial system we used the paper "Market Procyclicality and Systemic Risk" by Paolo Tasca and Stefano Battistan[1].

But let's go back to the beginning, because first we have to understand what actually is systemic risk. One definition which explains the key aspect quite clearly is the following:

> Systemic risk refers to the risk or probability of breakdowns or losses in an entire system as opposed to breakdowns in individual parts or components and is evidence by co-movement/correlation among most or all parts [2]

Imagine a row of dominoes, if one stone falls there might be a cascading effect such that (parts or) all other stones will fall sooner or later, depending on how close they are related to each other. In this thesis we wanted to analyse if and how different network structures influence such cascading effects.
Our basic setting considered financial institutions, also known as banks. Those banks have at least one financial instrument (asset) in common and also hold some claims on each other. We described these interbank claims with the help of a matrix, which is the key to the interconnectedness of the banks in the system, because the different entries of the matrix represent how the individual banks are related to each other. Furthermore we simulated a single shock on the common asset and analysed how the different network structures of financial institutions behave afterwards during a certain time period.
In chapter 1 we introduce the general principle of banks, how they manage their balance sheet activities and what different parameter could influence these activities and behaviours. Therefore we present the concepts of financial ratios, especially Debt Ratio, Leverage, Procyclicality, Value at Risk and how they possibly interact with each other.

We explain in chapter 2 how we established the financial system and give a short mathematical introduction of the asset price model. Having build up the model, in chapter 3, we introduce the numerical backgrounds of the simulation framework and the used programming language. Chapter 4 starts with a general analysis approach to find parameters, which were used for detailed investigations. The analysis chapter is split up into three parts, part one deals with the used parameter setting, part two analyses the basis network structures and part three explores incomplete network structures.
A short introduction of the numerical approach, the underlying algorithm, the used programming language and code can be found in the appendix. All used graphs were generated with 'R'.

1.1 Basic Principles

The basic principle of a bank is easily explained, on the one side we have savers like you and me who deposit their savings in a bank account. The bank pays regular interest on this savings.
On the other side the banks lend these savings to other debtors to help them to make further investments. These debtors have to pay interest on the given credits. In general the interest which the bank pays for saving accounts is less than the interest achieved from debtors. One possible reason for this obvious inequality is that the bank carries a much higher risk in lending the money to others, than to keep it for the savers. Another reason might be that the amount of money one individual saver himself "lends" to the bank is much lower than those amounts which banks lend to their debtors. Furthermore the maturity of the money held by the bank is often much lower than the maturity of the money issued by the bank. These structural differences of cash flows are expensive especially for the bank who passes those costs to the savers. For sure this inequality is also needed to finance the whole process of banking. It is therefore essential for banks to track all their flows of money and react carefully on external influences to maintain their balance sheet in a satisfying way.
In principle a bank's balance sheet consists of assets, liabilities and equity which is the difference between those assets and liabilities. In our model of a simplified balance sheet approach we have external assets and interbank claims on the asset side.
The liability side consists of obligations to other banks, book value of external funds and equity.

1.2 Debt Ratio

Financial ratios are common measurements to evaluate a company‘s value or to compare it to other competitors in the same field. In terms of systemic risk we need a ratio which describes the whole financial situation of a bank. Debt ratio is the ratio of total debt to total assets, it can be used to get an idea of the overall level of financial risk of a company. In principle it can be said that the greater the amount of debt held by a financial institution the greater the effects resulting from reactions on monetary changes. One of the key factors for bank's balance sheet managers is therefore to handle the debt of the bank carefully.

1.3 Leverage

Leverage is closely related to the debt ratio of a financial institution. To get a better understanding of how those two are connected we want to give some basic examples on leverage effects and how dangerous they could be.

- Investment without leverage
  We have an initial cash investment of 100 €, a rate of return of 10%, which finally gives us 10 € return on this investment.

- Investment with leverage
  We initially invest 10 € and borrow 90 € from the bank, to whom we pay 5% as cost of loan. We end up with a total investment of 100 €. The rate of return is 10% as before, therefore we get 10 € return again.

In both cases we end up with a return on investment of 10 €, the essential difference is the amount of own capital which was invested. In the first case we took 100 € of our own money and gained a 10% return on this. In the second case we invested just 10 € of our own money, 90 € we borrowed at an interest rate of 5%. Hence we have to consider our net profit, which is the difference between the return and the interest that we have to pay on the borrowed money.
We therefore gained

$$10 \text{ € (return on investment) - } 90 \text{ €} \times 0.05 \text{ (cost of loan)} = 5.5 \text{ €}$$

At a first glance it looks like that we only made a profit of 5.5 € out of an investment of 100 €, but if we take a closer look we have to consider the amount of our own capital invested. In the second case we only used 10 € of our own money, and got a net return of 5.5 € which finally gives us an overall return of 55%. Compared to the 10% return on the investment without leverage we get an idea of the amplifying effects of leverage.

We formulate the following equations

- without leverage

$$NR_1 = \frac{RoI}{investment} = \frac{RoI}{E}$$

- with leverage

$$NR_2 = \frac{\frac{RoI}{investment} - costofloan}{equity} = \frac{\frac{RoI}{D+E} - D \times r}{E}$$

NR_1 = net return 1 $\qquad$ E = Equity

NR_2 = net return 2 $\qquad$ D = Debt

RoI = Return on investment $\qquad$ r = interest rate

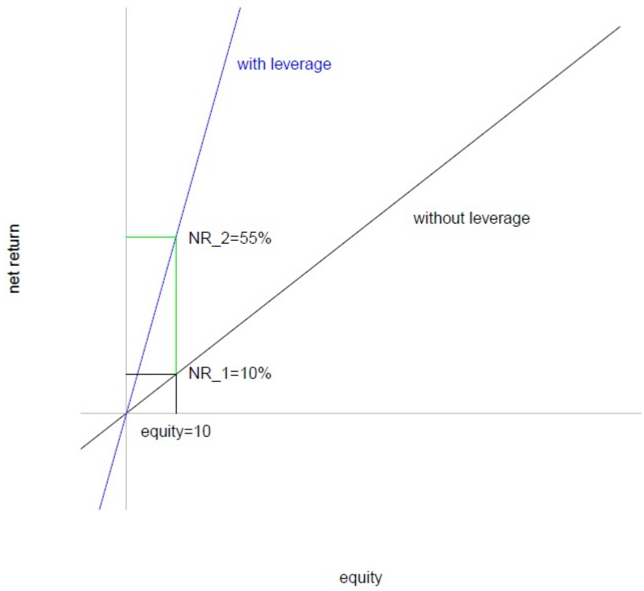


Figure 1: Net Return with/without Leverage

The graph shows that if we change the amount of equity the impact on the leveraged curve is higher than on the curve without leverage.

We have this effect not only in the positive direction also in the negative direction where higher leveraged investments run faster into troubles than those with a lower leverage ratio.

To visualize this important effect we delve a little bit deeper and show what happens to our profit and losses if the value of our investment decreases.

- Value decrease of investment 1%
  We again invest 10 € of our own money and 90 € of borrowed money. After we made the investment the value of this investment decreases by 1%. Therefore our total investment of 100 € shrinks to a net investment of 99 €. Nevertheless we gain a return of 10% which gives us 9.9 €. Our net investment of 99 € consists of 90 € debt, which we have to pay back and 9 € equity. Additionally we have to pay cost of loan and we want to fill up our equity to the initial amount. Therefore we have to subtract this from our 10% return to calculate our net return. Our net return consists of

  $$9.9 \text{ €} - 4.5 \text{ € (cost of loan)} - 1\text{€(equity pay back)} = 4.4 \text{ €}$$

  We end up with a total return of 44%. That shows that a loss on our investment of 1% decreases our rate of return by more than 10% in this situation.

As one can imagine this could end up even more drastically.

- Value decrease of investment 6%
  Our initial investment of 100 € is worth only 94€, whereby 90 € belong to the debtors and 4 € is the remaining equity. We gain a return of 10% on this net investment of 94 €. After paying back cost of loan we end up with

  $$9.4 \text{ €} - 4.5 \text{ €} = 4.9 \text{ €}$$

  Together with our remaining amount of equity we end up with only 8.9 € instead of initially 10 € equity which means we suffered an overall loss of 11% !

The graphs below visualize how Value losses of an investment directly effect the net return depending on the grade of leverage of the underlying investment.

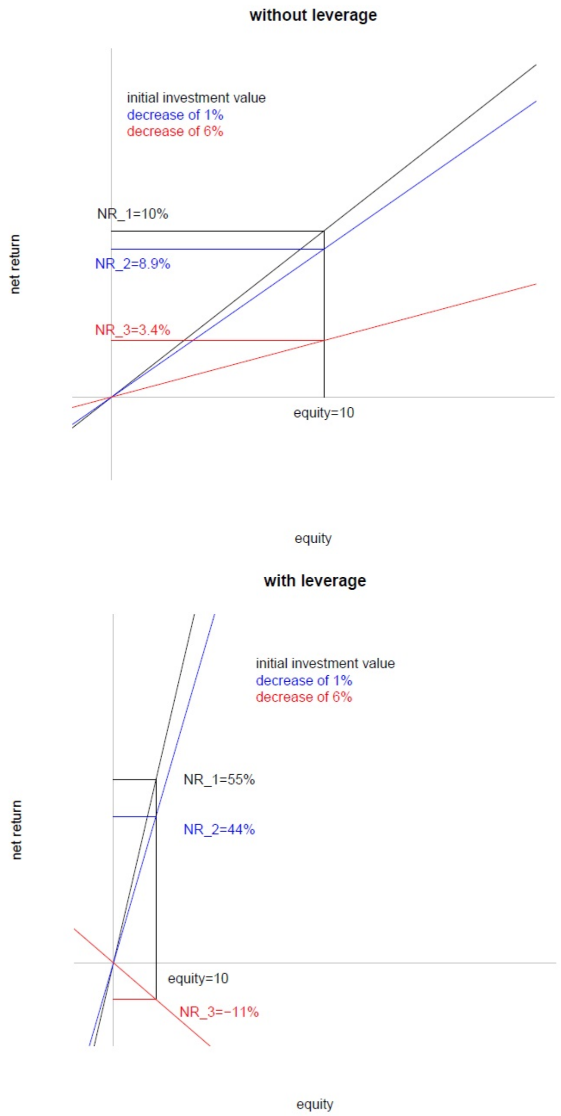


Figure 2: Net Return effects depending on Leverage and Value losses

1.4 Procyclical Leverage

Applying those mechanisms to the usual banking business we observe that during booms asset prices rise and therefore leverage decreases as debt remains constant. In order to target their leverage banks purchase more assets and increase their debt. If there is a negative impact on the asset price we observe the reverse mechanism, i.e. leverage moves up and the targeted leverage can be readjusted by selling assets which leads to a reduction of the banks debt.
On the other hand if banks don't or just slowly readjust their target leverage we have to include procyclicality which amplifies those leverage effects even more. A formal definition of procyclicality is the following:

> Strictly speaking, procyclicality refers to the tendency of financial variables to fluctuate around a trend during the economic cycle. Increased procyclicality thus simply means fluctuations with broader amplitude [3]

Increased procyclicality strengthens movements on capital or on leverage. Procyclicality on capital is very intuitive, if we have a good environment, where financial institutions are profitable and they are able to assign greater parts in the market, then an increase of an asset price is directly related to better capital conditions for those institutions who held those asset. Furthermore assets which experience an increase in its price are highly demanded and this results in an additional increase in its asset price.

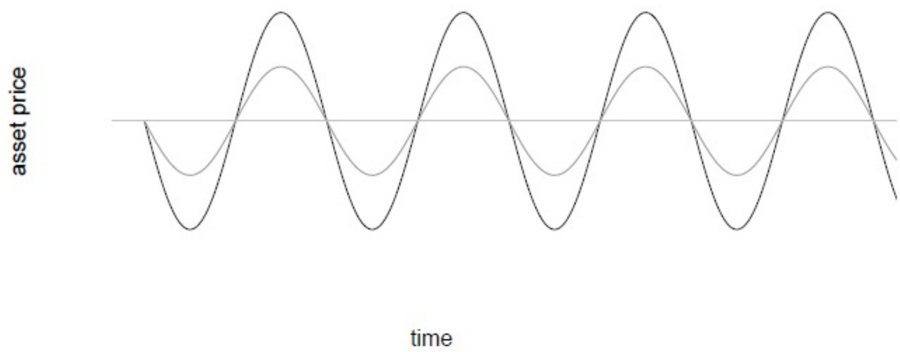


Figure 3: Amplifying effect of Procyclicality

If we want to get a better understanding on procyclical leverage we have to understand the relationship between leverage and balance sheet size. In the paper "Liquidity and Leverage" by Tobias Adrian and Hyung Song Shin[4] the authors explain in a very intuitive way how this principles work.
Theoretically there are different ways for financial institutions to leverage up again.

1. Equity buyback through a debt issue
2. Selling assets to pay dividends
3. increased borrowing to fund new assets

Each of the three cases end up with a readjustment of the leverage. While in case 1 and 2 the readjustment of leverage depends strongly on the modification of equity, case 3 uses variation of debt to maintain a certain leverage. As mentioned earlier banks therefore use an active balance sheet management which basically uses the techniques of case 3.

We illustrate these techniques in the following example:
Consider a fictive financial institution with a leverage ratio of 10, for every unit of equity we have in total 10 units of assets.
A simplified balance sheet[1] therefore looks like

Assets	Liabilities
100	10 (Equity)
	90 (Debt)

Additionally we assume constant debt prices and the possibility of fluctuations in asset prices.
If we increase the asset price by 1% we end up with a leverage of $\frac{101}{11} = 9.18$. Readjusting the leverage ratio to 10, we need to take additional debt: $\frac{101+debt}{11} = 10 \Leftrightarrow debt = 9$.
With this additional debt one purchases securities worth 9, so we finally end up with

Assets	Liabilities
110	11 (Equity)
	99 (Debt)

Over all we see that an increase of 1% of the asset price, results in 10% additional debt. This refers to an upward-sloping demand curve.

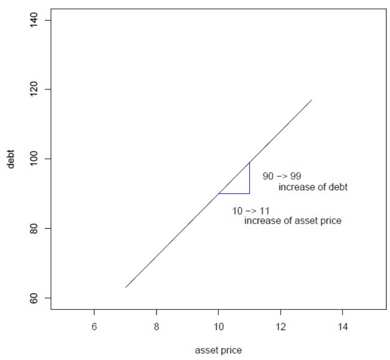


Figure 4: Upward-sloping Demand Curve

[1]satisfying **A**ssets = **D**ebt + **E**quity

The reverse effect can be seen if we consider a decrease of 1 unit on the asset price.

Assets	Liabilities
109	10 (Equity)
	99 (Debt)

We receive a leverage ratio of $\frac{109}{10} = 10.9$ which can be readjusted by selling 9 units of securities and paying down debt at the same time. We end up with the initial balance sheet and a leverage ratio of 10. Here we see that a decrease in the asset price leads to a sale of securities, the supply curve is downward-sloping. The same considerations can be made in terms of debt ratio, which is $\frac{D}{A}$. In the following table we display the procyclical behaviour in terms of both leverage and debt ratio.

	Initial	**Increase of A**	**Readjust-ment**	**Decrease of A**	**Readjust-ment**
Leverage $L = \frac{A}{A-D}$	$\frac{100}{100-90} = 10$	$\frac{101}{101-90} = 9.18$	$\frac{110}{110-99} = 10$	$\frac{109}{109-99} = 10.9$	$\frac{100}{100-90} = 10$
Debt Ratio $\frac{D}{A}$	$\frac{90}{100} = 0.9$	$\frac{90}{101} = 0.89$	$\frac{90+0.9}{101} = 0.9$	$\frac{90.9}{100} = 0.909$	$\frac{90.9-0.9}{100} = 0.9$

We observe that debt ratio and leverage behave similarly. Readjusting the target leverage due to active balance sheet management entails upward-sloping demands and downward-sloping supplies. The inverse nature of the demand and supply curves are even stronger when the leverage of the financial intermediary is procyclical - that is, when leverage is high during booms and low during busts. During the leverage targeting we notice that the amount of equity remains untouched. This can be used to define a risk measure, the debt ratio, which exactly refers to the fact of constant equity.

1.5 Value-at-Risk

Value-at-Risk, short VaR, is a risk measure widely used in finance, which measures and quantifies the level of risk within a financial institution or a portfolio of assets over a fixed time horizon.
If we talk about Value-at-Risk for a certain confidence level $1-\alpha$ then we can say that VaR is the α-quantile for profit and loss of a certain portfolio over a certain time horizon. We denote

$$F_L(l) = P(L \leq l)$$

as density function of the corresponding loss distribution, where L represents the maximum loss at a certain point in the future. Together with a confidence level α, we can say that the Value-at-Risk of our portfolio at the confidence level α is given by the smallest number l such that the probability that the loss L exceeds l is not larger than $(1-\alpha)$. Formally

$$VaR_\alpha = inf\{l \in \mathbb{R} : P(L > l) \leq 1-\alpha\} = inf\{l \in \mathbb{R} : F_L(l) \geq \alpha\}$$

We can say that speaking in probabilistic terms, the Value-at-Risk is a quantile of the loss distribution[6].

Based on the paper of Tasca and Battiston[2] we use their simplified approach. They assume that each bank i in the system uses a balance sheet management to obtain a certain amount of equity equal to their Value-at-Risk to stay solvent. On the other way around we could consider this as maintaining a certain target leverage . If we define V as the unit-VaR, i.e. VaR per Euro of assets held by a specific bank, then we end up with the following equality.

$$\begin{gathered} equity = V \times assets \\ \Rightarrow assets - debt = V \times assets \\ \Rightarrow debt = assets \times (1-V) \end{gathered}$$

The bank has a target leverage or debt ratio of $\frac{debt}{assets} = (1-V)$. Therefore we can say maintaining a certain debt ratio/target leverage is directly linked to the unit-VaR which can be seen as one of the banks risk measurements.

1.6 Interconnectedness

Due to the presented parameters and effects influencing financial intermediation we want to introduce the main purpose of this thesis, which is how systemic risk behaves in different network structures. Those different network settings refer to the way how each bank of the system is interconnected with each other.

To give you an example lets speak about the case if an unusual event, such as a drastically decrease in the price of a commonly used asset occurs. This event affects an interconnected bank (in a financial system) in different ways, primarily it affects the asset portfolio of the individual bank which has to be maintained by each bank itself. But due to the interconnectedness this changes in asset prices could be transported from one bank to the other through the whole system. Depending on the size of each bank and the amount of this asset held by the individual bank those impacts could differ a lot, e.g. a bank with a large balance sheet might handle such impacts easier than banks with a smaller balance sheet.

The interconnectedness of banks is the key aspect of this thesis. It is simulated with a matrix where each entry represents a claim held by bank i and issued by bank j. We want to investigate how different network structures handle shocks and which parameters are key drivers for financial contagion. Therefore we consider different types of interconnectedness and search for parameters where we see cascading effects. With those parameter we examine further simulations to explore if and how contagion effects behave throughout the system.

2 Establishing the Financial System

The main purpose of this chapter is to establish a network of financial institutions with respect to the parameters mentioned in the previous section. As a basis, especially for the used formulas but also for the basic concept, the paper "Market Procyclicality and Systemic Risk" by Paolo Tasca and Stefano Battiston was used.
We first consider bank's balance sheets and how they deal with leverage and the interaction with other participants in the financial system.

2.1 Balance sheet

A balance sheet is a summary over all financial balances which a bank has at a certain time point. Normally financial institutions deliver their balance sheet for a particular year with key date of December 31st.
The financial statement of a bank consists of assets, liabilities and equity. The sub items of assets are listed in decreasing order of liquidity, meaning how fast and easily they can be turned into cash. On the liability side the sub items are ordered according to the priority of their payment. Both, assets and liabilities, consist of positions with different durations, long-term and short-term. In practice the asset-liability management has to make sure that the duration of assets match to the banks liabilities.
In our analysis we do not distinguish between those different categories of assets or liabilities, we want to focus on the following simplified balance sheet:

$$\mathbf{a}ssets = \mathbf{l}iabilities + \mathbf{e}quity$$

2.1.1 Asset side

The asset side usually consists of different categories such as customer loans, securities and interbank placements. Due to the fact that all these assets do not have a homogeneous term structure we use a simplified approach. We focus on two main parts of the asset side without considering time structures. In our approach we have to look at the amount of external funds held by bank i. It is the sum over the quantity Q_{il} of external asset l multiplied with the specific asset price s_l. It can be seen as a simplified version which covers customer loans and securities. Despite this we have interbank claims, it is the sum over all debt issued by bank j and held by i multiplied with the corresponding present value of bank j's debt defined as discounted value of future payoffs. For sake of simplicity we assume that bank j's debt has a maturity of 1 year. The asset side can be written as

$$a_i = \sum_{l=1}^{m} Q_{il} s_l + \sum_{j=1}^{n} W_{ij} \frac{h_j}{(1+r_f+\beta\phi_j)}$$

The single variables of interbank claims are defined in the following manner:

W_{ij} $n \times n$ matrix with entries referring to the quantity of debt issued by j and held by i

h_j book value of bank j's obligation to the other banks in the network

r_f risk free rate

$\beta\phi_j$ credit spread associated with issuer j. $\beta \in (0, 1)$ in particular can be understood as the factor loading on the bank j's leverage, which can also be understood as the responsiveness of the rate of return to the firm's financial condition[1]

The asset side of a real bank balance sheet has for sure more positions, but in terms of practicability it is sufficient for us to rely on those asset classes.

2.1.2 Liability side

On the liability side we find all the obligations of a bank arising from transactions of the past, this could also be long or short term. Furthermore we find equity on the liability side, which are funds owed to the shareholders. The liabilities are equal to the assets a_i:

$$a_i = h_i + b_i + e_i$$

with

a_i market value of bank i's assets

h_i book value of bank i's obligations to other banks in the system

b_i book value of bank i's external funds with actors outside the network

e_i equity of bank i

We summarize our simplified balance sheet and present it in the table below.

Assets	Liabilites
$\sum_{l=1}^{m} Q_{il} s_l$	h_i
$\sum_{j=1}^{n} W_{ij} \frac{h_j}{(1+r_f+\beta\phi)}$	b_i
	e_i

Table 1: Simplified balance sheet of bank i

2.2 Leverage and Value-at-Risk

As we have seen in chapters 1.3 and 1.4 there are different ways to define leverage. In this thesis we use debt-asset ratio as the adequate measurement. One reason is that under these assumptions we can leave the amount of equity untouched, an approach which several studies showed to be appropriate [4] [5]. As shown in chapter 1.4 the classical definitions of leverage and debt ratio behave in the same way which strengthens our choice for the debt-to-asset ratio.

We define ϕ_i as the debt ratio of bank i:

$$\begin{aligned}\phi_i &= \frac{h_i + b_i}{a_i} \\ &= \frac{h_i + b_i}{\sum\limits_{l=1}^{m} Q_{il} s_l + \sum\limits_{j=1}^{n} W_{ij} \frac{h_j}{(1+r_f+\beta\phi_j)}}\end{aligned}$$

As mentioned before, the asset side consists in our case of the sum over the quantity of the external assets and the interbank claims. A closer look on the interbank claims shows that the rate of return on interbank claims depend linearly on the credit-worthiness of the obligor, which is measured by its leverage, whereby r_f is the risk-free rate and $\beta\phi_j$ is the *credit spread* associated with issuer j. β can be understood as how the rate of return respond to the financial conditions of the bank [1].

Leverage $\phi_i \in (0,1)$ is a key indicator for each bank and it is important to maintain it carefully. If $\phi_i > 1$ we end up with the situation that bank i's debt has exceeded its assets, which clearly means that bank i ran into default. As mentioned earlier in our considerations we focus on the debt-to-asset ratio which allows us to handle the equity as a constant. Considering equity as constant leads us directly to the concept of unit-VaR which we introduced in chapter 1.5. With the help of this risk measure we are able to maintain an active balance sheet management.

2.2.1 Active Balance Sheet Management

After introducing those theoretical settings we want to take a closer look on how this might work in practice. Therefore we recapitulate how banks react on market movements.

- **Falling market** When asset prices decrease we observe an increase in leverage.

  $$A \searrow \qquad \Rightarrow \qquad \tfrac{D}{A} \nearrow$$

  Therefore the bank has to reduce its balance sheet using the possibility to sell some of their external assets and simultaneously use this money paying back external debts. Hence we can reduce our leverage back to the targeted one.

- **Rising market** On the other side we see that leverage decreases if asset prices increase.

  $$A \nearrow \qquad \Rightarrow \qquad \tfrac{D}{A} \searrow$$

  In this case the bank wants to increase their balance sheet by taking on some more external funds. The bank invests its new obtained cash in external opportunities.

This concept refers to the procyclicality of leverage which we introduced in greater detail in chapter 1.4.

As we want to focus on this type of the bank's reaction on market movements we have to make some restriction on other possible developments.

(a) The banks in our setting are not able to change their position in equity, i.e. they cannot issue new equity. Furthermore they are not able to replace equity with debts.

(b) Bank i's interbank debts h_i is constant over time: $h_i(t) = h_i \forall t \geq 0$. We see that the notional value of interbank debt stays constant but that doesn't prevent banks from changes in counterparts or how they adjust their amount of shares. These changes are related to the $n \times n$-matrix with which we can control how banks are related to each other.

Assumptions (a), (b) together with the balance sheet identity $a_i = h_i + b_i + e_i$ lead to the observation that every change in the external assets corresponds to an equal change in the external funds on the liability side[1].

2.2.2 Deriving a Formal Rule

We want to formalize how banks react on market movements. Therefore we have to consider different time points and observe what exactly happens at each of these dates.

- $t = 0$
  At $t = 0$ bank i sets its leverage equal target leverage $\phi_i(0) = \phi^*$.
  As stated before we set the interbank debt constant over time, e.g. $h_i(t) = h_i \ \forall t \geq 0$.
  The initial leverage of bank i can be written as:

$$\phi_i(0) = \frac{h_i + b_i(0)}{\sum_{l=1}^{m} Q_{il}(0)s_l(0) + \sum_{j=1}^{n} W_{ij} \frac{h_j}{1+r_f+\beta\phi_j}} \tag{1}$$

  With all given values at time $t = 0$ we can calculate from the equation above $\sum_{l=1}^{m} Q_{il}(0)s_l(0)$, which is the value of the portfolio of external assets, or if we just have one asset, its the value of this specific asset.

In our further calculations we considered just one asset.
If in addition we want to consider a portfolio of m assets we have to insert some additional steps. Due to the calculations above we observe a portfolio value which we have to split up among the different assets. This could be done by assigning feasible weights to each asset l and bank i.
In a first step we actually start with one common asset for every bank in the system.

- $t = 1$
  At time $t = 1$ we simulate a shock on the portfolio/asset price, while the quantity Q_{il} and book value of external funds b_i stay as in $t = 0$. According to this price shock we have to calculate the new leverage:

$$\phi_i(1) = \frac{h_i + b_i(0)}{\sum_{l=1}^{m} Q_{il}(0)s_l(1) + \sum_{j=1}^{n} W_{ij} \frac{h_j}{1+r_f+\beta\phi_j}} \neq \phi_i^* \tag{2}$$

- $t = 2$
  In the upcoming time step bank i has to readjust their balance sheet, therefore they have to change the quantities on the asset resp. liability side, i.e.

$$\sum_{l=1}^{m} Q_{il}(0) \rightarrow \sum_{l=1}^{m} Q_{il}(2) \tag{3}$$

and

$$b_i(0) \rightarrow b_i(2) \tag{4}$$

As mentioned above the leverage at $t = 2$ should again be equal to the target leverage, i.e. $\phi_i(2) = \phi_i^*$.

Mathematically spoken we have $\phi_i(2) = \phi_i(0) = \phi^*$ which implies

$$\begin{aligned}\phi_i(2) &= \frac{h_i + b_i(2)}{\sum\limits_{l=1}^{m} Q_{il}(2)s_l(1) + \sum\limits_{j=1}^{n} W_{ij} \frac{h_j}{1+r_f+\beta\phi_j}} \\ &= \frac{h_i + b_i(0)}{\sum\limits_{l=1}^{m} Q_{il}(0)s_l(0) + \sum\limits_{j=1}^{n} W_{ij} \frac{h_j}{1+r_f+\beta\phi_j}} \\ &= \phi^*\end{aligned} \tag{5}$$

From this equality we can rewrite the equation (2) for leverage at $t = 1$:

$$\frac{h_i + b_i(0)}{\phi_i(1)} = \sum_{l=1}^{m} Q_{il}(0)s_l(1) + \sum_{j=1}^{n} W_{ij} \frac{h_j}{1 + r_f + \beta\phi_j}$$

$$\Rightarrow \sum_{j=1}^{n} W_{ij} \frac{h_j}{1 + r_f + \beta\phi_j} = \frac{h_i + b_i(0)}{\phi_i(1)} - \sum_{l=1}^{m} Q_{il}(0)s_l(1)$$

This can be substituted in the leverage equation (5) at $t = 2$

$$\begin{aligned}\phi_i(2) &= \frac{h_i + b_i(2)}{\sum\limits_{l=1}^{m} Q_{il}(2)s_l(1) + \frac{h_i+b_i(0)}{\phi_i(1)} - \sum\limits_{l=1}^{m} Q_{il}(0)s_l(1)} \\ &= \frac{h_i + b_i(2)}{\frac{h_i+b_i(0)}{\phi_i(1)} + \Delta Q_{il}(2)s_l(1)}\end{aligned}$$

with ΔQ_{il} refers to the change in quantity of external asset in the portfolio of bank i.

We can rewrite the equation above and get

$$\frac{h_i + b_i(0)}{\phi_i(1)} + \Delta Q_{il}(2)s_l(1) = \frac{h_i + b_i(2)}{\phi_i^*} \tag{6}$$

As we know from our initial assumption that any variation in the external assets held by bank i will correspond to an equal amount of variation in the external funds on the liability side we can substitute the following equation

$$b_i(2) = b_i(0) + \Delta Q_{il}(2)s_l(1) \tag{7}$$

and end up with

$$\frac{h_i + b_i(0)}{\phi_i(1)} + \Delta Q_{il}(2)s_l(1) = \frac{h_i + b_i(0) + \Delta Q_{il}(2)s_l(1)}{\phi_i^*}$$

which results after some arrangements in:

$$\Delta Q_{il}(2)s_l(1) = \frac{h_i + b_i(0)}{\phi_i(1)} \left(\frac{\phi_i^* - \phi_i(0)}{1 - \phi_i^*} \right)$$

Finally we obtain the following equation for the rate of change of demand for asset l from bank i

$$\frac{Q_{il}(2) - Q_{il}(0)}{Q_{il}(0)} = \frac{\sum_{j=1}^{n} W_{ij} \frac{h_j}{1+r_f+\beta\phi_j} + Q_{il}(0)s_l(1)}{Q_{il}(0)s_l(1)} \left(\frac{\phi_i^* - \phi_i(0)}{1 - \phi_i^*} \right)$$

$$= \frac{1}{\alpha_{il}} \left(\frac{\phi_i^* - \phi_i(0)}{1 - \phi_i^*} \right)$$

Where $\alpha_{il} = \frac{Q_{il}(0)s_l(1)}{a_i(1)}$ the ratio of the external asset l held by bank i to the total asset value.

In a similar way we can derive the change in debt, based on equation

$$\frac{b_i(2) - b_i(0)}{b_i(0)} = \frac{h_i + b_i(0)}{b_i(0)\phi_i(0)} \left(\frac{\phi^* - \phi_i(0)}{1 - \phi^*} \right)$$

$$= \frac{1}{\kappa_i \phi_i(0)} \left(\frac{\phi_i^* - \phi_i(0)}{1 - \phi_i^*} \right)$$

where $\kappa_i = \frac{b_i(0)}{h_i + b_i(0)}$ ratio of external debt to total debt.
With the derived formulas we are now able to calculate changes in the quantity of an external asset and debt. As we want to introduce a model which is close to reality we introduce ϵ_i as an additional factor which displays how fast banks react on changes according to market movement. We define $\epsilon \in (0,1)$, where values close to 0 correspond to a slow or almost not existing reaction on price developments. If a bank i reacts quite promptly to price movements we assign values close to 1 to ϵ_i.
According to generate a model which is close to reality we have to restrict our differential equations to some limiting constraints.

- the change in the quantities of external assets of bank i is equal to the sum over all changes of all external assets l that bank i holds
$$\frac{dQ_i}{Q_i} = \sum_{l=1}^{m} \left(\frac{dQ_{il}}{Q_{il}} \right) \text{ s.t. } \frac{dQ_{il}}{Q_{il}} = 0 \text{ for some } l \in \Omega_m$$
- $dQ_{il} \geq -Q_{il} \forall l \in \Omega_m$ and $i \in \Omega_n$
- $db_i \geq -b_i \forall i \in \Omega_n$

Finally we derived differential equations for the changes of

the demand for external asset

$$\frac{dQ_{il}}{Q_{il}} = \frac{\epsilon_i}{\alpha_{il}} \left(\frac{\phi_i^* - \phi_i}{1 - \phi_i^*} \right) dt \tag{8}$$

the amount of external debts

$$\frac{db_i}{b_i} = \frac{\epsilon_i}{\kappa_i \phi_i} \left(\frac{\phi_i^* - \phi_i}{1 - \phi_i^*} \right) dt \tag{9}$$

If a bank i wants to change the quantity of more than one external asset, we can easily generalize the equation (8) with
$Q_i = \sum_{l=1}^{m} Q_{il}$ and $\alpha_i = \sum_{l=1}^{m} \alpha_{il}$:

$$\frac{dQ_i}{Q_i} = \frac{\epsilon_i}{\alpha_i} \left(\frac{\phi_i^* - \phi_i}{1 - \phi_i^*} \right) dt \tag{10}$$

This procedure can also be applied to our model.
Hence we just have one asset equation (8) simplifies to (10)

2.3 Dynamics of the Asset Price

In mathematical finance modelling the dynamics of the asset price is often based on the concept of Geometric Brownian motion satisfying a stochastic differential equation[7].

If we examine asset price developments we observe no predictable way forward. This means in the evolution of an asset price is some kind of randomness. If we translate this into the modelling language we talk about Brownian motion which describes stochastic evolution. In this chapter we briefly want to present the underlying concepts of Brownian motion and how this helps us understanding the dynamics of the asset price.

Brownian Motion

Brownian Motion, named after Robert Brown, has its origins in the discovery of irregular movement of a grain of pollen suspended on water. This random behaviour is a result of the collision of the water molecules with the particles. In the mathematical sense the standard brownian motion is called a *Wiener Process*[2] which is a time-continuous stochastic process. A formal definition[7] is the following

Definition 1. *A Wiener Process* $W = \{W(t), t \geq 0\}$ *is a Gaussian process*[3] *with continuous paths and independent increments such that*

- $W(0) = 0$ *with probability* 1
- $\mathbb{E}[W(t)] = 0$ *and*
- $Var(W(t) - W(s)) = t - s \quad \forall 0 \leq s \leq t$
- $W(t) - W(s) \sim N(0, t - s)$ *for* $0 \leq s \leq t$
- *on any two disjoint intervals* $(t_1, t_2), (t_3, t_4)$ *with* $t_1 \leq t_2 \leq t_3 \leq t_4$ *the increments* $W(t_2) - W(t_1)$ *and* $W(t_4) - W(t_3)$ *are independent*

[2]named after Norbert Wiener

[3]stochastic process, for which all the finite-dimensional distributions have a multivariate normal distribution

The Wiener Process can be described as the limit of a random walk. The basic idea of a symmetric random walk refers to tossing a fair coin. A fair coin means that tossing head or tail can happen with equal probability. This symmetric random walk starts at $X_0 = 0$ and every further movement is added to the previous sequence. To keep it simple we assign $+1$ to head and -1 to tail respectively. If we consider the partial sum

$$S_n = X_1 + X_2 + \cdots + X_n$$

and let $n \to \infty$ we can say that the Brownian motion/Wiener Process can be seen as the limit of a random walk

$$P\left(\frac{S_{[nt]}}{\sqrt{n}} < x\right) \to P(W(t) < x).$$

This result is based on the central limit theorem[4] which states that, given certain conditions, the mean of a sufficient large number of iterates of independent random variables, each with a well-defined mean and well-defined variance, will be approximately normally distributed[8].

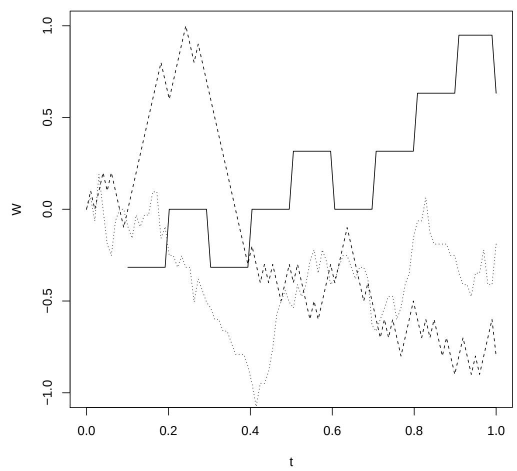


Figure 5: Path of Brownian motion as the limit of a random walk; continuous line $n = 10$, dashed line $n = 100$, dotted line $n = 1000$

[4]here with $\frac{S_n}{\sqrt{n}} \to N(0,1)$

Another important fact about Brownian motion is, that it has infinite simple variation, i.e.$V[W(t)] = \infty$. If we consider several different paths of Brownian motion we would observe that no path is like the other, but if we look closer we see that the fine scale structure is the same. This means each path and each part of any path has infinite variation. The smaller the partition gets, the more variation can be seen. The paths of Brownian motion are continuous but nowhere differentiable.
Despite if we consider a differentiable function we observe that the variation of this function has a limit, as the partition of the function gets smaller.
If we want to use methods of calculus on stochastic processes, like Brownian motion, we have to use Itô-Calculus instead[5]. We introduce this concept later when we show that Geometric Brownian motion is a solution to a stochastic differential equation.

Geometric Brownian Motion

As one can see in Figure 5 the standard Brownian Motion can take on positive and negative values. If we want to model asset prices we expect those prices to be strictly positive, therefore we introduce a non-negative variation of the Brownian Motion, called the Geometric Brownian Motion.
It is a stochastic process, which has the property of having independent multiplicative increments and is defined as a function of the standard Brownian motion

$$S(t) = x \exp\left\{ \left(\mu - \frac{\sigma^2}{2}\right) t + \sigma W(t) \right\}, t > 0 \tag{11}$$

where $S(0) = x, x \in \mathbb{R}$ refers to the starting value, $\sigma > 0$ refers to the volatility and μ interpreted as the drift part are two constants.

Another aspect for choosing Geometric Brownian motion as a model for asset prices is that it satisfies basic economic principles, meaning that it fulfils the condition that no one should be able to make profit with certainty. Regardless of the development of the past we are not sure what will be the next movement of the asset price.

[5]allows us to integrate one stochastic process with respect to another stochastic process

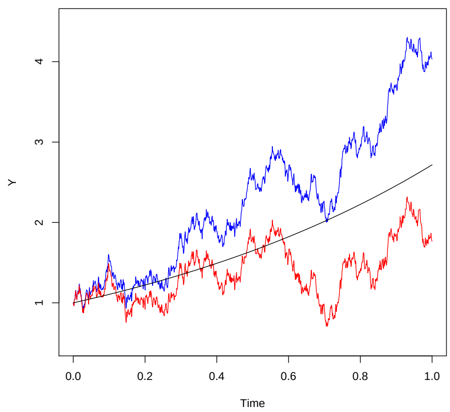


Figure 6: Geometric Brownian motion, Brownian motion, drift part

This condition is also known as *Markov Property*[6] As mentioned earlier the Geometric Brownian Motion solves a stochastic differential equation of the form

$$dS(t) = \mu S_t dt + \sigma S_t dW_t \tag{12}$$

In order to present this result in a concise way we have to go back one step an start once again with a short explanation of the meaning of a stochastic differential equation. Our basic idea is to model the price of an asset $S(t)$ at a certain time t. The variation on the asset price can be described by

$$\Delta S = S(t + \Delta t) - S(t).$$

The return of a specific asset is therefore defined as the ratio $\dfrac{\Delta S}{S}$, whereby these returns could consist of a deterministic and a stochastic part.
The deterministic, also known as the drift part, is predictable with the expected return from the asset held during a certain time period. The stochastic part on the other side is non-predictable and is assumed to be related to random changes in the asset price market, also known as volatility. We can formalize this in the following manner

$$\frac{\Delta S}{S} = \mu \Delta t + \sigma \Delta X \tag{13}$$

[6]The future given the present state is independent of the past

where $\Delta X = X(t+\Delta t) - X(t)$ refers to the variation of shocks. The natural way is to assume that those variations of shocks have Gaussian behaviour, meaning $\Delta X \sim N(0,1)$. This together with the assumption that those shocks are independent leads to the assumption that X is a Wiener process.
The stochastic differential equation can be achieved from the difference equation (13) if $\Delta t \to 0$. We obtain

$$\frac{S'(t)}{S(t)} = \mu + \sigma W'(t) \Leftrightarrow S'(t) = \mu S(t) + \sigma S(t) W'(t) \tag{14}$$

which can be written in differential form as well

$$dS(t) = \mu S(t)dt + \sigma S(t)dW(t) \tag{15}$$

In the differential form we have the part of the Wiener process $dW(t)$, where we know that the variation of the process is infinite $V[W(t)] = \infty$ and the paths of the Wiener process are continuous but nowhere differentiable.

If we want to solve this stochastic differential equation we have to keep in mind that we should do it in a way similar to an ordinary differential equation. As our equation has some random parts, we can't use the standard chain rule, but a slightly modified version, which refers to Itô's formula.

Itô formula

Itô's formula serves as the stochastic calculus counterpart of a Taylor expansion stopped at the second order[7]. If we have a twice differentiable function $f(t,x)$ on both t and x, then Itô's lemma states

$$\begin{aligned} f(t,X_t) = & f(0,X_0) + \int_0^t f_t(u,X_u)du + \int_0^t f_x(u,X_u)dX_u \\ & + \frac{1}{2}\int_0^t f_{xx}(u,X_u)(dX_u)^2 \end{aligned} \tag{16}$$

or in differential form,

$$df(t,X_t) = f_t(t,X_t)dt + f_x(t,X_t)dX_t + \frac{1}{2}f_{xx}(t,X_t)(dX_t)^2 \tag{17}$$

This formula simplifies if X_t is a Brownian motion to

$$f(t, W_t) = f(0,0) + \int_0^t \left(f_t(u, W_u) + \tfrac{1}{2} f_{xx}(u, W_u)\right) du + \int_0^t f_x(u, W_u) dW_u$$

and in differential form to

$$df(t, W_t) = \left(f_t(t, W_t) + \tfrac{1}{2} f_{xx}(t, W_t)\right) dt + f_x(t, W_t) dW_t$$

In order to derive the stochastic differential equation for the Geometric Brownian motion (11) we choose

$$f(t, x) = S_0 \exp\left\{\left(\mu - \frac{\sigma^2}{2}\right) t + \sigma x\right\}$$

with

$$f(t, W_t) = S_t$$

$$f_t(t, x) = \left(\mu - \frac{\sigma^2}{2}\right) f(t, x)$$

$$f_x(t, x) = \sigma f(t, x)$$

$$f_{xx}(t, x) = \sigma^2 f(t, x)$$

Consequently we get

$$\begin{aligned} dS_t =& df(t, W_t) \\ =& \left(f_t(t, W_t) + \frac{1}{2} f_{xx}(t, W_t)\right) dt + f_x(t, W_t) dW(t) \\ =& \left(\left(\mu - \frac{\sigma^2}{2}\right) S_t + \frac{1}{2}\sigma^2 S_t\right) dt + \sigma S_t dW_t \\ =& \mu S_t dt + \sigma S_t dW_t \end{aligned} \tag{18}$$

which is the desired stochastic differential equation[7].
Although we derived our basic model, we need to understand how deterministic and diffusion part interact and influence the price dynamics. Mean rate of return μ and the volatility σ could vary over time and can be random. In our model framework σ is a constant and μ is influenced due to the trading size.

Market Liquidity

In the previous chapter we introduced the dynamics of the asset price and showed how a stochastic differential equation describes this behaviour. If we adapt this equation to our model we get the following

$$\frac{ds}{s} = \mu dt + \sigma dB \tag{19}$$

where σ refers to the volatility and μ refers to the deterministic, predictable part. We want to focus now on this predictable part and try to give an idea what μ describes.
If we look on the market where banks trade assets we observe a certain behaviour.

- Large bid size for an asset $\Leftrightarrow$ demand for this certain asset is high
- Large ask size for an asset $\Leftrightarrow$ supply for this certain asset is high

In other words banks can influence directly the demand for a certain asset and this implies that they can push prices in the direction of their trading[1]. Speaking in terms of trading volume we can conclude, that for a certain quantity $Q_l = \sum_i Q_{il}$ if banks place a bid on the order book

$$\Rightarrow \text{Demand} > \text{Supply} \Rightarrow dQ_l > 0 \text{ and the asset price } s_l \nearrow$$

On the other hand if banks place an ask on the order book

$$\Rightarrow \text{Demand} < \text{Supply} \Rightarrow dQ_l < 0 \text{ and the asset price } s_l \searrow$$

This means we assume that the expected asset price development are linearly dependent on the changes in trading size of this certain asset. We formalize this as in the underlying paper[1]

$$\mathbb{E}\left(\frac{ds_l}{s_l}\right) = \gamma_l \left(\frac{dQ_l}{Q_l}\right) \tag{20}$$

This linear dependency is described with $\gamma_l \geq 0$ and can be seen as a close relation to the concept of demand elasticity of price. That means whenever a market participant buys or sells a certain quantity of an asset this could have an effect on the specific asset.

If we talk about market liquidity we refer to the definition of the underlying paper, where market liquidity measures the size of the price response to trades an is inversely proportional to the scale of the market impact: $\frac{1}{\gamma_l}$. This means if trading a given quantity of an asset results in a small price change then the market is liquid, otherwise if this would produce a substantial price change, we call the market illiquid.

Due to this considerations we are able to formulate the final equation for our simulation model

$$\frac{ds_l}{s_l} = \gamma_l \left(\frac{dQ_l}{Q_l} \right) dt + \sigma dB_l \tag{21}$$

2.4 Summary of the model

If we want to analyse our financial system we have to consider the following equations and specify the parameters

$$\phi_i = \frac{(h_i + b_i)}{\sum_l Q_{il} s_l + \sum_j W_{ij} \frac{h_j}{(1+r_f+\beta\phi_j)}} \tag{22}$$

$$\frac{dQ_{il}}{Q_{il}} = \left(\frac{\epsilon_i}{\alpha_{il}}\right)\left(\frac{\phi_i^* - \phi_i}{1-\phi_i^*}\right) dt \tag{23}$$

$$\frac{db_i}{b_i} = \left(\frac{\epsilon_i}{\kappa_i \phi_i}\right)\left(\frac{\phi_i^* - \phi_i}{1-\phi_1^*}\right) dt \tag{24}$$

$$\frac{ds_l}{s_l} = \gamma_l \left(\frac{dQ_l}{Q_l}\right) dt + \sigma dB_l \tag{25}$$

We refer to $l = 1, \ldots, m$ as the number of assets and
$i = 1, \ldots, n$ as the number of financial institutions.
The target leverage ϕ_i^* could possibly range from zero to one, $\phi^* \in (0, 1)$.
The variance of the external assets is displayed by $\sigma \in (0, 1)$, in this model we took the value from the underlying paper [1]: $\sigma = 0.1$.
As ϵ_i determines the bank reaction to the accounting rule we have to consider cases where $\epsilon_i \in [0, 1]$.
The price response of assets to banks trades is displayed by $\gamma_l > 0$, we search for usable values between zero and five.
The face value of interbank obligations h_i is always greater than zero and stays constant over time.
b_i denotes the face value of external funds, $b_i > 0$.
The sensitivity of interbank obligations to leverage is determined by $\beta \in (0, 1)$.
The risk-free rate equal to $r_f = 0.01$.

3 Finding Parameters

In a first step we wanted to find specific values for target leverage ϕ^*, bank reaction to the accounting rule ϵ, the price response of assets to banks' trades γ and the relation of face value of interbank obligations h to external funds h.

We wanted to verify the results of the underlying paper [1] and ran some simulations on different parameter settings. With this grid of parameter settings we wanted to identify trends on the behaviour of systemic default and later on take some promising parameter constellations to dive deeper into the analysis of the different network structures.
For our considerations we focused on the following parameters:

3.1 ϵ and γ

The parameters ϵ and γ are used to describe the market procyclicality[1]

- $\epsilon \in (0, 1]$ with $\epsilon \gtrapprox 0$ representing a slow reaction of the bank on a change in asset-prices. On the other side $\epsilon \lessapprox 1$ corresponds to a quick reaction on asset-price changes.

- $\gamma \in (0, 3)$. If $\gamma \gtrapprox 0$ we say that the asset market is highly liquid, on the contrary if $\gamma \lessapprox 3$ the asset market is said to be illiquid.

In our first overview of parameters we tested each constellation of

$$\epsilon \in \{0.1, 0.2, \ldots, 1\} \times \gamma \in \{0.3, 0.6, \ldots, 2.7\}$$

In doing so we were able to identify different types of procyclicality as noticed in the underlying paper[1]. We talk about weak procycliality if both parameters ϵ and γ are close to zero and strong procyclitality if both parameters are close to their maximum ($\epsilon \lessapprox 1, \gamma \lessapprox 2.7$).
Medium procyclicality refers to those constellation where one of the parameters is close to its maximum and the other is close to its minimum.
As one can see for ϵ and γ close to zero we see the most diversification effects due to the different behaviours of the financial institutions. In the extreme

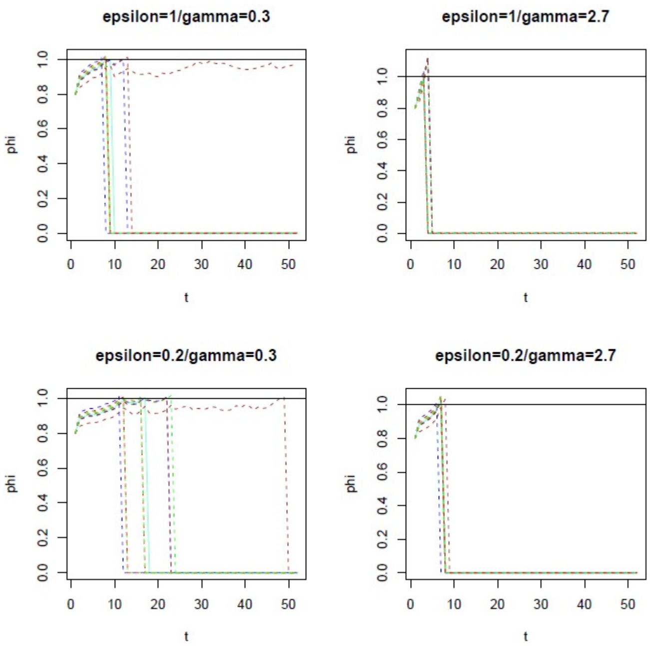


Figure 7: Market Procyclicality

case of ϵ and γ close to our upper limits we observe no more diversification within the different banks. This findings are similar to those presented in the underlying paper[1]. For further analysis we focused on parameters similar to those in the lower left corner of Figure 7.

3.2 Relation of b to h

There are three possibilities of how the book value h_i of bank i's obligations to other banks in the network is related to the book value b_i of bank i's external funds with actors outside the banking system. We made an additional assumption at the beginning[1], where $b_i + h_i = 1$ at $t = 0$. Also keep in mind that h_i stays constant over time

- $b > h$
- $b < h$
- $b = h$

To be precise we used values of $b_i \in \{0.8, 0.9\}$, $b_i \in \{0.1, 0.2\}$ and the corresponding values for h_i to achieve the assumed equation $b_i + h_i = 1$.
In case 3 $b_i = h_i = 0.5$.
We expected that after an initial shock we end up either with leverage $\phi > 1$ or that leverage ϕ firstly goes up but doesn't reach the default line and then returns closely to the initial value of ϕ.
For the settings $b > h$ and $b = h$ we end up with the expected results and moreover there was slightly no difference on how b and h were related to each other. For the case $b < h$ we got slightly different results, meaning that we observed in most of the parameter settings an initial increase of ϕ and those ϕ's who survived default didn't settle down to the initial value but dropped to a much lower level with no observations of up-movement.

In Figure 8 we see an almost similar behaviour for all three relations, if we take a closer look we observe that in the case of $b < h$ there is not a real readjustment of ϕ to its initial value. In some more extreme cases we can even see a complete decrease of the ϕ-values to zero.
We implemented those b to h relations in the whole $\epsilon - \gamma$-range and conclude using $b > h$ for further analysis as best choice.

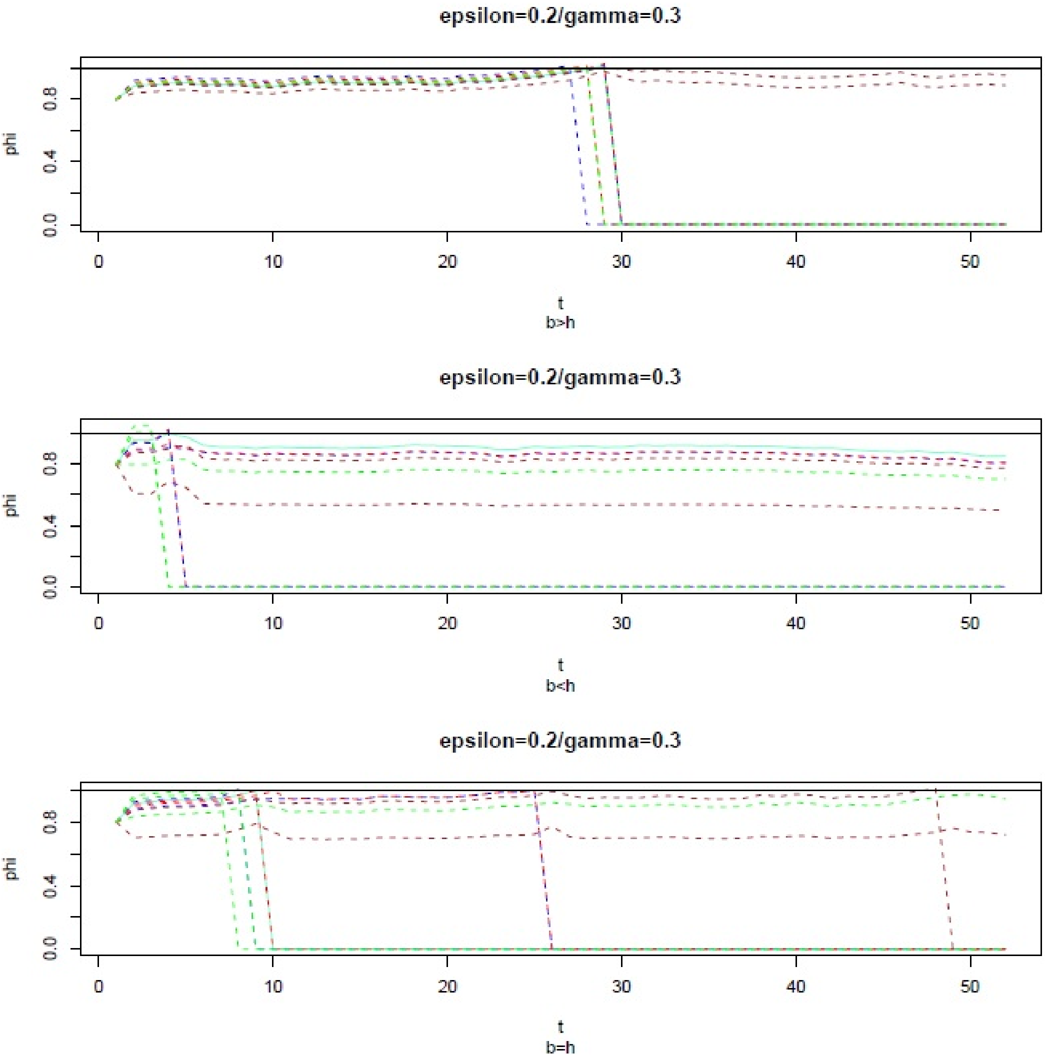


Figure 8: Relation b to h

3.3 Interdependency Matrix W_{ij}

As mentioned earlier the matrix W_{ij} refers to the amount of debt held by i and issued by j. Those entries can be seen as the percentage amount of debt in relation to total assets.

Therefore we wanted to identify the percentage of debt and how those different matrices behave in the simulation framework. In a first approach we set up two different environments.

- $W_{ij} \in (0, 0.2]$
- $W_{ij} \in [0.2, 0.4]$

We used those two matrix settings in all constellations of b to h and in the whole parameter range of ϵ and γ and conclude that both types of matrices follow the same tendencies but the matrices with values $W_{ij} \in (0, 0.2]$ are more sensitive to changes in other parameters and hence are better for further investigations.

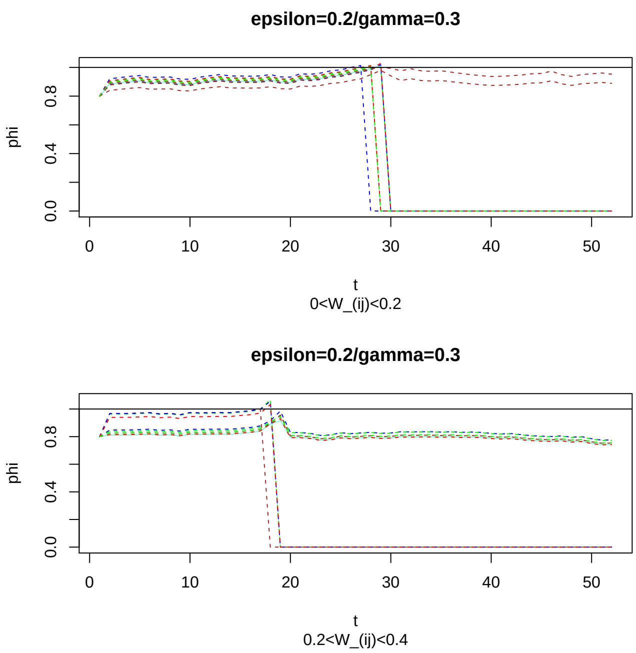


Figure 9: Range of matrix entries

3.4 Target Leverage $\phi^\star$

Additionally we searched for useful values of the target leverage $\phi^\star$. First investigations led to the result, that despite of all other parameters we get no default for $\phi^\star < 0.7$ and immediate default for $\phi^\star > 0.9$. As we want to focus on the behaviour of network structures we need a value which is sensitive on changes. We refined our search for a satisfying target leverage and tested $\phi^\star \in \{0.8, 0.85, 0.88\}$.
Finally we identified $\phi^\star = 0.8$ as our best choice, because the other values led to the predicted faster defaults and the chance of distinguishing different behaviours was lower.

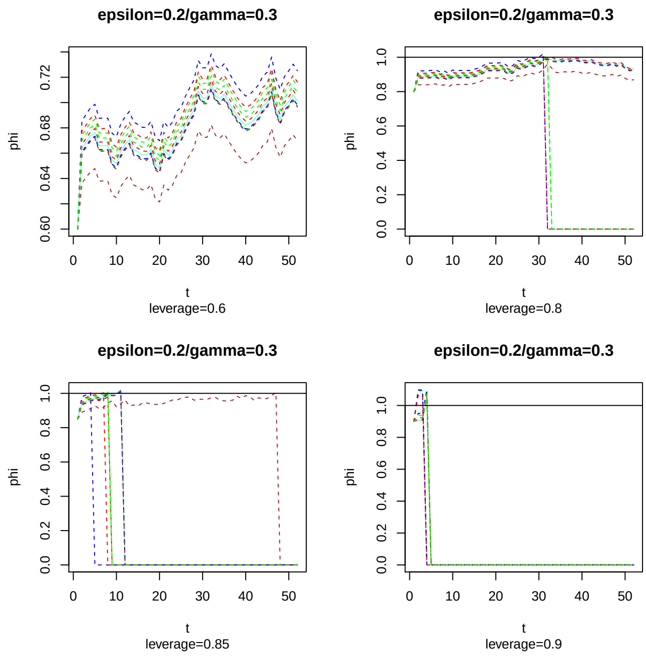


Figure 10: Target Leverage

3.5 Summary

We analysed two types of matrices[7] and three possible constellations of b and h which gave us basically 6 different scenarios. Each of the 6 scenarios was applied to our initial 5 network structures. We ended up with $6 \times 5 = 30$ network scenarios whereby each scenario ran through the whole remaining range of parameters $\epsilon \in \{0.1, 0.2, \ldots, 1\}, \gamma \in \{0.3, 0.6, \ldots, 2.7\}$ and $\phi^\star \in \{0.9, 0.85, 0.88\}$. The aim of this approach was to get a feeling of how the different parameter constellations and network settings tend to react. As we just did one simulation run on each of the settings we are not able to say that the results are completely reproducible but at least we are able to recognize some trends and more important we are able to identify some constellations which we could use for further analysis.

- $\epsilon \times \gamma$ range
  We observed immediate default in the cases where ϵ and γ are large. Furthermore we saw that for $\gamma \in 0.3, 0.6$ and arbitrary values of ϵ we were able to find different parameter settings which allows us to analyse in greater detail. We decided to use an array of four settings for further analysis.

- b and h constellations:
  We observed that the case $b = h$ behaves almost equal to the case of $b > h$. In setting $b < h$ we observe an almost similar behaviour except for some constellations. We took $b > h$ for further analysis.

- W_{ij}:
  We get similar results for $W_{ij} \in (0, 0.2]$ and $W_{ij} \in (0.2, 0.4)$. The only difference is that in case of higher values in the matrix we end up with earlier defaults and the time steps between different defaults in one run shrink. More over its much harder to distinguish between defaults of different banks in the network. And as one of our goals is to analyse the behaviour of the network before and after the first

[7] in the sense of how the range of entries are

default it is important to get a setting where it is possible to observe what happens after the first default. Using smaller values allows us to analyse the upcoming behaviour after an initial default in a much more precise way.

Final Parameter Settings

As we wanted to analyse the network structure we wanted to choose parameters which allowed us to distinguish, therefore we used the following set up based on the observations which we discussed above:

- $b > h \wedge h + b = 1$
- $0 < W_{ij} \leq 0.2$
- array setting consisting of four possibilities

set 1 $\epsilon = 0.2 \gamma = 0.3$

set 2 $\epsilon = 0.2 \gamma = 0.6$

set 3 $\epsilon = 0.3 \gamma = 0.3$

set 4 $\epsilon = 0.3 \gamma = 0.6$

Additionally we have to specify some more parameters, where we don't want to go into deeper details why we have chosen those values, most of them seem to represent conditions close to reality

- $r_f = 0.01$
- $\sigma = 0.1$
- $\beta = 0.5$

4 Analysis of the Interconnectedness

In this chapter we introduce our simulation framework, starting with a short abstract of the used parameter and the intention behind this usage. We briefly present the key aspect of this thesis, the matrix representing the different types of network system and give a short introduction on Monte Carlo simulations.

4.1 Simulation Framework

Choosing the right parameters for our final simulation framework was not an easy thing. First it is important to figure out what we want to analyse with the parameters and second at the beginning of our journey we are not even sure if we have chosen the right ones. Due to our pre-runs where we isolated some constellations which seemed to be satisfying for our final simulation procedure, we kept the relation of $b > h$ and took values between 0 and 0.2 for the entries of our interdependency matrix. During our parameter search we found out that the key parameters for our purpose seemed to be the constellation of ϵ and γ. As we wanted to simulate not only one combination we decided to choose an array of $\epsilon \times \gamma$-settings which additionally allowed us to look closer and conclude which factors are probably key drivers due to a certain behaviour.

4.2 Interdependency Matrix

The main purpose of this thesis is to model systemic risk under the assumption of different network structures. In this upcoming section we introduce how to implement those different architectures.

As mentioned before we state that the banks in our financial system are interconnected via interbank claims holding on each other. We used a $n \times n$-matrix with entries $W_{ij}, W_{ij} \geq 0, W_{ii} = 0$ representing the quantity of debt held by i and issued by j. Due to the entries of the matrix we can control if and how the financial institutions in the system are interconnected.

For this purpose we established five basic settings:

- complete financial system, every bank is connected to each other bank
- two separated systems in each system the banks are fully connected to each other
- one central bank that only issues debt to all other banks in the system, no further connection
- one central bank that only holds debt of all other banks in the system, no further connection
- one central bank that holds and issues debt to all other banks in the system

Additionally we took the fully interconnected system and modified it to generate different systems which were not fully interconnected any more. We did this by multiplying the matrix representing the fully interconnected system with randomly generated unity matrices.
After doing the first simulation framework we split up the setting to a part where we only analysed the five basic settings and a part where we focused on incomplete financial systems, based on the fully interconnected network.

4.3 Monte Carlo Simulation

Monte Carlo Simulations are quite useful if we want to approximate a certain behaviour. In our simulation problem we cannot predict how a financial system would react on a shock and furthermore we are not able to predict how the individual participant would behave in case of a financial shock. If we want to estimate a certain event we use the technique of repeating a procedure or function using in each repetition random numbers. In every single run we observed a certain outcome and by taking the sample mean of all these outcomes we were able to approximate a certain behaviour. We repeated our basic procedure for 2000 times, which is a quite common used amount of repetitions for Monte Carlo Simulations.
In our set up we wanted to approximate the upcoming event of systemic default and how the system behaves after an initial default has happened. We wanted to explore

- the first time of default and the number of first time defaults
- average time gap till the next two defaults
- total number of defaults

Additionally we wanted to explore if there is a dependency between time of default and the amount of debt held or issued by a certain bank. We analysed this by comparing the individual times of default for each bank with the corresponding amounts of debt held and issued by this specific bank.

5 Results

This chapter is structured in the following manner. We have three sub chapters of analysis, in part one we present our initial simulation run, consisting of our 5 basic networks and 3 variations of incomplete network structures based on the fully interconnected system. Part 2 deals with the analysis of the variations made on the 5 basic network structures, whereby in part 3 we want to focus on the analysis of the incomplete networks. Each of these three parts consists of the summary, the used matrices, their graphical interpretation and finally the tables containing the derived results. The graphs represent the underlying matrices and the thickness of the edges correspond to the matrix entries. The arrow points in the direction of the issuer of debt. The summary should give an overview on the derived results and inspire you to take a closer look through the underlying matrices and tables of results.
Due to the fact that part 2 and 3 are the separated and detailed continuations of part 1 we focus in part 1 on the analysis of the array setting of the parameters ϵ and γ and elaborate the drivers behind those setting structures. In part 2 and 3 we finally analyse those structures in greater detail, not focussing any more on the array setting, as there should be no huge differences to the results derived in part 1.

5.1 Part One: Analysis of Array Setting

As mentioned above in this part we focus on the analysis of the array setting of parameters ϵ and γ.

	$\gamma = 0.3$	$\gamma = 0.6$
$\epsilon = 0.2$	set 1	set 2
$\epsilon = 0.3$	set 3	set 4

The reaction of the bank on asset price changes is captured by ϵ and the higher ϵ the faster is the reaction of the bank on those asset price changes. The asset market is highly liquid if γ is small and liquidity decreases as γ gets larger.
Our initial simulation consisted of matrices A - E referring to the 5 basic network structures and matrices F- H representing incomplete variations of matrix A. Table 5.1.1 is split up into 4 sections representing the 4 array settings and in column 3 - 7 we find the calculated results according to "first time step of default", "how many first time defaults", "average time gap till next default", " average time gap till next default" and " overall numbers of default". Column 2 states the particular matrix and column 1 refers to the array set. Table 5.1.2 on the other hand displays for each bank the average time of default in each particular setting and network.

Analysis of table 5.1.1

We observe that in an environment where banks react slower on asset price changes and markets are more liquid, the first time of default occurs last (set 1). Earliest defaults can be observed in the case where banks react faster and markets are more illiquid (set 4).
If we slow down the reaction of the bank on asset price changes but keep the market more illiquid, we see that the first time of default occurs a little bit later (set 2). On the other side if we keep the fast bank reaction and set the market more liquid we observe that the time of first default is still later than in set 2 but earlier than in set 1.

Based on our observation we could rank the settings by first time of default

$$\text{set } 4 < \text{set } 2 < \text{set } 3 < \text{set } 1$$

The average number of banks run into first time default at almost the same time is displayed in column 4 of table 5.1.1. We observed that in set 1 and set 4 the number of first time defaults is slightly higher than in the other two array settings. The average time gap till next default and the next but one default are displayed in column 5 and 6 of this table. Here we observed almost the same behaviour as in the case of first time default, the network structures in set 4 have a shorter time gap till the next default than the others and the ranking remains as stated earlier.

The last column of table 5.1.1 refers to the overall number of defaults and we observed that in cases were defaults are earlier and time gaps till next default are smaller the overall number of defaults is larger. This could be justified as in all four settings we observed the same behaviour but in set 4 it's compacted in the sense that time gaps are shorter than in the other settings. If we would run our simulations not only for $t = 50$ time steps but for $t = 80$ we would see a convergence to the almost same number of total defaults.

Table 5.1.2 displays for each bank $B1$ - $B10$ the specific average time of default in each matrix A -H and each set. We immediately observed that bank 4 has an exceptional position and according to our analysis of the array setting we observed that the default behaviour of bank 4 is contrary to the developed result in table 5.1.1. To point it out again, bank 4 defaults first in set 1 and last in set 4, whereas in table 5.1.1 we observed that the average time of first default is later in set 1 compared to set 4. To clarify this behaviour we want to refer to the upcoming chapters, where we did deeper research in the correlation of default and interconnectedness.

a) Matrices

matrix A

$$\begin{pmatrix}
0 & 0.1 & 0.03 & 0.012 & 0.04 & 0.01 & 0.1 & 0.03 & 0.12 & 0.045 \\
0.1 & 0 & 0.021 & 0.01 & 0.016 & 0.012 & 0.011 & 0.03 & 0.015 & 0.024 \\
0.021 & 0.012 & 0 & 0.13 & 0.014 & 0.021 & 0.018 & 0.043 & 0.013 & 0.015 \\
0.015 & 0.075 & 0.023 & 0 & 0.022 & 0.011 & 0.012 & 0.021 & 0.011 & 0.022 \\
0.021 & 0.023 & 0.021 & 0.2 & 0 & 0.015 & 0.021 & 0.034 & 0.02 & 0.063 \\
0.0137 & 0.051 & 0.004 & 0.12 & 0.034 & 0 & 0.11 & 0.039 & 0.012 & 0.032 \\
0.0532 & 0.11 & 0.013 & 0.15 & 0.02 & 0.013 & 0 & 0.1 & 0.015 & 0.027 \\
0.041 & 0.02 & 0.041 & 0.13 & 0.015 & 0.002 & 0.02 & 0 & 0.013 & 0.015 \\
0.021 & 0.012 & 0.1 & 0.12 & 0.023 & 0.012 & 0.013 & 0.013 & 0 & 0.024 \\
0.054 & 0.023 & 0.025 & 0.2 & 0.11 & 0.015 & 0.023 & 0.012 & 0.043 & 0
\end{pmatrix}$$

matrix B

$$\begin{pmatrix}
0 & 0.1 & 0.03 & 0.012 & 0.04 & 0 & 0 & 0 & 0 & 0 \\
0.1 & 0 & 0.021 & 0.01 & 0.016 & 0 & 0 & 0 & 0 & 0 \\
0.021 & 0.012 & 0 & 0.13 & 0.014 & 0 & 0 & 0 & 0 & 0 \\
0.015 & 0.075 & 0.023 & 0 & 0.022 & 0 & 0 & 0 & 0 & 0 \\
0.021 & 0.023 & 0.021 & 0.2 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.11 & 0.039 & 0.012 & 0.032 \\
0 & 0 & 0 & 0 & 0 & 0.013 & 0 & 0.1 & 0.015 & 0.027 \\
0 & 0 & 0 & 0 & 0 & 0.002 & 0.02 & 0 & 0.013 & 0.015 \\
0 & 0 & 0 & 0 & 0 & 0.012 & 0.013 & 0.013 & 0 & 0.024 \\
0 & 0 & 0 & 0 & 0 & 0.015 & 0.023 & 0.012 & 0.043 & 0
\end{pmatrix}$$

matrix C

$$\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.021 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.015 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.021 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.0137 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.0532 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.041 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.021 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.054 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

matrix D

$$\begin{pmatrix} 0 & 0.1 & 0.03 & 0.012 & 0.04 & 0.01 & 0.1 & 0.03 & 0.12 & 0.045 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

matrix E

$$\begin{pmatrix} 0 & 0.1 & 0.03 & 0.012 & 0.04 & 0.01 & 0.1 & 0.03 & 0.12 & 0.045 \\ 0.1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.021 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.015 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.021 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0137 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0532 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.041 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.021 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.054 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

Matrices F,G and H resulting from multiplication of matrix A with different unity matrices to generate incomplete network structures

matrix F

$$
\begin{pmatrix}
0 & 0 & 0 & 0 & 0.04 & 0 & 0 & 0 & 0.12 & 0 \\
0 & 0 & 0 & 0.01 & 0 & 0 & 0.011 & 0.03 & 0.015 & 0.024 \\
0.021 & 0 & 0 & 0.13 & 0.014 & 0.021 & 0 & 0.043 & 0.013 & 0.015 \\
0 & 0.075 & 0.023 & 0 & 0.022 & 0.011 & 0.012 & 0 & 0 & 0 \\
0.021 & 0.023 & 0 & 0 & 0 & 0.015 & 0.021 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.12 & 0 & 0 & 0.11 & 0.039 & 0.012 & 0 \\
0.0532 & 0 & 0 & 0.15 & 0.02 & 0 & 0 & 0.1 & 0.015 & 0 \\
0.041 & 0.02 & 0.041 & 0.13 & 0 & 0.002 & 0.02 & 0 & 0.013 & 0.015 \\
0 & 0 & 0 & 0 & 0.023 & 0 & 0 & 0.013 & 0 & 0.024 \\
0 & 0.023 & 0 & 0 & 0 & 0.015 & 0.023 & 0.012 & 0 & 0
\end{pmatrix}
$$

matrix G

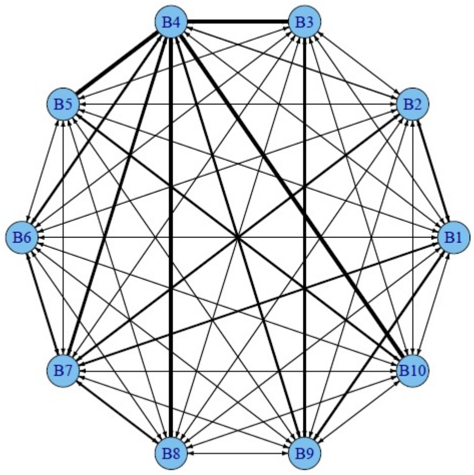
$$
\begin{pmatrix}
0 & 0 & 0.03 & 0 & 0.04 & 0 & 0.1 & 0.03 & 0 & 0.045 \\
0.1 & 0 & 0.021 & 0 & 0 & 0 & 0.011 & 0 & 0.015 & 0.024 \\
0 & 0.012 & 0 & 0 & 0 & 0.021 & 0.018 & 0.043 & 0.013 & 0.015 \\
0.015 & 0.075 & 0.023 & 0 & 0.022 & 0.011 & 0.012 & 0 & 0.011 & 0.022 \\
0.021 & 0.023 & 0.021 & 0 & 0 & 0.015 & 0 & 0 & 0.02 & 0.063 \\
0 & 0.051 & 0.004 & 0.12 & 0 & 0 & 0 & 0.039 & 0.012 & 0.032 \\
0 & 0.11 & 0.013 & 0.15 & 0.02 & 0 & 0 & 0 & 0.015 & 0.027 \\
0 & 0 & 0 & 0.13 & 0.015 & 0 & 0.02 & 0 & 0.013 & 0 \\
0.021 & 0 & 0 & 0 & 0.023 & 0.012 & 0.013 & 0.013 & 0 & 0.024 \\
0 & 0.023 & 0.025 & 0 & 0.11 & 0 & 0.023 & 0 & 0 & 0
\end{pmatrix}
$$

matrix H

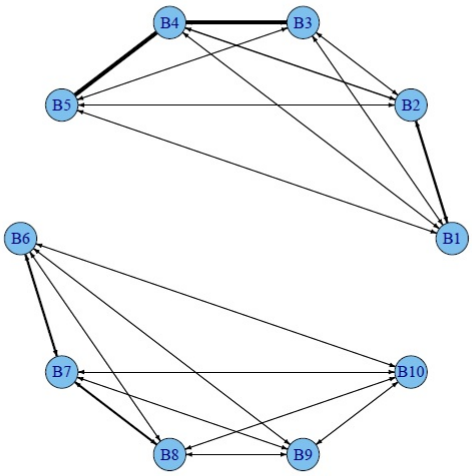
$$
\begin{pmatrix}
0 & 0 & 0.03 & 0.012 & 0.04 & 0.01 & 0 & 0.03 & 0.12 & 0.045 \\
0 & 0 & 0 & 0.01 & 0 & 0.012 & 0 & 0.03 & 0 & 0.024 \\
0.021 & 0 & 0 & 0 & 0.014 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0.023 & 0 & 0 & 0 & 0 & 0.021 & 0.011 & 0.022 \\
0.021 & 0.023 & 0 & 0.2 & 0 & 0 & 0.021 & 0.034 & 0.02 & 0.063 \\
0.0137 & 0 & 0.004 & 0.12 & 0.034 & 0 & 0.11 & 0.039 & 0.012 & 0 \\
0.0532 & 0 & 0.013 & 0 & 0.02 & 0.013 & 0 & 0 & 0.015 & 0.027 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0.02 & 0 & 0 & 0.015 \\
0 & 0.012 & 0 & 0.12 & 0 & 0.012 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.2 & 0 & 0 & 0.023 & 0 & 0 & 0
\end{pmatrix}
$$

b)Graphs

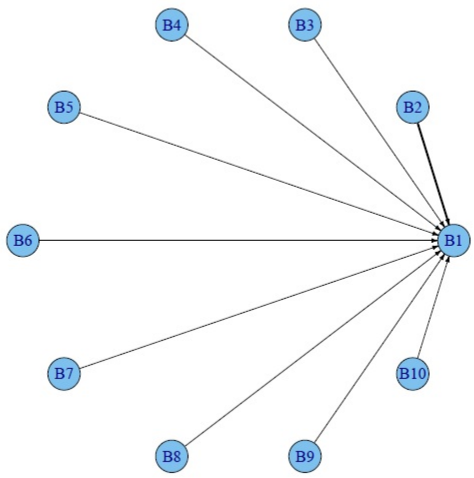
network A



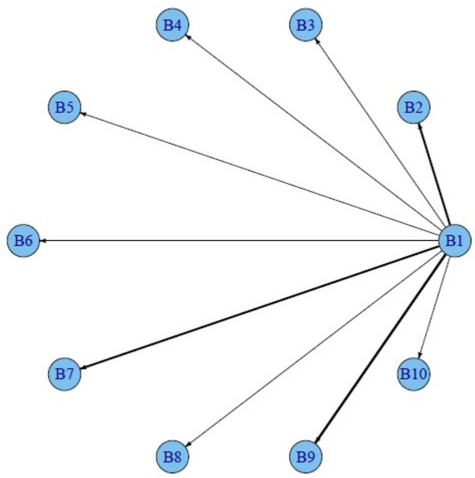
network B



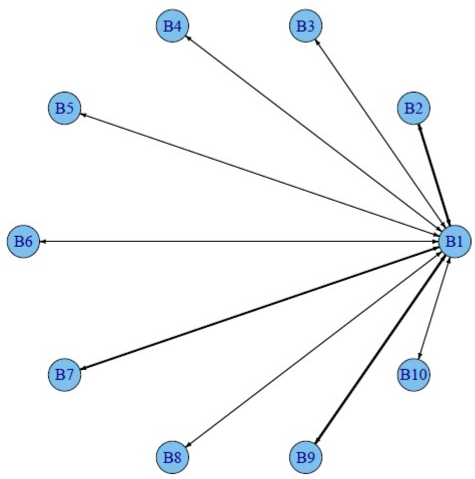
network C



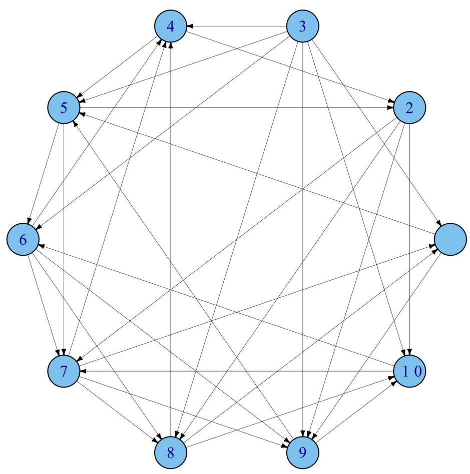
network D



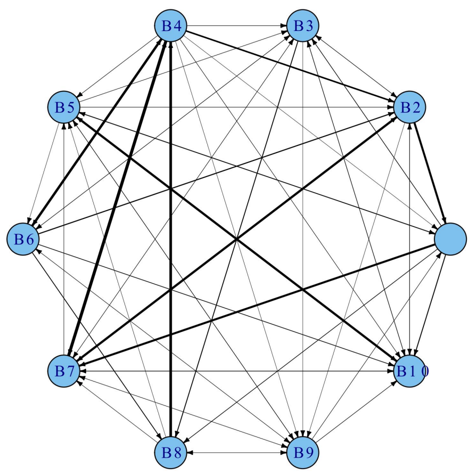
network E



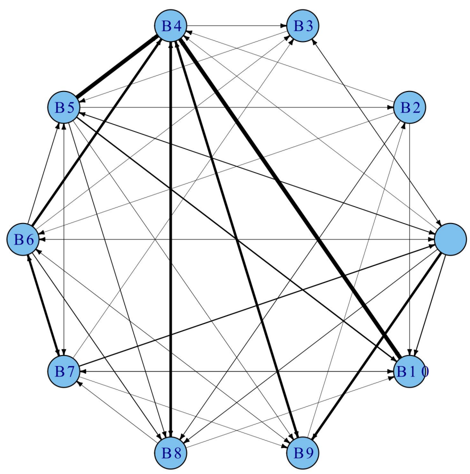
network F



network G



network H



c) Tables

Table 5.1.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SET I	A	21.02	2.19	3.55	2.72	7.15
	B	23.59	5.97	1.65	1.74	8.23
	C	23.24	5.12	2.44	2.52	8.09
	D	21.56	2.16	5.4	1.78	8.21
	E	23.7	6.71	1.79	2.24	8.34
	F	21.99	2.57	3.3	2.05	7.78
	G	22.05	2.52	3.27	2.57	7.95
	H	23.12	4.85	1.18	2.35	7.74
SET II	A	14.95	1.4	2.1	1.69	9.18
	B	17.54	5.89	1	1.18	9.92
	C	17.17	4.97	1.44	1.45	9.72
	D	15.62	1.24	3	1.44	9.94
	E	17.7	6.68	1.27	1.32	9.94
	F	16.26	1.7	1.85	1.47	9.7
	G	16.32	1.62	1.84	1.59	9.86
	H	17.27	4.55	1.71	1.35	9.46
SET III	A	18.27	1.48	2.55	2.14	8.67
	B	21.17	5.61	1.44	1.39	9.61
	C	20.7	4.69	1.92	2.09	9.41
	D	18.9	1.31	4.01	2.05	9.62
	E	21.38	6.3	1.58	1.53	9.67
	F	19.54	1.78	2.39	1.97	9.27
	G	19.64	1.67	2.42	2.1	9.46
	H	20.7	4.35	2.73	1.74	9.07
SET IV	A	10.68	1.57	1.47	1.28	9.41
	B	12.42	6.2	1	1.02	9.98
	C	12.18	5.56	1.19	1.23	9.85
	D	11.14	1.39	2.03	1	9.99
	E	12.55	7.13	1.12	1.03	9.99
	F	11.66	1.99	1.40	1.24	9.87
	G	11.69	1.91	1.41	1.21	9.97
	H	12.33	4.95	1.08	1.15	9.69

Table 5.1.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
	A	23.49	21.9	22.93	3.87	23.53	23.04	21.02	21.69	22.48	23.46
	B	23.65	23.93	23.98	23.84	23.54	23.59	23.65	22.65	24.02	23.89
S	C	16.5	23.24	23.96	24	23.96	23.89	23.61	23.97	23.96	23.92
E	D	21.56	24.14	24.23	24.16	24.2	24.16	24.14	24.23	23.64	24.19
T	E	24.15	23.7	24.05	23.99	23.94	24.13	24.01	24.09	23.51	24.12
I	F	23.99	24.17	23.39	15.4	24.16	23.39	21.99	23.09	24.13	24.25
	G	24.28	22.51	24.13	21.72	23.89	23.42	22.05	23.91	23.89	23.26
	H	23.78	23.81	23.46	10.06	23.13	23.12	23.64	23.62	23.78	23.57
	A	20.38	22.17	20.87	10.04	18.8	17.12	14.95	22.49	16.53	18.07
	B	19.01	18.44	18.12	18.72	17.55	17.54	17.59	19.47	18.13	18.7
S	C	18.35	17.17	18.19	18.09	18.19	18.21	17.61	17.98	17.97	17.88
E	D	15.62	19.31	18.62	18.46	18.68	18.45	19.31	18.62	19.51	18.74
T	E	18.5	17.7	18.25	18.04	18.36	18.13	18.21	18.09	18.68	18.12
II	F	19.11	19.37	17.7	19.92	20.07	17.51	16.26	19.55	19.79	19.39
	G	19.14	20.14	19.47	19.65	20.15	17.64	16.32	18.44	18.25	20.39
	H	17.92	17.98	19.57	14.42	17.28	17.27	17.95	19.19	18.2	19.23
	A	24.22	24.41	24.04	6.79	22.96	20.74	18.27	24.39	20	22.09
	B	22.75	22.52	22	22.41	21.19	21.17	21.22	22.56	22.03	22.53
S	C	19.11	20.7	22.04	21.93	22.04	22.09	21.28	21.81	21.8	21.73
E	D	18.9	23.2	22.6	22.46	22.68	22.44	23.2	22.6	23.2	22.67
T	E	22.24	21.38	22.17	21.89	22.24	22.01	22.11	21.95	22.38	22
III	F	23.09	23.24	21.37	19.05	23.68	21.05	19.54	22.96	23.57	23.24
	G	23.05	23.24	23.16	22.32	23.62	21.22	19.64	22.36	22.09	23.88
	H	21.67	21.76	22.78	12.67	20.72	20.7	21.65	22.73	22.08	22.68
	A	14.29	15.52	14.59	12.67	13.18	12.09	10.68	16.06	11.69	12.67
	B	13.56	13.09	12.82	13.3	12.42	12.42	12.47	14.11	12.83	13.3
S	C	16.06	12.18	12.86	12.82	12.86	12.9	12.5	12.75	12.75	12.7
E	D	11.14	13.63	13.11	13.05	13.16	13.05	13.63	13.11	13.76	13.18
T	E	13.19	12.55	12.92	12.8	13.03	12.85	12.91	12.84	13.76	12.85
IV	F	13.54	13.83	12.67	16.57	14.31	12.50	11.66	13.93	14.15	13.88
	G	13.67	14.23	13.96	13.99	14.56	12.58	11.69	13.19	13.01	14.79
	H	12.85	12.87	14.22	15.33	12.34	12.33	12.85	13.74	13.05	13.78

5.2 Part Two: Analysis of the 5 basic network structures

In this analysis we focused on the five basic network structures where matrix A represents the fully interconnected system and matrix B refers to a system where we have two separated networks. In matrix C we assigned bank 1 as central bank, which means that bank 1 issues all debt and consequently all other banks are holding debt of bank 1. Matrix D represents the reverse version, bank 1 holds all debt, which is issued by all other banks. In Matrix E bank 1 acts as a centralized bank which issues and holds all debt of all other banks. It is a combination of matrix C and D. In every variation we had one specific matrix generated by multiplication of a 0-1-matrix with a matrix consisting of randomly generated values between 0.01 and 1.99. This particular matrix was multiplied with each of the basis matrices A-E and we finally end up with a weighted version of these matrices.
To point it out once again in every variation we had one weighted basis matrix which was multiplied with the 5 original structures (matrices A - E) presented in the previous section. Due to this procedure we generated in every variation a different situation related to the amount of debt held or issued by each bank. This offers us the possibility to accentuate other factors which might be important in terms of systemic risk and behaviour in financial systems. We kept our array of parameter settings for ϵ and γ and refer to the different settings if necessary.
In a first step we calculated the sum in each row and each column of the matrices and identified the minimum and maximum of both. We have four criteria which we used for further analysis

maxCol refers to the bank which issued most of the debt

minCol refers to the bank which issued fewest

maxRow refers to the bank which held the most debt

minRow refers to the bank which held the fewest debt

Moreover we were able to rank in each matrix and each variation the banks that we assign 1 to the specific bank which defaults first and respectively 10 to the bank which defaults last. To keep a clear structure we first study the behaviour of matrix A in the different variations, then we analyse matrix B, C, D and finally matrix E. After the discussion of the results we present the used matrices, graphical interpretations and corresponding tables for each variation. The first tables respectively display the average time steps of first default, number of first time defaults and average time steps to upcoming defaults. The second tables in each case state the average time of default for each bank in each network.

Analysis of matrix A

The fully interconnected system is represented by matrix A. We observed that in set 1 - 3 the bank with the most debt issued defaults first. Moreover if we compare issued to held debt for each bank, we see that the bank which defaults first has the highest ratio. If we want to analyse the upcoming events of the remaining banks we first have to adapt our matrix, as the bank which defaulted has now 0 in every corresponding entry of the matrix and therefore the maximum and minimum values of each column and row have to be recalculated. We compared those banks, which defaulted after this initial default, with our indicators but couldn't observe a fixed rule out of it. We observed a weak tendency that those banks which held the most debt in the remaining system default more often than the others, but there were also a lot of second defaults which happen for no obvious reason.
A closer look on set 4[8] showed that in this $\epsilon \times \gamma$-constellation the first time of default neither corresponds to maximum amount of debt issued nor to the ratio of issued to held debt.
The only thing we observed is that the variation of time of default for bank 4 is greater than the variation of time of default for all other banks. This might lead to the fact that other banks run into first time default than in set 1 - 3.

[8]faster reaction on asset price changes and markets illiquid

Analysis of matrix B

In this system we have two separated network systems, each consisting of 5 fully interconnected banks. We were using the same indicators again and observe that in set 2 - 4 in almost all networks the first time of default occurred by the bank which held the most debt. In set 1 those banks which ran into first time default were those that held the fewest debt or issued the most debt. Furthermore the ratio of issued to held debt was almost in all cases the highest in the bank which defaulted first. Over all we observed that the average time till the next default is shorter compared to the network where we have one system of 10 banks. Due to this short intervals between second and third default we were not able to conclude anything.

Analysis of matrix C

Matrix C represented the case where bank 1 is the only bank which can issue debt and all other banks hold debt only from bank 1. We observed that in set 1 and in most of the cases in set 3 bank 1 defaults first. In set 2 and 4 we saw a weak tendency towards first time default of the bank which holds most of debt.

Analysis of matrix D

In this network structure we present the case where we have one bank which holds all debt issued by the other banks. We observed that due to the simulated shock this specific bank has the shortest time till default no matter which set of ϵ and γ values was used.

Analysis of matrix E

Matrix E is a combination of the previous two systems, in which bank 1 works as a central bank that issues and holds the debt of all other banks in the system. We observed different results which didn't allow us to make any conclusion. In spite of there were weak tendencies that in set 2 - 4 the banks default first, which have the lowest ratio of issued to held debt.

Summary

Although the sample size of our simulation is not big enough to conclude in a conciser way we wanted to state the tendencies we observed:

- Those banks which issued most debt run into first time of default preferred in set 1 and 3
- Banks which held most debt run into first time of default preferred in set 2 and 4
- If a bank works as a central bank which issues and holds debt of all other banks we have to use the ratio of issued to held debt and see weak tendencies that those banks with lowest ratio run earlier into default.

Variation 1

a) Matrices

matrix A variation 1

$$
\begin{pmatrix}
0 & 0.17 & 0.0597 & 0.0138 & 0.0348 & 0.0118 & 0.024 & 0.0078 & 0.0372 & 0.01395 \\
0.029 & 0 & 0.01848 & 0.0115 & 0.0056 & 0.0024 & 0.0187 & 0.0546 & 0.02085 & 0.0144 \\
0.0063 & 0.0144 & 0 & 0.1534 & 0.01218 & 0.0399 & 0.02214 & 0.05203 & 0.01885 & 0.00285 \\
0.01545 & 0.0915 & 0.0092 & 0 & 0.03344 & 0.00363 & 0.02004 & 0.0168 & 0.00242 & 0.00132 \\
0.02079 & 0.04554 & 0.00483 & 0.042 & 0 & 0.0276 & 0.00714 & 0.04522 & 0.0186 & 0.03906 \\
0.016851 & 0.01989 & 0.002 & 0.1764 & 0.06154 & 0 & 0.0033 & 0.05967 & 0.01536 & 0.04736 \\
0.04788 & 0.165 & 0.01768 & 0.183 & 0.0326 & 0.01716 & 0 & 0.104 & 0.012 & 0.05184 \\
0.00492 & 0.0098 & 0.04715 & 0.247 & 0.006 & 0.00314 & 0.0108 & 0 & 0.02574 & 0.01245 \\
0.00042 & 0.00792 & 0.083 & 0.2304 & 0.0023 & 0.01836 & 0.02145 & 0.02509 & 0 & 0.02496 \\
0.0243 & 0.00023 & 0.0365 & 0.298 & 0.1056 & 0.0201 & 0.04278 & 0.0012 & 0.02709 & 0
\end{pmatrix}
$$

matrix B variation 1

$$
\begin{pmatrix}
0 & 0.17 & 0.0597 & 0.0138 & 0.0348 & 0 & 0 & 0 & 0 & 0 \\
0.029 & 0 & 0.01848 & 0.0115 & 0.0056 & 0 & 0 & 0 & 0 & 0 \\
0.0063 & 0.0144 & 0 & 0.1534 & 0.01218 & 0 & 0 & 0 & 0 & 0 \\
0.01545 & 0.0915 & 0.0092 & 0 & 0.03344 & 0 & 0 & 0 & 0 & 0 \\
0.02079 & 0.04554 & 0.00483 & 0.042 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.0033 & 0.05967 & 0.01536 & 0.04736 \\
0 & 0 & 0 & 0 & 0 & 0.01716 & 0 & 0.104 & 0.012 & 0.05184 \\
0 & 0 & 0 & 0 & 0 & 0.00314 & 0.0108 & 0 & 0.02574 & 0.01245 \\
0 & 0 & 0 & 0 & 0 & 0.01836 & 0.02145 & 0.02509 & 0 & 0.02496 \\
0 & 0 & 0 & 0 & 0 & 0.0201 & 0.04278 & 0.0012 & 0.02709 & 0
\end{pmatrix}
$$

matrix C variation 1

$$
\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.029 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.0063 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01545 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02079 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.016851 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.04788 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00492 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00042 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.0243 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

matrix D variation 1

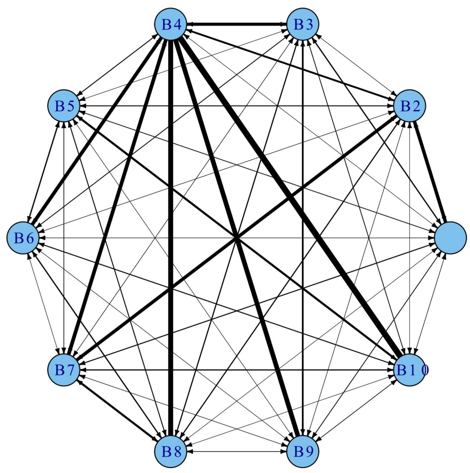
$$\begin{pmatrix} 0 & 0.17 & 0.0597 & 0.0138 & 0.0348 & 0.0118 & 0.024 & 0.0078 & 0.0372 & 0.01395 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

matrix E variation 1

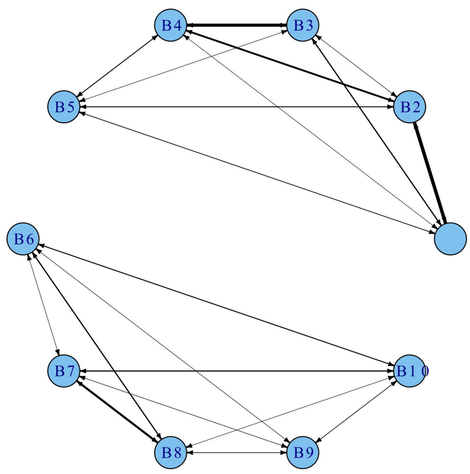
$$\begin{pmatrix} 0 & 0.17 & 0.0597 & 0.0138 & 0.0348 & 0.0118 & 0.024 & 0.0078 & 0.0372 & 0.01395 \\ 0.029 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0063 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.01545 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.02079 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.016851 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.04788 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.00492 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.00042 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0243 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

b) Graphs

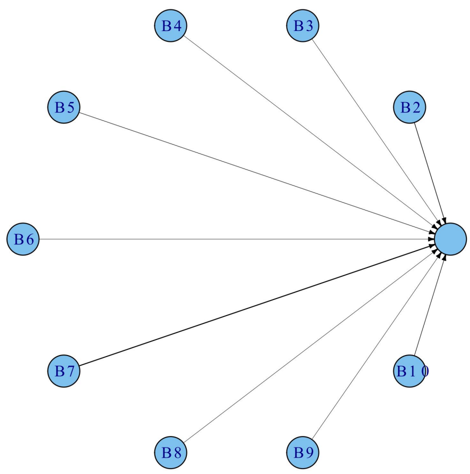
network A variation1



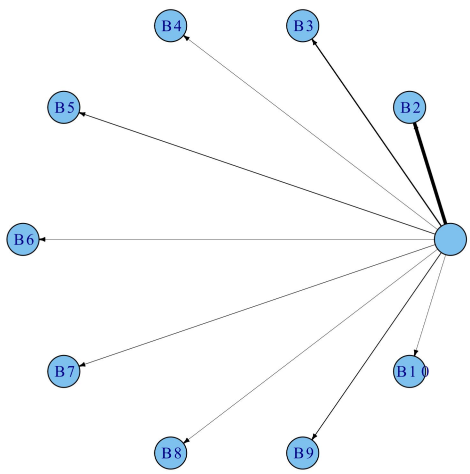
network B variation1



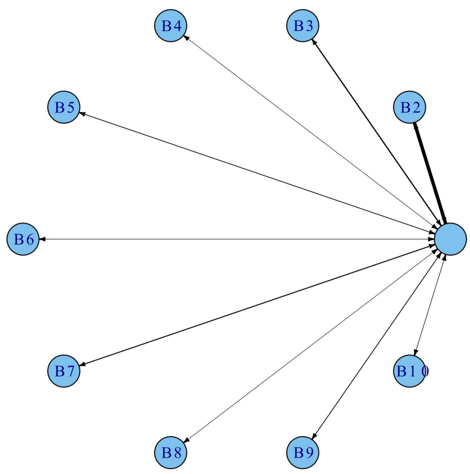
network C variation1



network D variation1



network E variation1



c) Tables

Table 5.2.1.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SET I	Av1	17.42	1.75	5.86	5.39	6.61
	Bv1	22.94	3.81	2.59	2.7	8.06
	Cv1	23.63	7.03	2.15	2.21	8.26
	Dv1	22.16	2.54	4.34	2.08	8.23
	Ev1	23.73	7.29	2.06	2.28	8.3
SET II	Av1	12.21	1.07	3.36	3.26	8.7
	Bv1	16.89	3.37	1.51	1.45	9.84
	Cv1	17.69	7	1.39	1.62	9.89
	Dv1	16.31	1.71	2.33	1.55	9.92
	Ev1	17.8	7.2	1.39	1.49	9.94
SET III	Av1	15.08	1.16	4.22	4.24	8.12
	Bv1	20.36	3.26	1.92	2.01	9.47
	Cv1	21.33	6.6	1.89	1.84	9.6
	Dv1	19.66	1.67	3.16	2.23	9.62
	Ev1	21.52	6.95	2	1.8	9.66
SET IV	Av1	8.85	1.06	2.17	2.19	9.03
	Bv1	11.99	3.95	1.2	1.19	9.95
	Cv1	12.55	7.33	1.15	1.26	9.95
	Dv1	11.58	2.14	1.67	1.04	9.98
	Ev1	12.64	7.66	1.13	1.23	9.99

Table 5.2.1.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
SET I	Av1	23.27	14.72	22.06	0.77	22.68	23.01	17.42	20.09	20.93	22.99
	Bv1	23.52	21.89	23.94	23.93	23.82	23.88	22.94	21.12	23.89	23.19
	Cv1	21.35	23.8	23.99	23.93	24.02	24.05	23.63	23.99	23.91	24
	Dv1	22.16	22.34	24.08	24.22	24.17	24.2	24.14	24.17	24.17	24.22
	Ev1	23.73	23.57	23.66	24.06	23.97	24.02	23.76	23.97	23.83	24.01
SET II	Av1	19.56	23.58	21.86	3.09	21.35	18.2	12.21	23.79	15.37	18.3
	Bv1	17.45	19.73	17.92	18.08	18.5	18.11	16.89	20.17	17.78	19.42
	Cv1	19.53	17.87	18.2	18.04	18.11	18.14	17.69	18.19	18.22	18.08
	Dv1	16.31	19.59	18.75	18.38	18.53	18.37	18.43	18.35	18.54	18.38
	Ev1	17.8	18.99	18.7	18.09	18.35	18.19	17.81	18.26	18.54	18.15
SET III	Av1	23.3	20.53	24.31	1.72	24.21	22.11	15.08	24.25	18.66	22.23
	Bv1	21.03	22.53	21.8	21.98	22.46	22.02	20.36	22.49	21.57	22.74
	Cv1	21.98	21.65	22.16	21.87	21.96	22	21.33	22.18	22.22	21.92
	Dv1	19.66	22.46	22.65	22.37	22.56	22.34	22.47	22.3	22.59	22.37
	Ev1	21.52	22.45	22.33	21.95	22.2	22.08	21.55	22.12	22.4	22
SET IV	Av1	13.74	21.85	15.54	6.26	15.32	12.81	8.85	18.5	10.88	12.78
	Bv1	12.36	14.67	12.72	12.82	13.15	12.85	11.99	14.95	12.62	13.96
	Cv1	14.82	12.69	12.91	12.79	12.84	12.86	12.55	12.91	12.95	12.83
	Dv1	11.58	14.15	13.25	13.02	13.09	13.01	13.06	13.01	13.1	13.02
	Ev1	12.64	13.66	13.33	12.86	13.02	12.92	12.65	12.94	13.21	12.89

Variation 2

a) Matrices

matrix A variation 2

$$\begin{pmatrix}
0 & 0.11 & 0.0396 & 0.00036 & 0.0784 & 2e-04 & 0.154 & 0.0165 & 0.084 & 0.08775 \\
0.14 & 0 & 0.01638 & 0.0033 & 0.0096 & 0.00036 & 0.01947 & 0.0186 & 0.0201 & 0.0192 \\
0.02415 & 0.01824 & 0 & 0.2106 & 0.00322 & 0.02856 & 0.0225 & 0.00387 & 0.00065 & 0.0114 \\
0.0051 & 0.027 & 0.0069 & 0 & 0.00726 & 0.02046 & 0.00624 & 0.00777 & 0.0088 & 0.02464 \\
0.03948 & 0.01863 & 0.0147 & 0.206 & 0 & 0.00825 & 0.03591 & 0.01258 & 0.008 & 0.05859 \\
0.025756 & 0.0867 & 0.00392 & 0.15 & 0.05406 & 0 & 0.0968 & 0.05889 & 0.02052 & 0.0128 \\
0.013832 & 0.2145 & 0.0039 & 0.2535 & 0.0388 & 0.02041 & 0 & 0.058 & 0.0291 & 0.02295 \\
0.06806 & 0.009 & 0.02952 & 0.0741 & 0.0105 & 0.00394 & 0.0184 & 0 & 0.00845 & 0.00285 \\
0.01974 & 0.01068 & 0.192 & 0.1596 & 0.023 & 0.01476 & 0.00572 & 0.01053 & 0 & 0.00552 \\
0.0594 & 0.00345 & 0.00675 & 0.06 & 0.1782 & 0.0213 & 0.00322 & 0.01368 & 0.02924 & 0
\end{pmatrix}$$

matrix B variation 2

$$\begin{pmatrix}
0 & 0.11 & 0.0396 & 0.00036 & 0.0784 & 0 & 0 & 0 & 0 & 0 \\
0.14 & 0 & 0.01638 & 0.0033 & 0.0096 & 0 & 0 & 0 & 0 & 0 \\
0.02415 & 0.01824 & 0 & 0.2106 & 0.00322 & 0 & 0 & 0 & 0 & 0 \\
0.0051 & 0.027 & 0.0069 & 0 & 0.00726 & 0 & 0 & 0 & 0 & 0 \\
0.03948 & 0.01863 & 0.0147 & 0.206 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.0968 & 0.05889 & 0.02052 & 0.0128 \\
0 & 0 & 0 & 0 & 0 & 0.02041 & 0 & 0.058 & 0.0291 & 0.02295 \\
0 & 0 & 0 & 0 & 0 & 0.00394 & 0.0184 & 0 & 0.00845 & 0.00285 \\
0 & 0 & 0 & 0 & 0 & 0.01476 & 0.00572 & 0.01053 & 0 & 0.00552 \\
0 & 0 & 0 & 0 & 0 & 0.0213 & 0.00322 & 0.01368 & 0.02924 & 0
\end{pmatrix}$$

matrix C variation 2

$$\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.14 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02415 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.0051 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.03948 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.025756 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.013832 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.06806 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01974 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.0594 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

matrix D variation 2

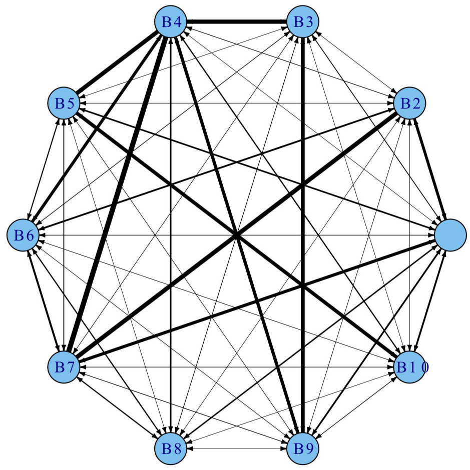
$$\begin{pmatrix} 0 & 0.11 & 0.0396 & 0.00036 & 0.0784 & 2e-04 & 0.154 & 0.0165 & 0.084 & 0.08775 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

matrix E variation 2

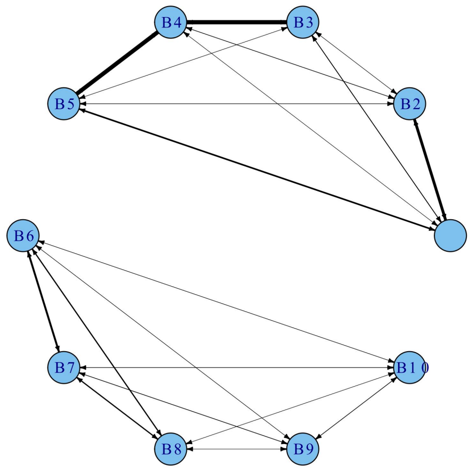
$$\begin{pmatrix} 0 & 0.11 & 0.0396 & 0.00036 & 0.0784 & 2e-04 & 0.154 & 0.0165 & 0.084 & 0.08775 \\ 0.14 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.02415 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0051 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.03948 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.025756 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.013832 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.06806 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.01974 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0594 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

b) Graphs

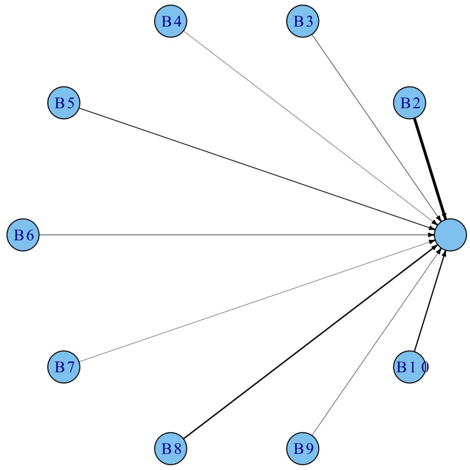
network A variation 2



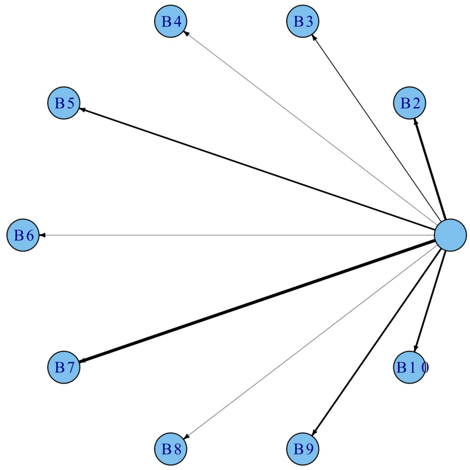
network B variation 2



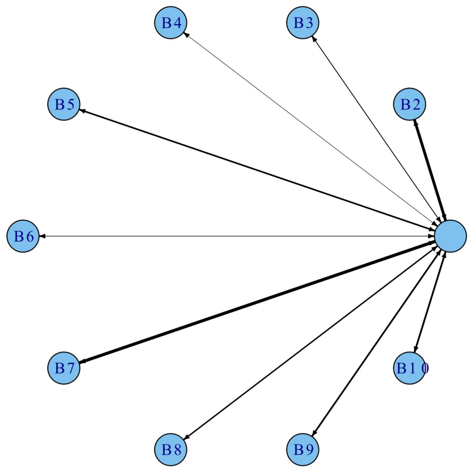
network C variation 2



network D variation 2



network E variation 2



Tables

Table 5.2.2.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SET I	Av2	18.72	1.91	4.18	4.34	6.76
	Bv2	23.5	5.92	1.24	2.25	8.15
	Cv2	22.78	3.72	3.04	2.05	7.98
	Dv2	21.21	2.03	6.21	2.17	8.12
	Ev2	23.44	4.99	1.7	2.4	8.3
SET II	Av2	13.09	1.21	2.44	2.68	8.84
	Bv2	17.41	5.68	1.34	1.36	9.89
	Cv2	16.76	3.3	1.69	1.31	9.63
	Dv2	15.12	1.08	3.46	1.6	9.92
	Ev2	17.36	4.89	1.11	1.43	9.94
SET III	Av2	16.12	1.3	3.03	3.26	8.3
	Bv2	20.99	5.49	1.73	1.87	9.54
	Cv2	20.23	3.16	2.32	2.12	9.31
	Dv2	18.39	1.24	4.56	2.5	9.59
	Ev2	20.94	4.48	1.41	1.9	9.66
SET IV	Av2	9.43	1.23	1.62	1.81	9.14
	Bv2	12.35	6.05	1.18	1.16	9.96
	Cv2	11.9	3.97	1.34	1.14	9.8
	Dv2	10.8	1.17	2.32	1	9.99
	Ev2	12.31	5.49	1.05	1.12	9.99

Table 5.2.2.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
SET I	Av2	23.43	16.96	20.34	1.51	22.99	22.39	18.72	22.93	21	23.51
	Bv2	23.49	23.69	23.46	21.76	23.5	23.78	23.55	22.65	23.58	23.73
	Cv2	13.8	22.78	23.96	23.86	23.92	23.92	23.95	23.82	23.92	23.82
	Dv2	21.21	23.89	24.07	23.97	24.24	23.97	23.07	24.1	24.19	24.17
	Ev2	23.84	23.44	23.98	24.07	24.08	23.98	23.55	23.89	23.99	24
SET II	Av2	20.57	23.13	22.18	4.93	21.03	17.13	13.09	21.43	15.09	19.71
	Bv2	18.93	17.62	17.44	19.24	17.41	17.77	17.6	19.86	18.94	18.59
	Cv2	17.98	16.76	18.14	18.24	18.02	18.11	18.11	17.82	18.02	17.86
	Dv2	15.12	19.68	18.75	18.45	19.19	18.45	20.22	18.58	19.27	19.32
	Ev2	18.15	17.36	18.38	18.14	18.52	18.03	19.24	17.86	18.56	18.44
SET III	Av2	24.31	22.32	23.65	2.73	24.52	20.72	16.12	24.69	18.45	23.64
	Bv2	22.29	21.27	21.03	21.7	20.99	21.57	21.25	22.77	22.55	22.34
	Cv2	17.56	20.23	22.04	22.08	21.88	22.03	22.01	21.63	21.88	21.69
	Dv2	18.39	23.5	22.86	22.46	23.23	22.45	23.48	22.56	23.3	23.33
	Ev2	21.85	20.94	22.32	21.99	22.54	21.86	22.55	21.67	22.58	22.49
SET IV	Av2	14.47	19.87	16.25	8.97	14.85	12.01	9.43	15.1	10.71	13.85
	Bv2	13.48	12.48	12.36	14.13	12.35	12.6	12.47	14.4	13.47	13.17
	Cv2	16.8	11.9	12.87	13	12.77	12.85	12.85	12.66	12.77	12.69
	Dv2	10.8	13.81	13.23	13.06	13.45	13.06	14.41	13.12	13.51	13.57
	Ev2	12.99	12.31	12.97	12.83	13.15	12.77	14.01	12.67	13.21	13.08

Variation 3

a) Matrices

matrix A variation 3

$$\begin{pmatrix}
0 & 0.132 & 0.0084 & 0.0102 & 0.0484 & 0.0112 & 0.099 & 0.0165 & 0.1296 & 0.02115 \\
0.049 & 0 & 0.02289 & 0.0081 & 0.00736 & 0.0096 & 0.01265 & 0.0177 & 0.0135 & 0.04488 \\
0.01638 & 0.02136 & 0 & 0.2379 & 0.02702 & 0.00315 & 0.0288 & 0.03182 & 0.02444 & 0.00465 \\
0.00285 & 0.08475 & 0.02438 & 0 & 0.02662 & 0.02189 & 0.015 & 0.00672 & 0.00935 & 0.0407 \\
0.04032 & 0.02737 & 0.00378 & 0.216 & 0 & 0.00075 & 0.0147 & 0.02754 & 0.0286 & 0.00378 \\
0.000411 & 0.03723 & 0.00496 & 0.0264 & 0.06222 & 0 & 0.1001 & 0.07293 & 0.01416 & 0.0208 \\
0.06118 & 0.0792 & 0.00091 & 0.1365 & 0.006 & 0.00377 & 0 & 0.039 & 0.02835 & 0.03294 \\
0.06273 & 0.0236 & 0.03772 & 0.0143 & 0.0099 & 0.00136 & 0.0036 & 0 & 0.01079 & 0.0243 \\
0.03654 & 0.02076 & 0.066 & 0.1812 & 0.03358 & 0.00564 & 0.01027 & 0.0052 & 0 & 0.04416 \\
0.00486 & 0.03128 & 0.03175 & 0.034 & 0.1496 & 0.003 & 0.01978 & 0.0156 & 0.08557 & 0
\end{pmatrix}$$

matrix B variation 3

$$\begin{pmatrix}
0 & 0.132 & 0.0084 & 0.0102 & 0.0484 & 0 & 0 & 0 & 0 & 0 \\
0.049 & 0 & 0.02289 & 0.0081 & 0.00736 & 0 & 0 & 0 & 0 & 0 \\
0.01638 & 0.02136 & 0 & 0.2379 & 0.02702 & 0 & 0 & 0 & 0 & 0 \\
0.00285 & 0.08475 & 0.02438 & 0 & 0.02662 & 0 & 0 & 0 & 0 & 0 \\
0.04032 & 0.02737 & 0.00378 & 0.216 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.1001 & 0.07293 & 0.01416 & 0.0208 \\
0 & 0 & 0 & 0 & 0 & 0.00377 & 0 & 0.039 & 0.02835 & 0.03294 \\
0 & 0 & 0 & 0 & 0 & 0.00136 & 0.0036 & 0 & 0.01079 & 0.0243 \\
0 & 0 & 0 & 0 & 0 & 0.00564 & 0.01027 & 0.0052 & 0 & 0.04416 \\
0 & 0 & 0 & 0 & 0 & 0.003 & 0.01978 & 0.0156 & 0.08557 & 0
\end{pmatrix}$$

matrix C variation 3

$$\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.049 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01638 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00285 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.04032 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.000411 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.06118 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.06273 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.03654 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00486 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

matrix D variation 3

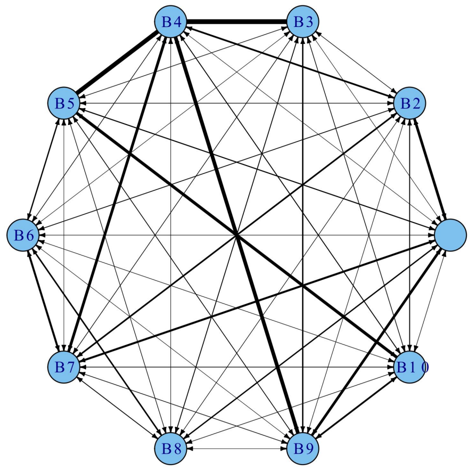
$$\begin{pmatrix}
0 & 0.132 & 0.0084 & 0.0102 & 0.0484 & 0.0112 & 0.099 & 0.0165 & 0.1296 & 0.02115 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

matrix E variation 3

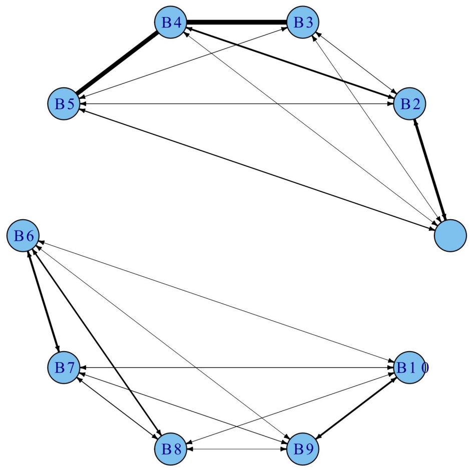
$$\begin{pmatrix}
0 & 0.132 & 0.0084 & 0.0102 & 0.0484 & 0.0112 & 0.099 & 0.0165 & 0.1296 & 0.02115 \\
0.049 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01638 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00285 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.04032 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.000411 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.06118 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.06273 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.03654 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00486 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

b) Graphs

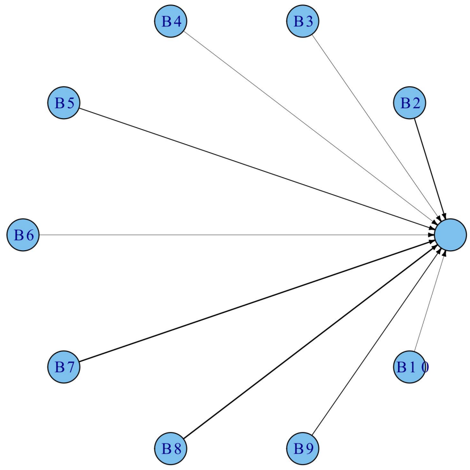
network A variation 3



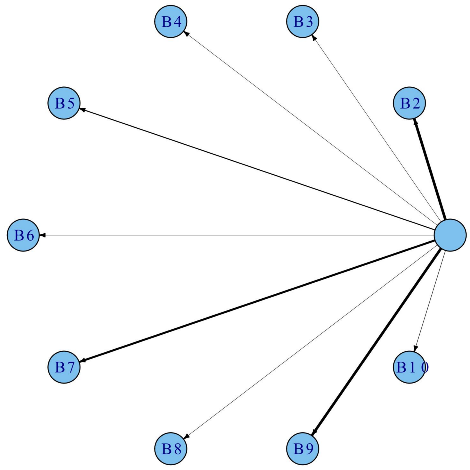
network B variation 3



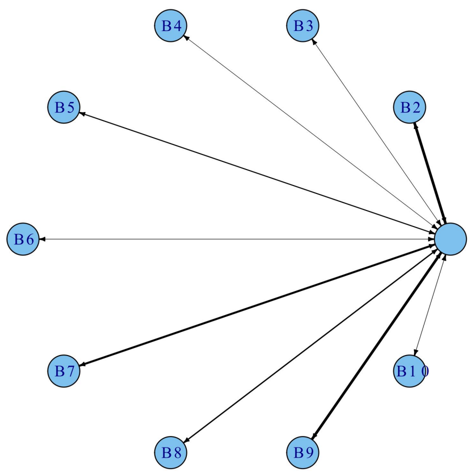
network C variation 3



network D variation 3



network E variation 3



c) Tables

Table 5.2.3.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SET I	Av3	22.12	3.36	1.83	2.9	7.4
	Bv3	23.35	5	2.74	2.31	8.15
	Cv3	23.51	6.79	2.41	2.55	8.19
	Dv3	21.66	2.2	5.29	1.3	8.18
	Ev3	23.88	7.86	2.2	2	8.35
SET II	Av3	16.18	2.66	1.34	1.68	9.37
	Bv3	17.23	4.64	1.13	1.47	9.9
	Cv3	17.56	6.82	1.33	1.36	9.82
	Dv3	15.69	1.27	2.91	1.35	9.93
	Ev3	17.89	7.77	1.3	1.27	9.95
SET III	Av3	19.53	2.68	1.58	2.2	8.87
	Bv3	20.77	4.43	1.79	1.82	9.55
	Cv3	21.18	6.5	1.78	2.07	9.52
	Dv3	18.97	1.33	3.91	2.12	9.6
	Ev3	21.67	7.61	1.58	1	9.69
SET IV	Av3	11.52	2.97	1.17	1.33	9.64
	Bv3	12.22	5.08	1.1	1.22	9.97
	Cv3	12.43	6.98	1.12	1.23	9.91
	Dv3	11.18	1.41	1.98	1.4	9.99
	Ev3	12.7	8.26	1.15	1	10

Table 5.2.3.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
SET I	Av3	23.68	20.22	23.55	8.51	23.47	23.15	22.12	22.97	22.23	23.56
	Bv3	24.05	22.82	23.38	22.57	23.6	23.35	23.91	23.27	23.92	23.94
	Cv3	19.5	23.67	24.03	23.99	23.88	23.93	23.51	23.81	23.76	24
	Dv3	21.66	23.58	24.19	24.21	24.08	24.22	24.09	24.16	23.71	24.2
	Ev3	24.12	23.97	24.11	24.05	24.05	24.07	24.09	23.88	23.71	24.03
SET II	Av3	18.33	21.43	18.13	14.21	19.85	17.09	16.18	20.15	16.36	19.21
	Bv3	18.22	19.78	17.24	18.85	17.53	17.23	17.88	19.56	18.87	19.23
	Cv3	18.76	17.66	18.17	18.23	17.98	18.29	17.56	17.84	17.79	18.24
	Dv3	15.69	19.84	18.43	18.44	18.8	18.44	19.34	18.5	19.84	18.56
	Ev3	18.22	18.54	18.09	18.16	18.27	18.23	18.08	17.89	18.64	18.26
SET III	Av3	22.27	23.02	22.09	11.65	23.37	20.72	19.53	23.6	19.71	23.02
	Bv3	22.03	22.93	20.79	21.96	21.18	20.77	21.71	22.84	22.7	22.86
	Cv3	20.63	21.3	22.12	22.24	21.84	22.31	21.18	21.62	21.53	22.26
	Dv3	18.97	23.29	22.4	22.43	22.66	22.43	23.14	22.47	23.3	22.52
	Ev3	22.03	22.28	21.94	22.07	22.16	22.14	21.93	21.67	22.39	22.21
SET IV	Av3	12.84	16.67	12.81	15.29	14.02	12.14	11.52	14.38	11.62	13.5
	Bv3	12.87	14.24	12.23	13.48	12.42	12.22	12.69	13.98	13.39	13.59
	Cv3	15.45	12.52	12.88	12.94	12.75	12.99	12.43	12.66	12.62	12.94
	Dv3	11.18	13.95	13.04	13.04	13.22	13.04	13.63	13.07	13.95	13.09
	Ev3	12.91	13.26	12.84	12.89	12.93	12.91	12.84	12.7	13.43	12.95

Variation 4

a) Matrices

matrix A variation 4

$$\begin{pmatrix}
0 & 0.087 & 0.0528 & 0.01152 & 0.06 & 0.0175 & 0.024 & 0.0198 & 0.144 & 0.0477 \\
0.193 & 0 & 0.02541 & 9e-04 & 0.02032 & 0.00288 & 0.01364 & 0.0474 & 3e-04 & 0.03552 \\
0.01974 & 0.02004 & 0 & 0.208 & 0.007 & 0.02289 & 0.00612 & 0.01892 & 0.00962 & 0.0288 \\
0.02325 & 0.1245 & 0.0368 & 0 & 0.0242 & 0.00517 & 0.0036 & 0.03402 & 0.01595 & 0.0176 \\
0.01722 & 0.04393 & 0.0378 & 0.226 & 0 & 0.018 & 0.00798 & 0.01394 & 0.0168 & 0.05166 \\
0.014796 & 0.09639 & 0.00076 & 0.06 & 0.01768 & 0 & 0.1265 & 0.03939 & 0.00576 & 0.03936 \\
0.022344 & 0.132 & 0.01495 & 0.2205 & 0.038 & 0.0169 & 0 & 0.104 & 0.02655 & 0.03807 \\
0.01558 & 0.0106 & 0.04715 & 0.1833 & 0.02565 & 0.00076 & 0.0132 & 0 & 0.01495 & 0.02055 \\
0.03276 & 0.01536 & 0.188 & 0.1764 & 0.01265 & 0.00576 & 0.00208 & 0.00702 & 0 & 0.00792 \\
0.02106 & 0.02415 & 0.011 & 0.32 & 0.1221 & 0.00225 & 0.02783 & 0.01956 & 0.01376 & 0
\end{pmatrix}$$

matrix B variation 4

$$\begin{pmatrix}
0 & 0.087 & 0.0528 & 0.01152 & 0.06 & 0 & 0 & 0 & 0 & 0 \\
0.193 & 0 & 0.02541 & 9e-04 & 0.02032 & 0 & 0 & 0 & 0 & 0 \\
0.01974 & 0.02004 & 0 & 0.208 & 0.007 & 0 & 0 & 0 & 0 & 0 \\
0.02325 & 0.1245 & 0.0368 & 0 & 0.0242 & 0 & 0 & 0 & 0 & 0 \\
0.01722 & 0.04393 & 0.0378 & 0.226 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.1265 & 0.03939 & 0.00576 & 0.03936 \\
0 & 0 & 0 & 0 & 0 & 0.0169 & 0 & 0.104 & 0.02655 & 0.03807 \\
0 & 0 & 0 & 0 & 0 & 0.00076 & 0.0132 & 0 & 0.01495 & 0.02055 \\
0 & 0 & 0 & 0 & 0 & 0.00576 & 0.00208 & 0.00702 & 0 & 0.00792 \\
0 & 0 & 0 & 0 & 0 & 0.00225 & 0.02783 & 0.01956 & 0.01376 & 0
\end{pmatrix}$$

matrix C variation 4

$$\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.193 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01974 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02325 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01722 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.014796 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.022344 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01558 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.03276 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02106 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

matrix D variation 4

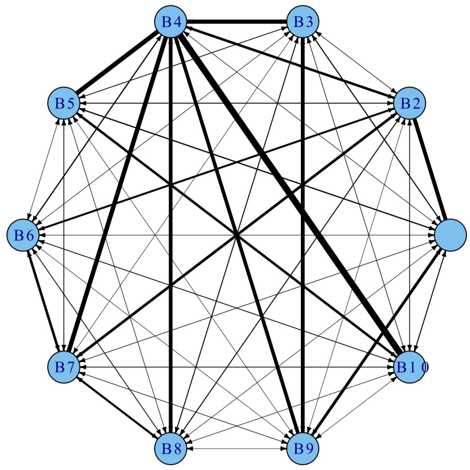
$$\begin{pmatrix}
0 & 0.087 & 0.0528 & 0.01152 & 0.06 & 0.0175 & 0.024 & 0.0198 & 0.144 & 0.0477 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

matrix E variation 4

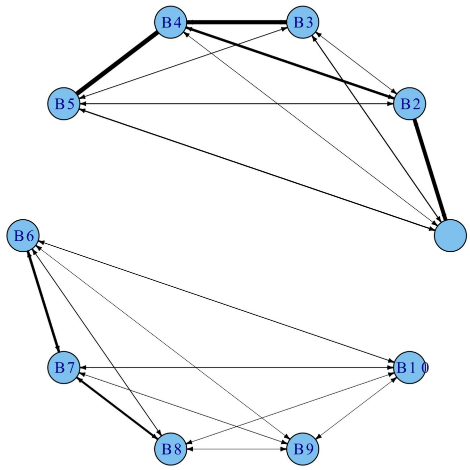
$$\begin{pmatrix}
0 & 0.087 & 0.0528 & 0.01152 & 0.06 & 0.0175 & 0.024 & 0.0198 & 0.144 & 0.0477 \\
0.193 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01974 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02325 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01722 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.014796 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.022344 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01558 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.03276 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02106 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

b) Graphs

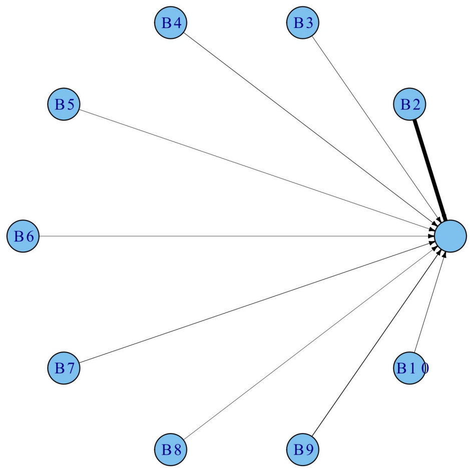
network A variation 4



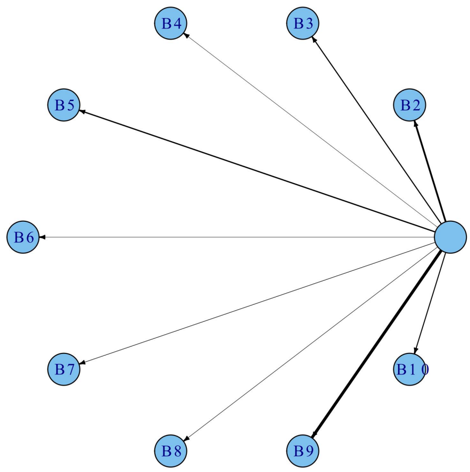
network B variation 4



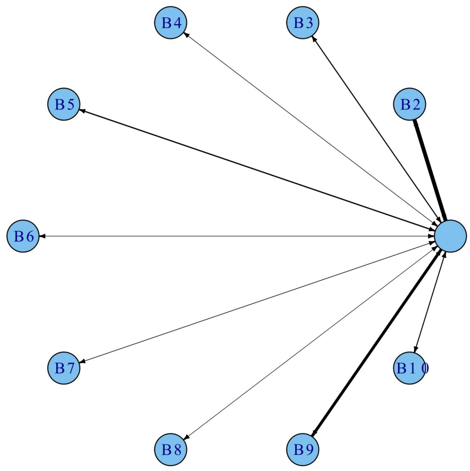
network C variation 4



network D variation 4



network E variation 4



c) Tables

Table 5.2.4.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SET I	Av4	17.89	1.77	5.45	4.54	6.66
	Bv4	23.36	5.09	2.49	2.25	8.21
	Cv4	22.1	2.71	3.81	2.12	7.86
	Dv4	21.71	2.21	5.19	2	8.2
	Ev4	22.76	3.08	2.53	2.69	8.25
SET II	Av4	12.43	1.09	3.08	2.75	8.88
	Bv4	17.21	4.72	1.25	1.46	9.91
	Cv4	16.21	2.06	2.08	1.5	9.55
	Dv4	15.76	1.26	2.85	1.53	9.92
	Ev4	16.71	2.52	1.47	1.61	9.92
SET III	Av4	15.43	1.18	3.87	3.57	8.3
	Bv4	20.75	4.54	1.74	1.67	9.56
	Cv4	19.55	1.97	2.83	1.77	9.21
	Dv4	19.05	1.35	3.85	1.92	9.61
	Ev4	20.2	2.4	1.92	2.27	9.62
SET IV	Av4	8.98	1.09	1.97	1.92	9.13
	Bv4	12.18	5.19	1.07	1.13	9.97
	Cv4	11.52	2.5	1.54	1.21	9.73
	Dv4	11.22	1.47	1.95	1.23	9.99
	Ev4	11.86	3.12	1.18	1.25	9.99

Table 5.2.4.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
SET I	Av4	22.27	20.42	18.57	1.18	23.54	22.73	17.89	21.74	21.08	23.13
	Bv4	23.43	24.01	23.91	23.92	23.49	23.43	23.36	22.3	23.79	23.7
	Cv4	11.49	22.1	23.86	23.87	23.89	23.82	23.86	23.82	23.81	23.85
	Dv4	21.71	24.15	24.25	24.19	24.29	24.16	24.18	24.19	22.8	24.21
	Ev4	22.29	22.76	24.03	23.96	23.95	24.04	23.96	24.06	23.8	24.06
SET II	Av4	22.88	23.81	23.6	3.81	20.27	17.51	12.43	23.48	15.27	18.83
	Bv4	19.2	18.02	18.17	18.32	17.34	17.3	17.21	19.77	18.67	19.05
	Cv4	17.36	16.21	18.23	18.01	18.25	18.29	18.03	18.27	17.9	18.23
	Dv4	15.76	19.08	18.78	18.44	18.84	18.48	18.54	18.5	19.61	18.73
	Ev4	18.14	16.71	18.59	18.03	18.64	18.32	18.14	18.31	18.7	18.54
SET III	Av4	25.47	25.24	23.69	2.12	24.01	21.25	15.43	25.55	18.64	22.78
	Bv4	22.56	21.88	22.06	22.09	20.94	20.86	20.75	22.38	22.55	22.56
	Cv4	15.51	19.55	22.16	21.9	22.18	22.2	21.93	22.2	21.75	22.16
	Dv4	19.05	22.91	22.77	22.42	22.84	22.49	22.55	22.51	22.9	22.73
	Ev4	21.26	20.2	22.52	21.94	22.55	22.27	22.05	22.27	22.43	22.43
SET IV	Av4	16.07	17.7	18.71	6.9	14.19	12.3	8.98	16.61	10.78	13.18
	Bv4	13.89	12.77	12.83	13.02	12.27	12.23	12.18	14.16	13.21	13.47
	Cv4	17.52	11.52	12.9	12.77	12.91	12.93	12.78	12.93	12.7	12.9
	Dv4	11.22	13.54	13.2	13.04	13.23	13.06	13.08	13.07	14	13.17
	Ev4	13.18	11.86	13.17	12.78	13.25	12.96	12.85	12.97	13.56	13.12

Variation 5

a) Matrices

matrix A variation 5

$$\begin{pmatrix}
0 & 0.04 & 0.0171 & 0.021 & 0.0512 & 0.0112 & 0.012 & 0.0576 & 0.0036 & 0.06435 \\
0.003 & 0 & 0.01848 & 0.0093 & 0.01024 & 0.02136 & 0.01859 & 0.0531 & 0.01575 & 0.01464 \\
0.02121 & 0.00324 & 0 & 0.2249 & 0.01428 & 0.03612 & 0.02592 & 0.02408 & 0.02535 & 0.0162 \\
0.00105 & 0.07875 & 0.01035 & 0 & 0.03432 & 0.00121 & 0.02016 & 0.04137 & 0.00726 & 0.02816 \\
0.00693 & 0.01725 & 0.02499 & 0.076 & 0 & 0.01815 & 0.03528 & 0.05882 & 0.0084 & 0.09387 \\
0.014522 & 0.07956 & 0.00476 & 0.1116 & 0.00986 & 0 & 0.1078 & 0.05967 & 0.00144 & 0.0208 \\
0.033516 & 0.1551 & 0.01872 & 0.186 & 0.0028 & 0.00234 & 0 & 0.075 & 0.0276 & 0.02862 \\
0.05125 & 0.0296 & 0.0697 & 0.1703 & 0.02595 & 0.00076 & 0.032 & 0 & 0.01573 & 0.0117 \\
0.0105 & 0.02328 & 0.155 & 0.2184 & 0.03358 & 0.00792 & 0.00923 & 0.01066 & 0 & 0.0372 \\
0.00648 & 0.01564 & 0.035 & 0.086 & 0.0011 & 0.0183 & 0.03289 & 0.00048 & 0.06794 & 0
\end{pmatrix}$$

matrix B variation 5

$$\begin{pmatrix}
0 & 0.04 & 0.0171 & 0.021 & 0.0512 & 0 & 0 & 0 & 0 & 0 \\
0.003 & 0 & 0.01848 & 0.0093 & 0.01024 & 0 & 0 & 0 & 0 & 0 \\
0.02121 & 0.00324 & 0 & 0.2249 & 0.01428 & 0 & 0 & 0 & 0 & 0 \\
0.00105 & 0.07875 & 0.01035 & 0 & 0.03432 & 0 & 0 & 0 & 0 & 0 \\
0.00693 & 0.01725 & 0.02499 & 0.076 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.1078 & 0.05967 & 0.00144 & 0.0208 \\
0 & 0 & 0 & 0 & 0 & 0.00234 & 0 & 0.075 & 0.0276 & 0.02862 \\
0 & 0 & 0 & 0 & 0 & 0.00076 & 0.032 & 0 & 0.01573 & 0.0117 \\
0 & 0 & 0 & 0 & 0 & 0.00792 & 0.00923 & 0.01066 & 0 & 0.0372 \\
0 & 0 & 0 & 0 & 0 & 0.0183 & 0.03289 & 0.00048 & 0.06794 & 0
\end{pmatrix}$$

matrix C variation 5

$$\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.003 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02121 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00105 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00693 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.014522 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.033516 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.05125 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.0105 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00648 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

matrix D variation 5

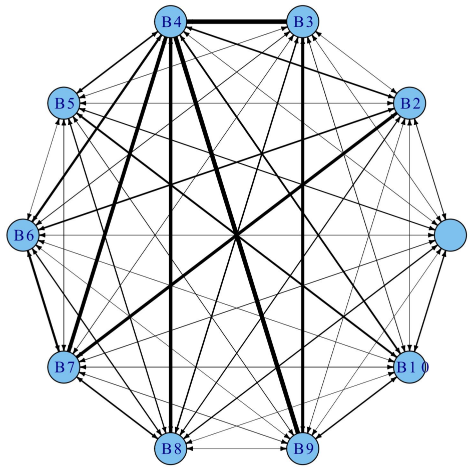
$$\begin{pmatrix} 0 & 0.04 & 0.0171 & 0.021 & 0.0512 & 0.0112 & 0.012 & 0.0576 & 0.0036 & 0.06435 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

matrix E variation 5

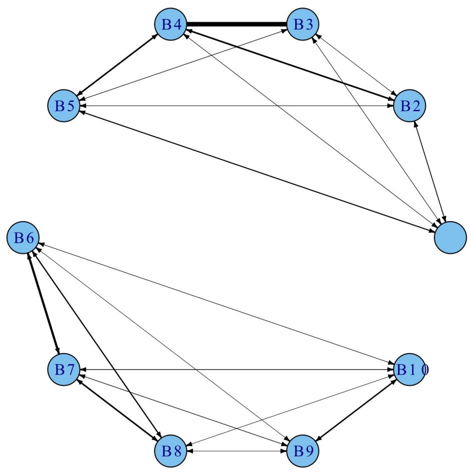
$$\begin{pmatrix} 0 & 0.04 & 0.0171 & 0.021 & 0.0512 & 0.0112 & 0.012 & 0.0576 & 0.0036 & 0.06435 \\ 0.003 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.02121 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.00105 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.00693 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.014522 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.033516 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.05125 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.0105 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.00648 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

b) Graphs

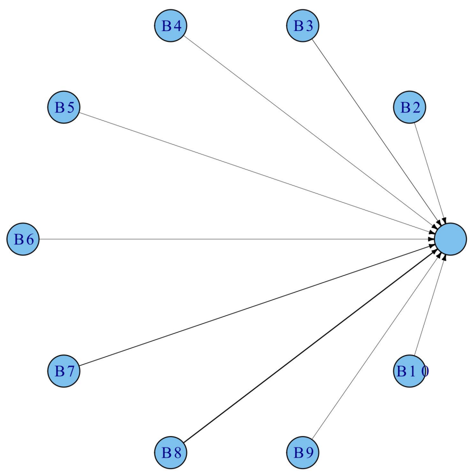
network A variation 5



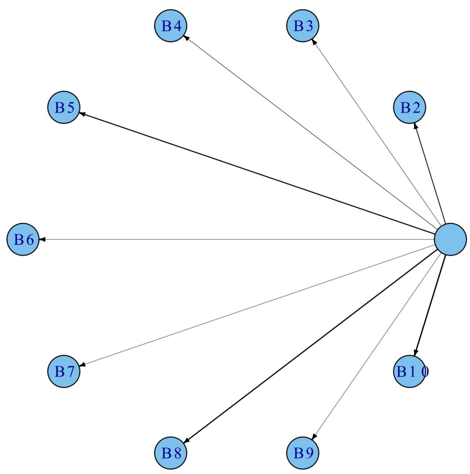
network B variation 5



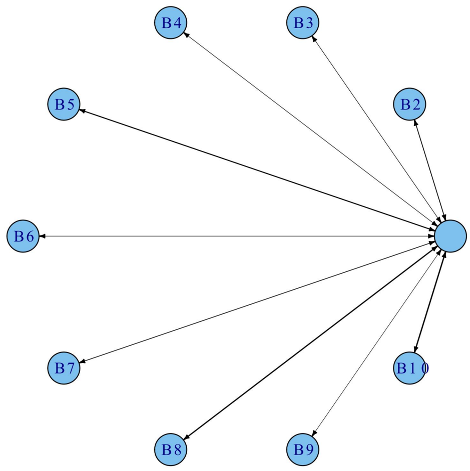
network C variation 5



network D variation 5



network E variation 5



c) Tables

Table 5.2.5.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SET I	Av5	19.67	2.41	2.49	5.87	6.73
	Bv5	23.46	5.35	1.46	2.19	8.2
	Cv5	23.78	7.81	1.98	2.29	8.29
	Dv5	22.82	3.12	3.46	2.16	8.33
	Ev5	23.87	7.84	1.71	2.4	8.33
SET II	Av5	13.9	1.71	1.67	3.45	8.93
	Bv5	17.43	5.17	1.27	1.29	9.91
	Cv5	17.82	7.68	1.5	1.48	9.91
	Dv5	16.78	2.59	1.94	1.29	9.95
	Ev5	17.92	7.74	1.18	1.39	9.95
SET III	Av5	17.03	1.78	2.11	4.45	8.32
	Bv5	21	4.86	1.77	1.88	9.59
	Cv5	21.56	7.46	1.8	1.81	9.63
	Dv5	20.24	2.46	2.61	1.89	9.68
	Ev5	21.68	7.61	1.67	1.73	9.68
SET IV	Av5	9.97	1.74	1.27	2.22	9.25
	Bv5	12.36	5.58	1.21	1.13	9.98
	Cv5	12.66	8.06	1.18	1.3	9.97
	Dv5	11.95	3.33	1.46	1.09	10
	Ev5	12.73	8.22	1.19	1.27	10

Table 5.2.5.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
SET I	Av5	23.36	17.48	20.77	2.2	23.49	23	20.21	22	19.67	22.71
	Bv5	23.75	23.46	23.46	23.71	24.01	23.46	23.85	23.36	24.02	23.88
	Cv5	21.91	24	24.01	23.88	24	24.09	23.78	23.81	24.02	24
	Dv5	22.82	24.17	24.18	24.22	24.17	24.19	24.18	24.13	24.16	24.08
	Ev5	23.89	23.95	24.05	24.07	23.88	24.02	23.87	24.02	24.09	23.69
SET II	Av5	19.18	24.02	23.19	7.91	19.39	17.6	14.46	22.7	13.9	21.95
	Bv5	17.74	19.38	17.43	18.78	18.66	17.45	17.9	19.47	18.54	18.77
	Cv5	19.36	18.17	18.06	18.19	18.18	18.1	17.82	17.91	18.07	18.19
	Dv5	16.78	18.46	18.32	18.34	18.57	18.29	18.29	18.62	18.28	18.61
	Ev5	17.95	18.54	18.21	18.35	18.6	18.21	17.92	18.3	18.12	18.72
SET III	Av5	23.27	22.72	24.68	4.35	23.42	21.35	17.72	24.97	17.03	25
	Bv5	21.46	22.93	21	22.31	22.51	21.03	21.7	22.69	22.52	22.65
	Cv5	22.23	22.13	21.93	22.16	22.11	22.01	21.56	21.69	21.93	22.12
	Dv5	20.24	22.51	22.32	22.36	22.53	22.29	22.3	22.49	22.22	22.47
	Ev5	21.71	22.35	22.07	22.27	22.39	22.07	21.68	22.14	21.95	22.39
SET IV	Av5	13.43	20.72	16.81	12.09	13.61	12.4	10.36	16.13	9.97	15.64
	Bv5	12.58	14.07	12.36	13.32	13.23	12.37	12.71	14.02	13.16	13.33
	Cv5	14.43	12.9	12.84	12.94	12.9	12.87	12.66	12.72	12.84	12.9
	Dv5	11.95	13.1	13	13.02	13.16	12.98	12.98	13.2	12.96	13.25
	Ev5	12.75	13.17	12.93	13.07	13.26	12.93	12.73	13.01	12.87	13.39

Variation 6

a) Matrices

matrix A variation 6

$$\begin{pmatrix}
0 & 0.016 & 0.0444 & 0.00612 & 0.0404 & 0.0109 & 0.058 & 0.0075 & 0.0408 & 0.0738 \\
0.01 & 0 & 0.00021 & 0.0099 & 0.02848 & 0.01752 & 0.00462 & 0.0489 & 0.02595 & 0.04368 \\
0.02247 & 0.01284 & 0 & 0.2496 & 0.0273 & 0.04074 & 0.01854 & 0.07482 & 0.013 & 0.027 \\
0.01395 & 0.11175 & 0.0046 & 0 & 0.01848 & 0.00638 & 0.01188 & 0.01176 & 0.01078 & 0.00308 \\
0.03171 & 0.01955 & 0.01575 & 0.104 & 0 & 0.0252 & 0.03003 & 0.04624 & 0.0252 & 0.10017 \\
0.003699 & 0.06936 & 0.00176 & 0.0636 & 0.00102 & 0 & 0.1727 & 0.01209 & 0.01764 & 0.04096 \\
0.000532 & 0.1672 & 0.01703 & 0.051 & 0.0148 & 0.00663 & 0 & 0.104 & 0.02625 & 0.05346 \\
0.00615 & 0.0118 & 0.01312 & 0.2314 & 0.00855 & 0.0027 & 0.0132 & 0 & 0.01157 & 0.02325 \\
0.01869 & 0.02124 & 0.1 & 0.0792 & 0.03887 & 0.0084 & 0.01937 & 0.01807 & 0 & 0.02952 \\
0.04644 & 0.03726 & 0.02425 & 0.224 & 0.0011 & 0.02025 & 0.03634 & 0.00396 & 0.0817 & 0
\end{pmatrix}$$

matrix B variation 6

$$\begin{pmatrix}
0 & 0.016 & 0.0444 & 0.00612 & 0.0404 & 0 & 0 & 0 & 0 & 0 \\
0.01 & 0 & 0.00021 & 0.0099 & 0.02848 & 0 & 0 & 0 & 0 & 0 \\
0.02247 & 0.01284 & 0 & 0.2496 & 0.0273 & 0 & 0 & 0 & 0 & 0 \\
0.01395 & 0.11175 & 0.0046 & 0 & 0.01848 & 0 & 0 & 0 & 0 & 0 \\
0.03171 & 0.01955 & 0.01575 & 0.104 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.1727 & 0.01209 & 0.01764 & 0.04096 \\
0 & 0 & 0 & 0 & 0 & 0.00663 & 0 & 0.104 & 0.02625 & 0.05346 \\
0 & 0 & 0 & 0 & 0 & 0.0027 & 0.0132 & 0 & 0.01157 & 0.02325 \\
0 & 0 & 0 & 0 & 0 & 0.0084 & 0.01937 & 0.01807 & 0 & 0.02952 \\
0 & 0 & 0 & 0 & 0 & 0.02025 & 0.03634 & 0.00396 & 0.0817 & 0
\end{pmatrix}$$

matrix C variation 6

$$\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02247 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01395 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.03171 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.003699 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.000532 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00615 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01869 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.04644 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

matrix D variation 6

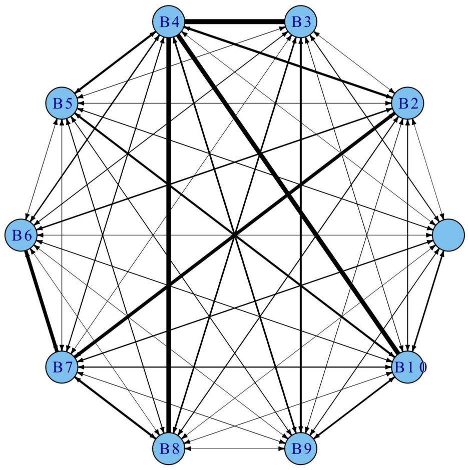
$$\begin{pmatrix} 0 & 0.016 & 0.0444 & 0.00612 & 0.0404 & 0.0109 & 0.058 & 0.0075 & 0.0408 & 0.0738 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

matrix E variation 6

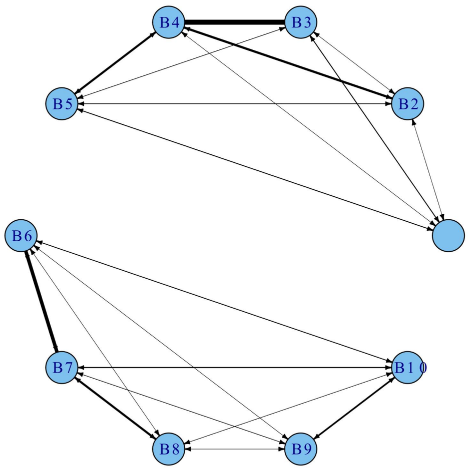
$$\begin{pmatrix} 0 & 0.016 & 0.0444 & 0.00612 & 0.0404 & 0.0109 & 0.058 & 0.0075 & 0.0408 & 0.0738 \\ 0.01 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.02247 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.01395 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.03171 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.003699 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.000532 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.00615 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.01869 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0.04644 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

b) Graphs

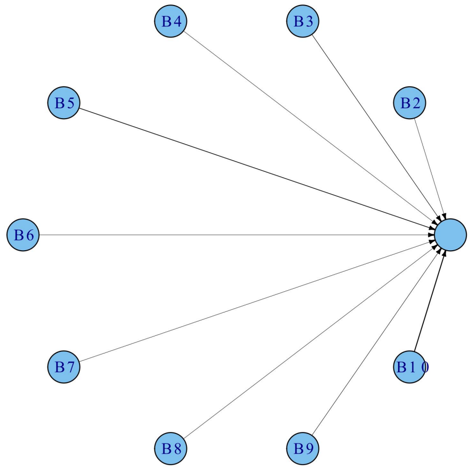
network A variation 6



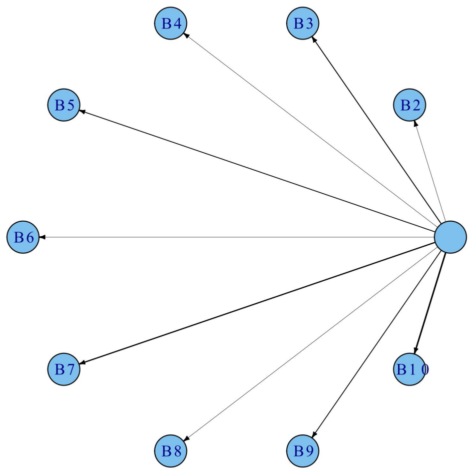
network B variation 6



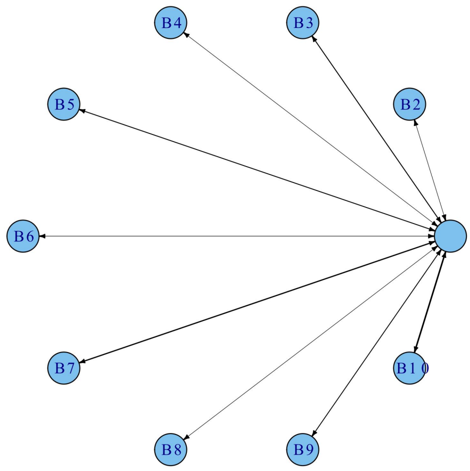
network C variation 6



network D variation 6



network E variation 6



c) Tables

Table 5.2.6.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SET I	Av6	21.92	2.96	2.43	2.09	7.27
	Bv6	23.02	3.89	2.39	2.12	8.18
	Cv6	23.87	8.47	2	2.28	8.29
	Dv6	22.69	2.94	3.66	1.5	8.33
	Ev6	23.78	7.33	2.07	2.3	8.35
SET II	Av6	15.96	2.29	1.51	1.44	9.29
	Bv6	16.98	3.5	1.49	1.18	9.91
	Cv6	17.94	8.41	1.32	1.59	9.91
	Dv6	16.7	2.33	2.03	1.75	9.95
	Ev6	17.83	7.18	1.4	1.46	9.95
SET III	Av6	19.27	2.29	1.85	1.64	8.72
	Bv6	20.48	3.4	1.79	1.52	9.56
	Cv6	21.72	8.29	1.58	1.87	9.63
	Dv6	20.15	2.27	2.74	1.08	9.68
	Ev6	21.56	6.97	1.71	1.79	9.68
SET IV	Av6	11.34	2.57	1.18	1.13	9.63
	Bv6	12.05	4.11	1.18	1.09	9.98
	Cv6	12.73	8.68	1.21	1.33	9.96
	Dv6	11.86	2.95	1.5	1	10
	Ev6	12.67	7.75	1.21	1.14	10

Table 5.2.6.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
SET I	Av6	23.6	16.88	23.1	9.13	23.41	23.43	21.92	20.89	22.57	22.85
	Bv6	24.1	23.22	23.02	23.64	24.09	23.37	23.81	22.98	24.11	23.86
	Cv6	21.98	24	24	23.95	23.91	23.86	23.8	23.91	23.87	23.87
	Dv6	22.69	24.22	24.21	24.19	24.25	24.24	24.19	24.21	24.25	24.16
	Ev6	23.78	24.03	24.09	23.99	24.02	24.06	23.78	24.04	24.03	23.97
SET II	Av6	18.05	21.75	17.53	14.81	17.9	17.37	15.96	21.31	16.58	19.59
	Bv6	18.35	19.66	16.98	18.55	18.37	17.24	17.66	19.87	18.59	19.13
	Cv6	19.38	18.09	18.08	18.04	18.02	18.23	18.26	18.23	17.99	17.94
	Dv6	16.7	18.33	18.53	18.3	18.48	18.3	18.65	18.31	18.49	18.72
	Ev6	17.83	18.19	18.4	18.09	18.29	18.26	18.67	18.23	18.25	18.46
SET III	Av6	21.92	21.54	21.26	12.15	21.77	20.94	19.27	23.04	20.08	22.53
	Bv6	22.38	22.85	20.48	22.09	22.36	20.79	21.32	22.82	22.5	22.61
	Cv6	22.28	21.92	21.9	21.85	21.82	22.18	22.17	22.14	21.78	21.72
	Dv6	20.15	22.36	22.54	22.25	22.5	22.29	22.5	22.26	22.51	22.49
	Ev6	21.56	22.05	22.23	21.92	22.14	22.17	22.39	22.11	22.11	22.27
SET IV	Av6	12.8	18.43	12.45	16.2	12.65	12.3	11.34	15.8	11.78	13.83
	Bv6	13.01	14.2	12.05	13.16	13.02	12.22	12.54	14.25	13.14	13.53
	Cv6	14.46	12.84	12.83	12.81	12.79	12.93	12.94	12.9	12.77	12.73
	Dv6	11.86	13.01	13.13	12.98	13.1	12.99	13.2	12.98	13.1	13.3
	Ev6	12.67	12.92	13.09	12.85	12.99	12.96	13.4	12.94	12.97	13.17

Variation 7

a) Matrices

matrix A variation 7

$$\begin{pmatrix}
0 & 0.086 & 0.0489 & 0.003 & 0.0236 & 0.0197 & 0.017 & 0.0258 & 0.0984 & 0.06165 \\
0.002 & 0 & 0.01008 & 0.0035 & 0.0048 & 0.00456 & 0.00154 & 0.0075 & 0.0243 & 0.02784 \\
0.03108 & 0.02292 & 0 & 0.0078 & 0.00196 & 0.00441 & 0.0288 & 0.0817 & 0.00429 & 0.0216 \\
0.01245 & 0.04575 & 0.0391 & 0 & 0.02376 & 0.01474 & 0.02172 & 0.03339 & 0.01133 & 0.01232 \\
0.00336 & 0.04002 & 0.01071 & 0.332 & 0 & 0.02535 & 0.01722 & 0.02244 & 0.0096 & 0.07497 \\
0.02603 & 0.0918 & 0.00768 & 0.228 & 0.01768 & 0 & 0.1243 & 0.02106 & 0.01296 & 0.05792 \\
0.064372 & 0.0737 & 0.02509 & 0.2835 & 0.0226 & 0.02444 & 0 & 0.191 & 0.01755 & 0.0513 \\
0.04797 & 0.0112 & 0.05125 & 0.2561 & 0.02865 & 0.00106 & 0.0098 & 0 & 0.00975 & 0.0177 \\
0.02478 & 0.0162 & 0.064 & 0.096 & 0.00506 & 0.02256 & 0.01963 & 0.01534 & 0 & 0.03504 \\
0.04266 & 0.01058 & 0.03225 & 0.042 & 0.1419 & 0.0252 & 0.00736 & 0.01752 & 0.07998 & 0
\end{pmatrix}$$

matrix B variation 7

$$\begin{pmatrix}
0 & 0.086 & 0.0489 & 0.003 & 0.0236 & 0 & 0 & 0 & 0 & 0 \\
0.002 & 0 & 0.01008 & 0.0035 & 0.0048 & 0 & 0 & 0 & 0 & 0 \\
0.03108 & 0.02292 & 0 & 0.0078 & 0.00196 & 0 & 0 & 0 & 0 & 0 \\
0.01245 & 0.04575 & 0.0391 & 0 & 0.02376 & 0 & 0 & 0 & 0 & 0 \\
0.00336 & 0.04002 & 0.01071 & 0.332 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.1243 & 0.02106 & 0.01296 & 0.05792 \\
0 & 0 & 0 & 0 & 0 & 0.02444 & 0 & 0.191 & 0.01755 & 0.0513 \\
0 & 0 & 0 & 0 & 0 & 0.00106 & 0.0098 & 0 & 0.00975 & 0.0177 \\
0 & 0 & 0 & 0 & 0 & 0.02256 & 0.01963 & 0.01534 & 0 & 0.03504 \\
0 & 0 & 0 & 0 & 0 & 0.0252 & 0.00736 & 0.01752 & 0.07998 & 0
\end{pmatrix}$$

matrix C variation 7

$$\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.002 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.03108 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01245 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00336 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02603 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.064372 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.04797 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02478 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.04266 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

matrix D variation 7

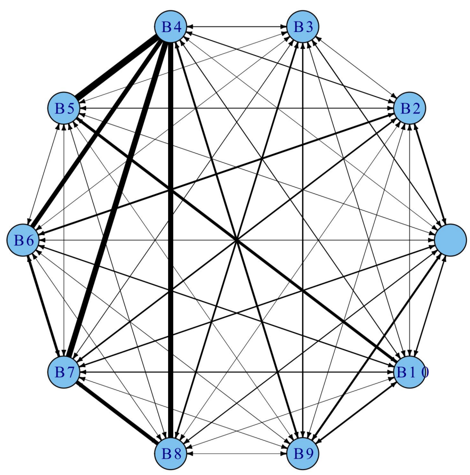
$$\begin{pmatrix}
0 & 0.086 & 0.0489 & 0.003 & 0.0236 & 0.0197 & 0.017 & 0.0258 & 0.0984 & 0.06165 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

matrix E variation 7

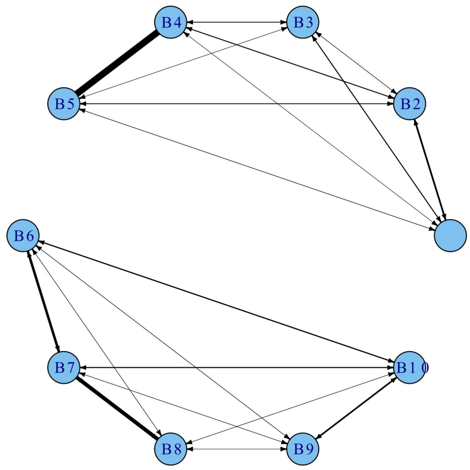
$$\begin{pmatrix}
0 & 0.086 & 0.0489 & 0.003 & 0.0236 & 0.0197 & 0.017 & 0.0258 & 0.0984 & 0.06165 \\
0.002 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.03108 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01245 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.00336 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02603 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.064372 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.04797 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.02478 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.04266 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}$$

b) Graphs

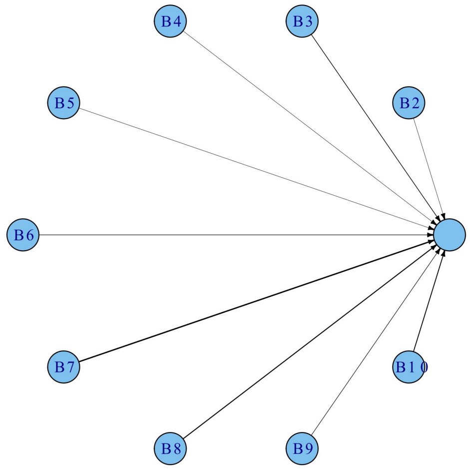
network A variation 7



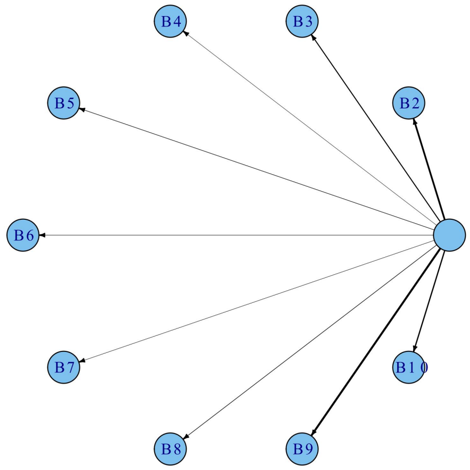
network B variation 7



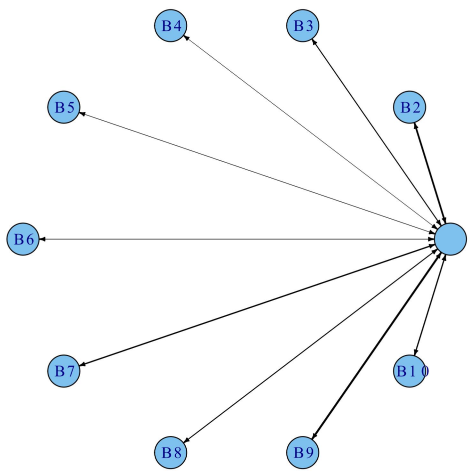
network C variation 7



network D variation 7



network E variation 7



c) Tables

Table 5.2.7.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SET I	Av7	15.66	1.6	11.13	2.84	6.61
	Bv7	22.19	3.18	2.62	2.62	7.84
	Cv7	23.48	6.36	2.39	2	8.21
	Dv7	22.09	2.47	4.35	2.27	8.26
	Ev7	23.56	6.08	1.95	2.22	8.32
SET II	Av7	10.84	1.01	6.61	1.82	8.87
	Bv7	16.3	2.46	1.45	1.52	9.76
	Cv7	17.55	6.47	1.44	3	9.85
	Dv7	16.25	1.63	2.37	1.49	9.94
	Ev7	17.63	6.08	1.3	1.39	9.94
SET III	Av7	13.34	1.1	8.52	2.39	8.26
	Bv7	19.66	2.46	1.87	1.99	9.35
	Cv7	21.14	6.03	1.94	1.7	9.54
	Dv7	19.59	1.61	3.2	1.97	9.65
	Ev7	21.23	5.65	1.69	1.92	9.67
SET IV	Av7	7.95	1	4.21	1.36	9.2
	Bv7	11.57	2.82	1.25	1.2	9.91
	Cv7	12.42	6.65	1.19	1.17	9.93
	Dv7	11.55	2.04	1.7	1.15	10
	Ev7	12.5	6.56	1.1	1.11	10

Table 5.2.7.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
SET I	Av7	23.32	18.74	21.66	1.46	23.07	22.28	15.66	19.02	22.75	22.29
	Bv7	23.74	22.54	23.59	23.16	22.74	23.66	22.19	18	23.76	23.18
	Cv7	20.04	23.84	23.92	23.95	23.83	23.95	23.48	23.84	23.82	23.84
	Dv7	22.09	24.07	24.16	24.08	24.16	24.17	24.13	24.19	23.89	24.12
	Ev7	23.96	23.76	24.06	23.98	24.02	24.07	23.56	23.99	23.9	24.08
SET II	Av7	20.7	24.51	22.76	5.12	18.6	17.35	10.84	24.58	18.08	21.56
	Bv7	17.85	20.5	19.62	18.45	16.67	17.89	16.3	20.63	18.35	19.82
	Cv7	19.38	18.25	18.05	18.07	18.25	18.07	17.55	17.92	17.9	17.95
	Dv7	16.25	18.97	18.65	18.33	18.43	18.4	18.41	18.45	19.08	18.73
	Ev7	18.25	18.75	18.38	18.07	18.37	18.17	17.63	18.09	18.59	18.39
SET III	Av7	24.38	24.49	25.08	2.76	22.42	20.99	13.34	24.25	21.85	24.61
	Bv7	21.74	23.54	23.32	22.05	20.17	21.82	19.66	21.65	22.39	23.31
	Cv7	20.98	22.25	21.88	21.95	22.26	21.95	21.14	21.72	21.7	21.78
	Dv7	19.59	22.82	22.62	22.3	22.46	22.4	22.4	22.5	22.69	22.66
	Ev7	22.07	22.44	22.25	21.9	22.24	22.08	21.23	21.93	22.38	22.27
SET IV	Av7	14.5	19.54	16.14	9.27	13.08	12.16	7.95	19.73	12.68	15.07
	Bv7	12.65	15.13	13.97	13.12	11.84	12.63	11.57	16.41	12.92	14.13
	Cv7	15.35	12.96	12.79	12.82	12.98	12.82	12.42	12.71	12.71	12.74
	Dv7	11.55	13.43	13.15	13.01	13.05	13.03	13.03	13.05	13.53	13.22
	Ev7	12.96	13.62	13.02	12.82	13.01	12.89	12.5	12.84	13.34	13.05

5.3 Part Three: Analysis of incomplete network structures

In an upcoming step we used matrix A as basis and multiplied it with randomly generated matrices consisting of 0 and 1 to simulate network systems which are not fully interconnected any more. We generated three different approaches where we started with the fully interconnected system and thinned out, that means our initial system got more and more incomplete from matrix A.0 to A.7.[9] In each of the three approaches we had 8 matrices representing network systems with different decreasing degrees of interconnectedness.
We used these matrices again in our array setting of ϵ and γ. Our analysis indicators were as before

maxCol refers to the bank which issued most of the debt

minCol refers to the bank which issued fewest

maxRow refers to the bank which held the most debt

minRow refers to the bank which held the fewest debt

and the ratio of issued to held debt.

We observed a weak tendency that in set 1[10], where banks react fast on asset prices and the market is highly liquid, those banks defaulted earlier that issued the most debt, whereas in set 2 - 4 those banks that held the most debt defaulted earlier. These results were similar to those found in part two. Furthermore we focused on the steps after this first default. Here we have to distinguish between those networks which were highly interconnected, e.g A.0 - A.4,[11] and those structures with low interconnection.
In the case of low interconnectedness we observed a similar behaviour of the banks in set 2 - 4. Those banks which held the most debt defaulted first

[9] respectively for B.0 to B.7 and C.0 to C.7

[10] $\epsilon = 0.2 \gamma = 0.3$

[11] B.0 - B.4, C.0 - C.4

and in the aftermath those banks which held the most debt in the remaining systems defaulted successively. In set 1 those loosely interconnected systems reacted a little bit different in the beginning. Here we saw, that those banks which initially issued the most debt defaulted first more often. In the case of second and third default we saw a weak tendency to those banks which held the most debt default next.

The analysis of those networks which were highly interconnected was a little bit challenging. We observed that in set 1 - 3 and for matrices A.0 - A.4[12] the banks almost always defaulted first which issued the most debt. For the upcoming defaults we were not able to conclude anything. In some cases we observed that those banks which issued most debt in the remaining system defaulted next, whereas in some other cases those banks which held most debt defaulted next. In set 4 we were not able to argue why a certain bank defaulted first, we observed no special rule.

[12] B.0 -B.4, C.0 - C.4

Matrices A.0 - A.7

a) Matrices

matrix A

$$
\begin{pmatrix}
0 & 0.1 & 0.03 & 0.012 & 0.04 & 0.01 & 0.1 & 0.03 & 0.12 & 0.045 \\
0.1 & 0 & 0.021 & 0.01 & 0.016 & 0.012 & 0.011 & 0.03 & 0.015 & 0.024 \\
0.021 & 0.012 & 0 & 0.13 & 0.014 & 0.021 & 0.018 & 0.043 & 0.013 & 0.015 \\
0.015 & 0.075 & 0.023 & 0 & 0.022 & 0.011 & 0.012 & 0.021 & 0.011 & 0.022 \\
0.021 & 0.023 & 0.021 & 0.2 & 0 & 0.015 & 0.021 & 0.034 & 0.02 & 0.063 \\
0.0137 & 0.051 & 0.004 & 0.12 & 0.034 & 0 & 0.11 & 0.039 & 0.012 & 0.032 \\
0.0532 & 0.11 & 0.013 & 0.15 & 0.02 & 0.013 & 0 & 0.1 & 0.015 & 0.027 \\
0.041 & 0.02 & 0.041 & 0.13 & 0.015 & 0.002 & 0.02 & 0 & 0.013 & 0.015 \\
0.021 & 0.012 & 0.1 & 0.12 & 0.023 & 0.012 & 0.013 & 0.013 & 0 & 0.024 \\
0.054 & 0.023 & 0.025 & 0.2 & 0.11 & 0.015 & 0.023 & 0.012 & 0.043 & 0
\end{pmatrix}
$$

matrix A.1

$$
\begin{pmatrix}
0 & 0.1 & 0.03 & 0.012 & 0 & 0 & 0.1 & 0.03 & 0 & 0 \\
0.1 & 0 & 0.021 & 0.01 & 0 & 0 & 0 & 0.03 & 0.015 & 0.024 \\
0 & 0.012 & 0 & 0.13 & 0 & 0.021 & 0 & 0.043 & 0 & 0 \\
0.015 & 0.075 & 0.023 & 0 & 0 & 0 & 0 & 0 & 0.011 & 0.022 \\
0.021 & 0 & 0.021 & 0 & 0 & 0.015 & 0.021 & 0 & 0 & 0 \\
0 & 0.051 & 0.004 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.0532 & 0 & 0.013 & 0.15 & 0 & 0 & 0 & 0 & 0.015 & 0.027 \\
0.041 & 0 & 0.041 & 0 & 0 & 0.002 & 0.02 & 0 & 0.013 & 0 \\
0.021 & 0 & 0 & 0 & 0 & 0.012 & 0.013 & 0 & 0 & 0 \\
0 & 0.023 & 0 & 0 & 0.11 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

matrix A.2

$$
\begin{pmatrix}
0 & 0.1 & 0.03 & 0.012 & 0 & 0.01 & 0.1 & 0.03 & 0.12 & 0 \\
0 & 0 & 0 & 0.01 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0.018 & 0.043 & 0.013 & 0.015 \\
0.015 & 0.075 & 0 & 0 & 0 & 0 & 0 & 0.021 & 0 & 0.022 \\
0 & 0.023 & 0 & 0.2 & 0 & 0 & 0 & 0.034 & 0.02 & 0.063 \\
0.0137 & 0 & 0.004 & 0.12 & 0 & 0 & 0.11 & 0.039 & 0 & 0 \\
0.0532 & 0.11 & 0 & 0.15 & 0 & 0.013 & 0 & 0 & 0 & 0 \\
0.041 & 0.02 & 0 & 0.13 & 0 & 0 & 0 & 0 & 0.013 & 0.015 \\
0 & 0.012 & 0 & 0.12 & 0 & 0 & 0 & 0.013 & 0 & 0 \\
0 & 0 & 0.025 & 0 & 0.11 & 0 & 0 & 0.012 & 0.043 & 0
\end{pmatrix}
$$

matrix A.3

$$
\begin{pmatrix}
0 & 0 & 0 & 0.012 & 0.04 & 0 & 0.1 & 0.03 & 0.12 & 0 \\
0.1 & 0 & 0.021 & 0 & 0.016 & 0 & 0.011 & 0 & 0 & 0 \\
0.021 & 0 & 0 & 0.13 & 0 & 0.021 & 0.018 & 0 & 0 & 0 \\
0.015 & 0.075 & 0.023 & 0 & 0.022 & 0 & 0.012 & 0 & 0 & 0.022 \\
0 & 0 & 0 & 0 & 0 & 0.015 & 0.021 & 0.034 & 0 & 0.063 \\
0.0137 & 0.051 & 0 & 0 & 0.034 & 0 & 0.11 & 0.039 & 0 & 0.032 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.1 & 0 & 0.027 \\
0 & 0 & 0.041 & 0.13 & 0.015 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.012 & 0.1 & 0 & 0.023 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.023 & 0.025 & 0.2 & 0.11 & 0.015 & 0.023 & 0.012 & 0.043 & 0
\end{pmatrix}
$$

matrix A.4

$$
\begin{pmatrix}
0 & 0.1 & 0.03 & 0.012 & 0 & 0 & 0.1 & 0.03 & 0 & 0 \\
0 & 0 & 0 & 0.01 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0 & 0.043 & 0 & 0 \\
0.015 & 0.075 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.022 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0.004 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.0532 & 0 & 0 & 0.15 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.041 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.013 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.11 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

matrix A.5

$$
\begin{pmatrix}
0 & 0 & 0 & 0.012 & 0 & 0 & 0.1 & 0.03 & 0 & 0 \\
0.1 & 0 & 0.021 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0.021 & 0 & 0 & 0 & 0 \\
0.015 & 0.075 & 0.023 & 0 & 0 & 0 & 0 & 0 & 0 & 0.022 \\
0 & 0 & 0 & 0 & 0 & 0.015 & 0.021 & 0 & 0 & 0 \\
0 & 0.051 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.027 \\
0 & 0 & 0.041 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.023 & 0 & 0 & 0.11 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

matrix A.6

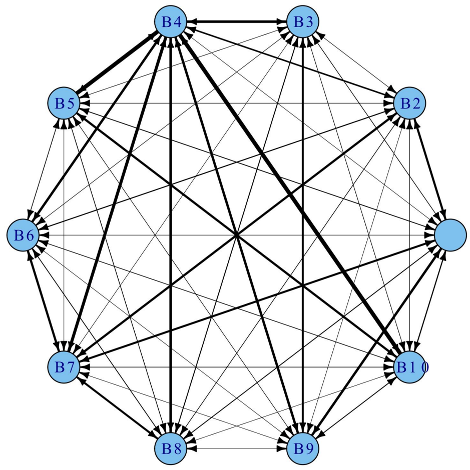
$$
\begin{pmatrix}
0 & 0 & 0 & 0.012 & 0 & 0 & 0.1 & 0.03 & 0.12 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0.018 & 0 & 0 & 0 \\
0.015 & 0.075 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.022 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.034 & 0 & 0.063 \\
0.0137 & 0 & 0 & 0 & 0 & 0 & 0.11 & 0.039 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.130 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.012 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0.025 & 0 & 0.11 & 0 & 0 & 0.012 & 0.043 & 0
\end{pmatrix}
$$

matrix A.7

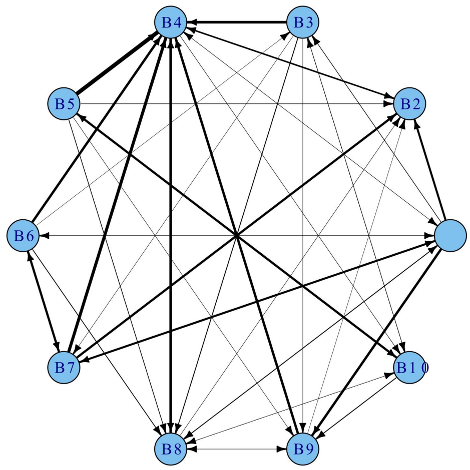
$$
\begin{pmatrix}
0 & 0 & 0 & 0.012 & 0 & 0 & 0.1 & 0.03 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.015 & 0.075 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.022 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.11 & 0 & 0 & 0 & 0 & 0
\end{pmatrix}
$$

b) Graphs

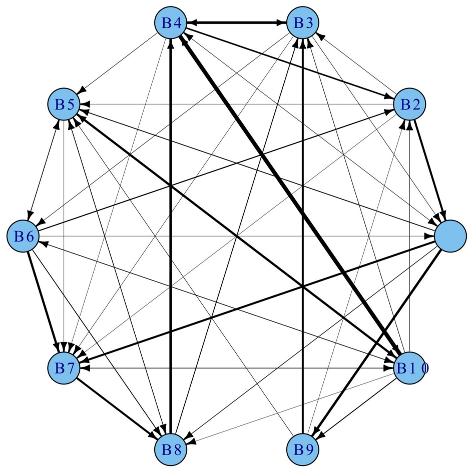
network A.0



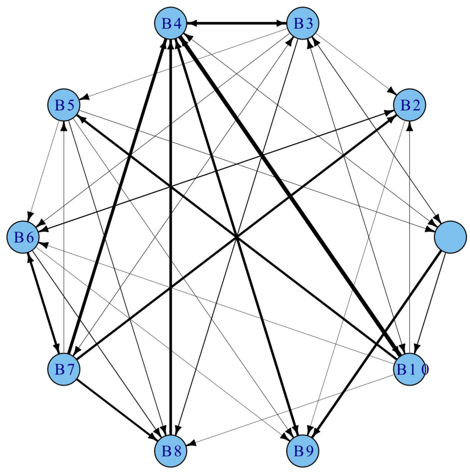
network A.1



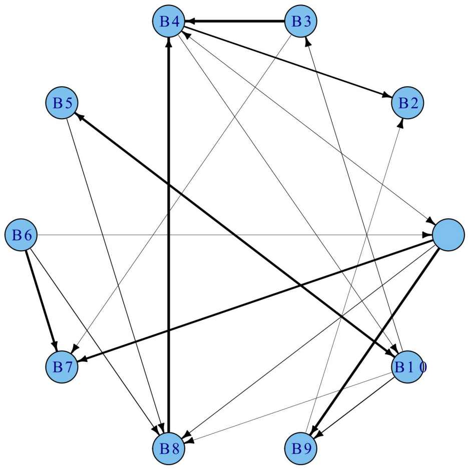
network A.2



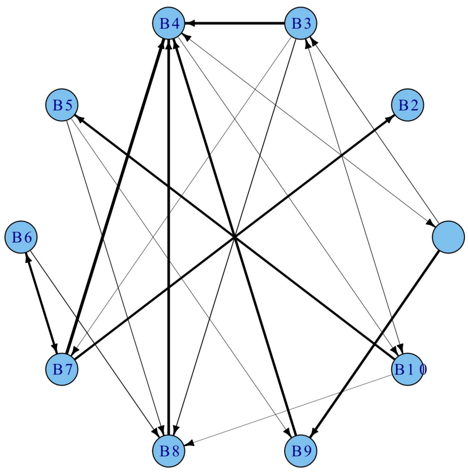
network A.3



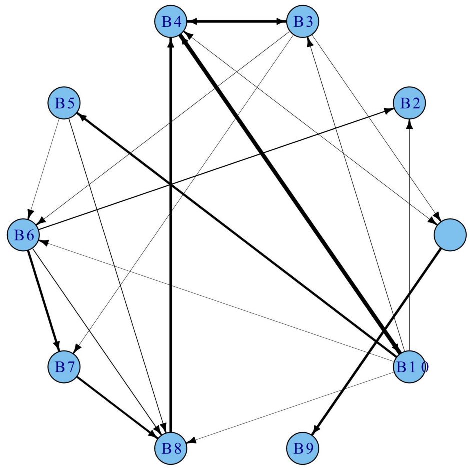
network A.4



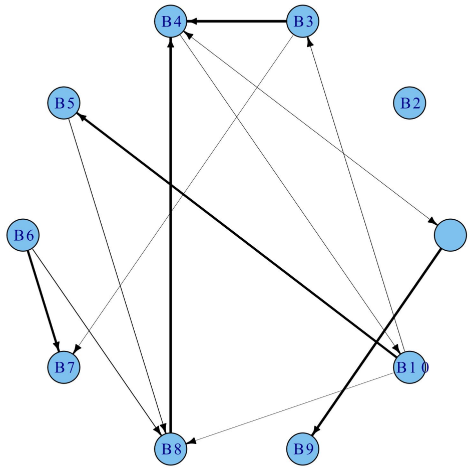
network A.5



network A.6



network A.7



c) Tables

Table 5.3.1.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SET I	A.0	21.02	2.19	3.55	2.72	7.15
	A.1	22.63	2.71	3.36	1.94	8.16
	A.2	22.08	3.41	2.57	2.37	7.29
	A.3	23.14	4.12	2.13	2.89	8.09
	A.4	22.82	3.36	2.55	2.10	8.03
	A.5	23.71	6.14	1.73	1.87	8.25
	A.6	23.27	4.58	2.17	2.8	8.06
	A.7	23.61	5.94	1.64	1.97	8.17
SET II	A.0	14.95	1.4	2.1	1.69	9.18
	A.1	16.83	1.95	1.79	1.31	9.9
	A.2	16.36	2.85	1.51	1.31	9.12
	A.3	17.26	3.62	1.41	1.6	9.9
	A.4	17.12	2.84	1.52	1.27	9.83
	A.5	18.02	6.01	1.21	1.42	9.93
	A.6	17.47	4.18	1.45	1.52	9.87
	A.7	17.96	5.76	1.22	1.2	9.91
SET III	A.0	18.27	1.48	2.55	2.14	8.67
	A.1	20.15	1.97	2.5	1.49	9.56
	A.2	19.69	2.77	1.87	1.72	8.62
	A.3	20.69	3.46	1.77	2.2	9.54
	A.4	20.45	2.7	1.99	1.81	9.46
	A.5	21.67	5.75	1.42	1.91	9.62
	A.6	20.96	3.92	1.89	2.05	9.52
	A.7	21.56	5.5	1.43	1.55	9.59
SET IV	A.0	10.68	1.57	1.47	1.28	9.41
	A.1	12.07	2.46	1.35	1.1	9.97
	A.2	11.71	3.37	1.22	1.18	9.48
	A.3	12.31	3.97	1.35	1.28	9.98
	A.4	12.29	3.25	1.21	1.16	9.95
	A.5	12.97	6.72	1.07	1.1	9.99
	A.6	12.56	4.55	1.18	1.33	9.97
	A.7	12.95	6.34	1.07	1.08	9.99

Tables 5.3.1.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
SET I	A.0	23.49	21.9	22.93	3.87	23.53	23.04	21.02	21.69	22.48	23.46
	A.1	23.25	24.18	24.31	22.19	24.3	24.15	22.63	24.23	24.24	24.07
	A.2	23.16	14.9	23.33	7.01	23.23	23	22.08	23.04	23.4	23.39
	A.3	24.07	24.08	23.71	23.22	22.93	23.2	23.86	23.6	23.78	23.14
	A.4	23.89	21.94	23.64	21.26	23.6	24.07	22.82	23.94	24.11	23.97
	A.5	23.67	23.99	24.08	23.7	23.88	24.04	24	23.97	23.98	24.01
	A.6	23.27	23.05	23.72	23.97	24.17	23.4	21.98	23.97	23.16	23.89
	A.7	23.71	23.19	23.61	23.77	23.64	24.17	23.55	24	24.17	23.94
SET II	A.0	20.38	22.17	20.87	10.04	18.8	17.12	14.95	22.49	16.53	18.07
	A.1	19.67	18.44	18.77	18.87	18.88	18.69	16.83	18.8	18.62	18.7
	A.2	17.38	21.66	17.73	12.73	17.38	17.14	16.36	19.39	18.39	18.8
	A.3	18.48	18.36	19.62	19.71	20.05	17.29	19.16	19.78	17.99	17.26
	A.4	18.13	20.67	17.88	19.43	19.78	18.81	17.12	18.95	18.97	18.36
	A.5	19.19	18.54	18.56	18.02	19.16	18.55	19.36	18.57	18.6	18.45
	A.6	17.47	20.24	17.97	19.18	18.93	17.72	20.25	18.73	20.02	18.31
	A.7	18.08	19.82	17.96	18.31	19.72	18.77	19.59	19.05	18.77	18.37
SET III	A.0	24.22	24.41	24.04	6.79	22.96	20.74	18.27	24.39	20	22.09
	A.1	22.67	22.33	22.63	21.94	22.71	22.58	20.15	22.64	22.48	22.57
	A.2	20.98	19.85	21.38	9.7	20.87	20.59	19.69	22.64	22.15	22.33
	A.3	22.42	22.22	23.05	23.01	23.14	20.73	22.85	23.27	21.74	20.69
	A.4	21.84	22.94	21.58	21.95	23.03	22.65	20.45	22.78	22.74	22.19
	A.5	22.79	22.24	22.32	21.67	22.76	22.31	22.64	22.35	22.37	22.19
	A.6	20.96	23.33	21.63	22.84	22.71	21.33	23.25	22.52	23.22	22.05
	A.7	21.71	22.9	21.56	21.97	23.13	22.55	22.97	22.82	22.55	22.1
SET IV	A.0	14.29	15.52	14.59	12.67	13.18	12.09	10.68	16.06	11.69	12.67
	A.1	14.13	13.22	13.37	13.85	13.47	13.33	12.07	13.43	13.29	13.35
	A.2	12.4	20.33	12.66	15.21	12.39	12.25	11.71	13.87	13.14	13.42
	A.3	13.23	13.12	14.05	14.09	14.42	12.34	13.57	14.21	12.85	12.31
	A.4	13.04	15.49	12.87	14.49	14.42	13.45	12.29	13.61	13.58	13.2
	A.5	13.94	13.35	13.31	12.97	13.95	13.3	13.95	13.31	13.33	13.25
	A.6	12.56	14.94	12.92	13.71	13.6	12.74	15.06	13.4	14.43	13.16
	A.7	13.04	14.56	12.95	13.19	14.27	13.46	14.13	13.68	13.46	13.22

Matrices B.0 - B.7

a) Matrices

matrix B.0

$$\begin{pmatrix}
0 & 0.17 & 0.0597 & 0.0138 & 0.0348 & 0.0118 & 0.024 & 0.0078 & 0.0372 & 0.01395 \\
0.029 & 0 & 0.01848 & 0.0115 & 0.0056 & 0.0024 & 0.0187 & 0.0546 & 0.02085 & 0.0144 \\
0.0063 & 0.0144 & 0 & 0.1534 & 0.01218 & 0.0399 & 0.02214 & 0.05203 & 0.01885 & 0.00285 \\
0.01545 & 0.0915 & 0.0092 & 0 & 0.03344 & 0.00363 & 0.02004 & 0.0168 & 0.00242 & 0.00132 \\
0.02079 & 0.04554 & 0.00483 & 0.042 & 0 & 0.0276 & 0.00714 & 0.04522 & 0.0186 & 0.03906 \\
0.016851 & 0.01989 & 0.002 & 0.1764 & 0.06154 & 0 & 0.0033 & 0.05967 & 0.01536 & 0.04736 \\
0.04788 & 0.165 & 0.01768 & 0.183 & 0.0326 & 0.01716 & 0 & 0.104 & 0.012 & 0.05184 \\
0.00492 & 0.0098 & 0.04715 & 0.247 & 0.006 & 0.00314 & 0.0108 & 0 & 0.02574 & 0.01245 \\
0.00042 & 0.00792 & 0.083 & 0.2304 & 0.0023 & 0.01836 & 0.02145 & 0.02509 & 0 & 0.02496 \\
0.0243 & 0.00023 & 0.0365 & 0.298 & 0.1056 & 0.0201 & 0.04278 & 0.0012 & 0.02709 & 0
\end{pmatrix}$$

matrix B.1

$$\begin{pmatrix}
0 & 0.17 & 0.0597 & 0 & 0.0348 & 0 & 0.024 & 0 & 0.0372 & 0.01395 \\
0 & 0 & 0.01848 & 0 & 0 & 0.0024 & 0 & 0 & 0.02085 & 0 \\
0 & 0 & 0 & 0 & 0 & 0.0399 & 0.02214 & 0 & 0 & 0.00285 \\
0.01545 & 0 & 0 & 0 & 0 & 0 & 0.02004 & 0 & 0 & 0.00132 \\
0.02079 & 0.04554 & 0.00483 & 0.042 & 0 & 0 & 0.00714 & 0.04522 & 0.0186 & 0.03906 \\
0.016851 & 0 & 0 & 0.1764 & 0 & 0 & 0.0033 & 0 & 0 & 0.04736 \\
0 & 0.165 & 0.01768 & 0 & 0 & 0 & 0 & 0 & 0.012 & 0.05184 \\
0 & 0 & 0.04715 & 0.247 & 0 & 0.00314 & 0.0108 & 0 & 0.02574 & 0.01245 \\
0.00042 & 0.00792 & 0 & 0.2304 & 0.0023 & 0 & 0.02145 & 0 & 0 & 0 \\
0.0243 & 0.00023 & 0.0365 & 0.298 & 0.1056 & 0 & 0 & 0.0012 & 0.02709 & 0
\end{pmatrix}$$

matrix B.2

$$\begin{pmatrix}
0 & 0 & 0 & 0.0138 & 0 & 0.0118 & 0.024 & 0 & 0 & 0 \\
0.029 & 0 & 0.01848 & 0.0115 & 0.0056 & 0.0024 & 0.0187 & 0 & 0.02085 & 0.0144 \\
0.0063 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.03344 & 0.00363 & 0 & 0 & 0.00242 & 0 \\
0 & 0.04554 & 0.00483 & 0 & 0 & 0 & 0.00714 & 0.04522 & 0.0186 & 0.03906 \\
0.016851 & 0 & 0 & 0 & 0.06154 & 0 & 0 & 0.05967 & 0 & 0 \\
0 & 0 & 0 & 0.183 & 0 & 0.01716 & 0 & 0.104 & 0.012 & 0 \\
0.00492 & 0.0098 & 0 & 0 & 0.006 & 0 & 0.0108 & 0 & 0 & 0.01245 \\
0.00042 & 0.00792 & 0.083 & 0 & 0 & 0 & 0 & 0 & 0 & 0.02496 \\
0 & 0 & 0 & 0.298 & 0 & 0.0201 & 0 & 0 & 0.02709 & 0
\end{pmatrix}$$

matrix B.3

$$\begin{pmatrix}
0 & 0.17 & 0.0597 & 0 & 0.0348 & 0.0118 & 0.024 & 0.0078 & 0 & 0.01395 \\
0.029 & 0 & 0.01848 & 0 & 0 & 0.0024 & 0.0187 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.1534 & 0.01218 & 0 & 0 & 0 & 0.01885 & 0 \\
0.01545 & 0.0915 & 0.0092 & 0 & 0.03344 & 0.00363 & 0.02004 & 0 & 0 & 0 \\
0.02079 & 0.04554 & 0 & 0.042 & 0 & 0 & 0 & 0 & 0.0186 & 0.03906 \\
0 & 0.01989 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.04736 \\
0.04788 & 0 & 0 & 0 & 0.0326 & 0 & 0 & 0.104 & 0.012 & 0 \\
0.00492 & 0.0098 & 0 & 0.247 & 0 & 0 & 0.0108 & 0 & 0.02574 & 0.01245 \\
0.00042 & 0 & 0 & 0.2304 & 0 & 0 & 0.02145 & 0 & 0 & 0.02496 \\
0 & 0.00023 & 0.0365 & 0.298 & 0 & 0 & 0.04278 & 0.0012 & 0.02709 & 0
\end{pmatrix}$$

matrix B.4

$$\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0.024 & 0 & 0 & 0 \\
0 & 0 & 0.01848 & 0 & 0 & 0.0024 & 0 & 0 & 0.02085 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.04554 & 0.00483 & 0 & 0 & 0 & 0.00714 & 0.04522 & 0.0186 & 0.03906 \\
0.016851 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.012 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.0108 & 0 & 0 & 0.01245 \\
0.00042 & 0.00792 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.298 & 0 & 0 & 0 & 0 & 0.02709 & 0
\end{pmatrix}$$

matrix B.5

$$\begin{pmatrix}
0 & 0.17 & 0.0597 & 0 & 0.0348 & 0 & 0.024 & 0 & 0 & 0.01395 \\
0 & 0 & 0.01848 & 0 & 0 & 0.0024 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.01545 & 0 & 0 & 0 & 0 & 0 & 0.02004 & 0 & 0 & 0 \\
0.02079 & 0.04554 & 0 & 0.042 & 0 & 0 & 0 & 0 & 0.0186 & 0.03906 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.04736 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.012 & 0 \\
0 & 0 & 0 & 0.247 & 0 & 0 & 0.0108 & 0 & 0.02574 & 0.01245 \\
0.00042 & 0 & 0 & 0.2304 & 0 & 0 & 0.02145 & 0 & 0 & 0 \\
0 & 0.00023 & 0.0365 & 0.298 & 0 & 0 & 0 & 0.0012 & 0.02709 & 0
\end{pmatrix}$$

matrix B.6

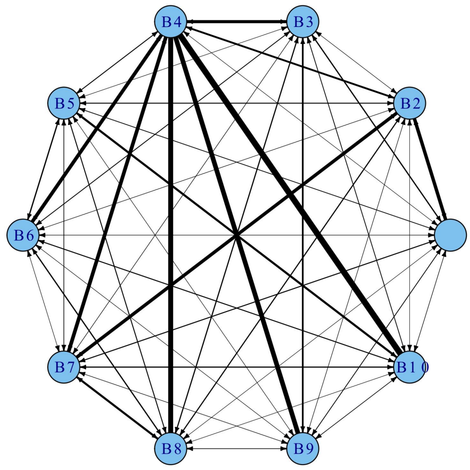
$$\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0.0118 & 0.024 & 0 & 0 & 0 \\
0.029 & 0 & 0.01848 & 0 & 0 & 0.0024 & 0.0187 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0.03344 & 0.00363 & 0 & 0 & 0 & 0 \\
0 & 0.04554 & 0 & 0 & 0 & 0 & 0 & 0 & 0.0186 & 0.03906 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.104 & 0.012 & 0 \\
0.00492 & 0.0098 & 0 & 0 & 0 & 0 & 0.0108 & 0 & 0 & 0.01245 \\
0.00042 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.02496 \\
0 & 0 & 0 & 0.298 & 0 & 0 & 0 & 0 & 0.02709 & 0
\end{pmatrix}$$

matrix B.7

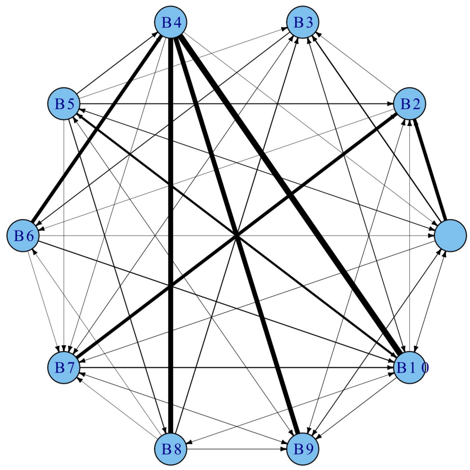
$$\begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0.024 & 0 & 0 & 0 \\
0 & 0 & 0.01848 & 0 & 0 & 0.0024 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.04554 & 0 & 0 & 0 & 0 & 0 & 0 & 0.0186 & 0.03906 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.012 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.0108 & 0 & 0 & 0.01245 \\
0.00042 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.298 & 0 & 0 & 0 & 0 & 0.02709 & 0
\end{pmatrix}$$

b) Graphs

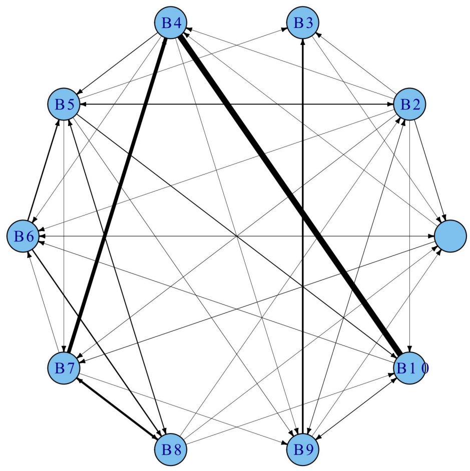
network B.0



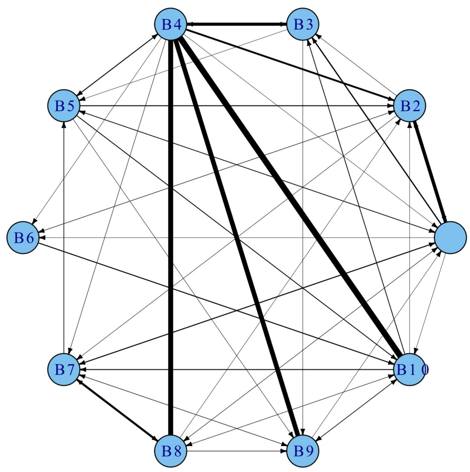
network B.1



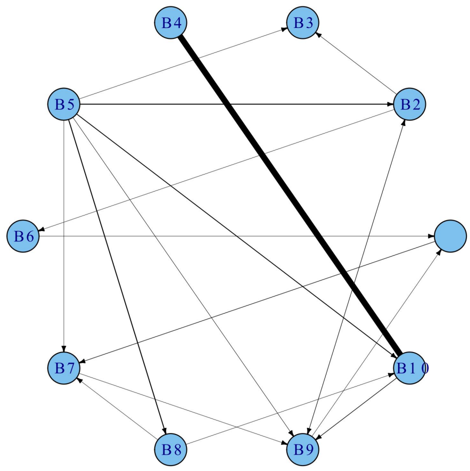
network B.2



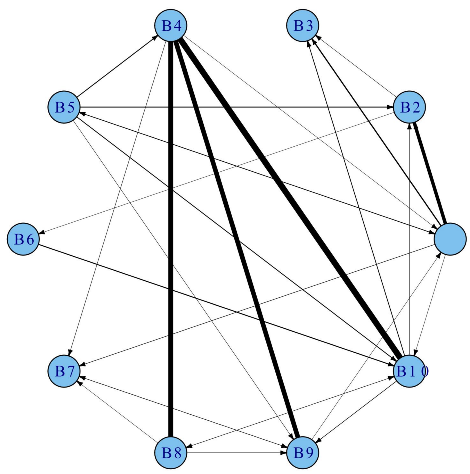
network B.3



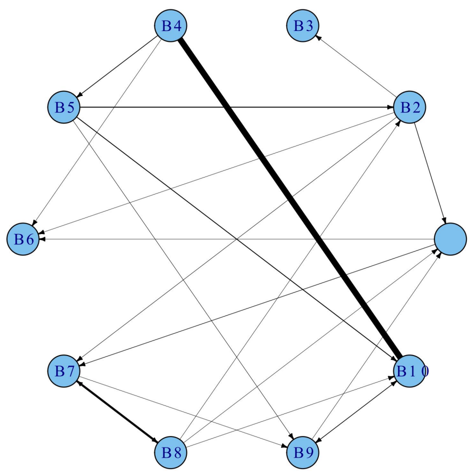
network B.4



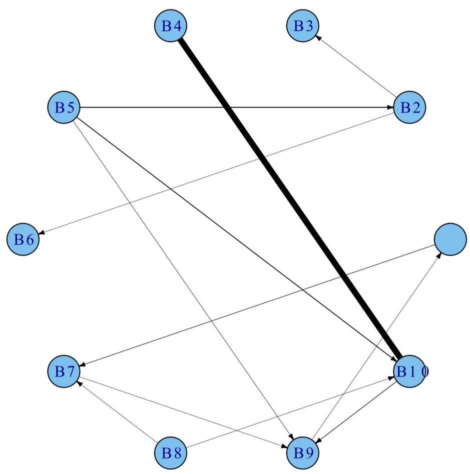
network B.5



network B.6



network B.7



c) Tables

Table 5.3.2.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SET I	B.0	17.42	1.75	5.86	5.39	6.61
	B.1	22.59	5.36	2.15	2.08	7.39
	B.2	21.4	2.22	4.23	2.28	7.47
	B.3	21.96	2.77	3.03	2.47	7.49
	B.4	23	3.62	2.52	2.67	8.09
	B.5	22.14	3.59	2.62	2.61	7.5
	B.6	23.3	4.48	2.35	2.52	8.13
	B.7	23.01	3.55	2.83	2.38	8.12
SET II	B.0	12.21	1.07	3.36	3.26	8.7
	B.1	16.69	4.99	1.27	1.49	9.18
	B.2	15.61	1.38	2.42	1.55	9.44
	B.3	16.2	2.09	1.68	1.43	9.24
	B.4	17.28	3.21	1.54	1.62	9.86
	B.5	16.5	2.98	1.53	1.63	9.36
	B.6	17.53	4.2	1.5	1.6	9.89
	B.7	17.3	3.14	1.65	1.57	9.86
SET III	B.0	15.08	1.16	4.22	4.24	8.12
	B.1	20.07	4.99	2.08	1.45	8.67
	B.2	18.76	1.45	3.1	2.11	8.95
	B.3	19.48	2.05	2.15	1.99	8.81
	B.4	20.7	3.04	1.99	2.11	9.51
	B.5	19.75	2.98	1.96	2.07	8.89
	B.6	21.02	3.87	1.89	2.08	9.56
	B.7	20.72	2.96	2.16	2.04	9.51
SET IV	B.0	8.85	1.06	2.17	2.19	9.03
	B.1	11.96	5.38	1.11	1.15	9.5
	B.2	11.27	1.54	1.66	1.27	9.72
	B.3	11.6	2.49	1.28	1.21	9.52
	B.4	12.44	3.64	1.25	1.28	9.96
	B.5	11.84	3.42	1.24	1.23	9.6
	B.6	12.6	4.59	1.2	1.29	9.98
	B.7	12.46	3.59	1.31	1.24	9.96

Table 5.3.2.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
SET I	B.0	23.27	14.72	22.06	0.77	22.68	23.01	17.42	20.09	20.93	22.99
	B.1	23.12	16.49	21.35	7.83	23.1	23.12	22.6	22.81	22.59	22.96
	B.2	23.82	23.53	22.79	11.15	23.88	23.65	21.4	20.05	23.6	23.32
	B.3	23.75	20.45	23.56	6.22	23.56	23.73	23.36	23.67	21.96	23.21
	B.4	24.07	23.98	24.15	20.72	23.51	24.06	24.05	24	23.77	23
	B.5	23.15	22.23	22.58	7.94	23.44	23.38	23.03	22.86	22.14	23.13
	B.6	23.98	23.87	24.02	22.4	23.98	23.99	23.51	23.07	23.85	23.3
	B.7	24.04	24	24.24	20.72	23.82	24.11	24.1	24.04	24.08	23.01
SET II	B.0	19.56	23.58	21.86	3.09	21.35	18.2	12.21	23.79	15.37	18.3
	B.1	17.3	20.1	20.9	11.26	18.61	17.58	16.72	16.9	16.69	17.16
	B.2	19.45	17.83	20.67	18.84	19.09	18.64	15.61	22.27	18.2	17.67
	B.3	18.14	21.15	18.68	11.17	19.17	18.56	17.59	18.1	16.2	17.28
	B.4	18.77	18.66	19.13	20.25	17.84	18.72	18.93	18.95	19.54	17.28
	B.5	17.35	20.74	20.88	12.14	18.12	19	20.53	17.04	16.5	17.39
	B.6	19.03	18.27	19.14	19.65	18.6	19.01	17.83	19.78	18.91	17.53
	B.7	18.64	18.79	19.1	20.29	18.17	18.81	18.87	18.63	19.33	17.3
SET III	B.0	23.3	20.53	24.31	1.72	24.21	22.11	15.08	24.25	18.66	22.23
	B.1	20.8	19.55	22.75	9.65	21.97	21.15	20.09	20.27	20.07	20.6
	B.2	23.08	21.61	23.2	16.19	22.95	22.51	18.76	23.06	22.03	21.29
	B.3	21.93	22.24	22.5	8.52	22.81	22.36	21.18	21.88	19.48	20.75
	B.4	22.55	22.44	22.85	22.05	21.4	22.51	22.74	22.73	23.04	20.7
	B.5	20.83	23.19	23.79	10.41	21.84	22.79	23.66	20.41	19.75	20.89
	B.6	22.77	22.02	22.74	22.53	22.41	22.7	21.42	22.99	22.67	21.02
	B.7	22.44	22.68	22.79	21.85	21.81	22.68	22.67	22.44	22.84	20.72
SET IV	B.0	13.74	21.85	15.54	6.26	15.32	12.81	8.85	18.5	10.88	12.78
	B.1	12.33	17.85	15.91	12.51	13.28	12.55	11.97	12.08	11.96	12.27
	B.2	13.88	12.79	15.24	19.19	13.66	13.28	11.27	17.28	13.01	12.63
	B.3	12.96	16.36	13.38	13.72	13.78	13.24	12.52	12.95	11.6	12.33
	B.4	13.48	13.41	13.83	15.42	12.84	13.45	13.61	13.63	14.37	12.44
	B.5	12.42	15.32	15.22	13.71	12.98	13.54	15	12.22	11.84	12.45
	B.6	13.61	13.15	13.7	14.35	13.34	13.62	12.83	14.5	13.54	12.6
	B.7	13.4	13.52	13.81	15.35	13.09	13.51	13.55	13.4	14.14	12.46

Matrices C.0-C.7

a) Matrices

matrix C.0

$$\begin{pmatrix}
0 & 0.1 & 0.03 & 0.012 & 0.04 & 0.01 & 0.1 & 0.03 & 0.12 & 0.045 \\
0.1 & 0 & 0.021 & 0.01 & 0.016 & 0.012 & 0.011 & 0.03 & 0.015 & 0.024 \\
0.021 & 0.012 & 0 & 0.13 & 0.014 & 0.021 & 0.018 & 0.043 & 0.013 & 0.015 \\
0.015 & 0.075 & 0.023 & 0 & 0.022 & 0.011 & 0.012 & 0.021 & 0.011 & 0.022 \\
0.021 & 0.023 & 0.021 & 0.2 & 0 & 0.015 & 0.021 & 0.034 & 0.02 & 0.063 \\
0.0137 & 0.051 & 0.004 & 0.12 & 0.034 & 0 & 0.11 & 0.039 & 0.012 & 0.032 \\
0.0532 & 0.11 & 0.013 & 0.15 & 0.02 & 0.013 & 0 & 0.1 & 0.015 & 0.027 \\
0.041 & 0.02 & 0.041 & 0.13 & 0.015 & 0.002 & 0.02 & 0 & 0.013 & 0.015 \\
0.021 & 0.012 & 0.1 & 0.12 & 0.023 & 0.012 & 0.013 & 0.013 & 0 & 0.024 \\
0.054 & 0.023 & 0.025 & 0.2 & 0.11 & 0.015 & 0.023 & 0.012 & 0.043 & 0
\end{pmatrix}$$

matrix C.1

$$\begin{pmatrix}
0 & 0.1 & 0.03 & 0.012 & 0 & 0.01 & 0.1 & 0.03 & 0.12 & 0 \\
0 & 0 & 0 & 0.01 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0.018 & 0.043 & 0.013 & 0.015 \\
0.015 & 0.075 & 0 & 0 & 0 & 0 & 0 & 0.021 & 0 & 0.022 \\
0 & 0.023 & 0 & 0.2 & 0 & 0 & 0 & 0.034 & 0.02 & 0.063 \\
0.0137 & 0 & 0.004 & 0.12 & 0 & 0 & 0.11 & 0.039 & 0 & 0 \\
0.0532 & 0.11 & 0 & 0.15 & 0 & 0.013 & 0 & 0 & 0 & 0 \\
0.041 & 0.02 & 0 & 0.13 & 0 & 0 & 0 & 0 & 0.013 & 0.015 \\
0 & 0.012 & 0 & 0.12 & 0 & 0 & 0 & 0.013 & 0 & 0 \\
0 & 0 & 0.025 & 0 & 0.11 & 0 & 0 & 0.012 & 0.043 & 0
\end{pmatrix}$$

matrix C.2

$$\begin{pmatrix}
0 & 0 & 0 & 0.012 & 0.04 & 0 & 0.1 & 0.03 & 0.12 & 0 \\
0.1 & 0 & 0.021 & 0 & 0.016 & 0 & 0.011 & 0 & 0 & 0 \\
0.021 & 0 & 0 & 0.13 & 0 & 0.021 & 0.018 & 0 & 0 & 0 \\
0.015 & 0.075 & 0.023 & 0 & 0.022 & 0 & 0.012 & 0 & 0 & 0.022 \\
0 & 0 & 0 & 0 & 0 & 0.015 & 0.021 & 0.034 & 0 & 0.063 \\
0.0137 & 0.051 & 0 & 0 & 0.034 & 0 & 0.11 & 0.039 & 0 & 0.032 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.1 & 0 & 0.027 \\
0 & 0 & 0.041 & 0.13 & 0.015 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.012 & 0.1 & 0 & 0.023 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.023 & 0.025 & 0.2 & 0.11 & 0.015 & 0.023 & 0.012 & 0.043 & 0
\end{pmatrix}$$

matrix C.3

$$
\begin{pmatrix}
0 & 0 & 0.03 & 0.012 & 0 & 0 & 0 & 0 & 0.12 & 0.045 \\
0 & 0 & 0 & 0 & 0 & 0.012 & 0 & 0 & 0.015 & 0 \\
0.021 & 0.012 & 0 & 0.13 & 0.014 & 0.021 & 0.018 & 0.043 & 0 & 0.015 \\
0.015 & 0 & 0.023 & 0 & 0 & 0 & 0 & 0 & 0.011 & 0.022 \\
0.021 & 0 & 0 & 0 & 0 & 0.015 & 0 & 0.034 & 0.02 & 0 \\
0 & 0.051 & 0 & 0 & 0 & 0 & 0.11 & 0.039 & 0.012 & 0 \\
0 & 0.11 & 0.013 & 0.15 & 0.02 & 0.013 & 0 & 0.1 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.12 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.023 & 0.025 & 0.2 & 0.11 & 0.015 & 0 & 0.012 & 0 & 0
\end{pmatrix}
$$

matrix C.4

$$
\begin{pmatrix}
0 & 0 & 0 & 0.012 & 0 & 0 & 0.1 & 0.03 & 0.12 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0.018 & 0 & 0 & 0 \\
0.015 & 0.075 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.022 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.034 & 0 & 0.063 \\
0.0137 & 0 & 0 & 0 & 0 & 0 & 0.11 & 0.039 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.012 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0.025 & 0 & 0.11 & 0 & 0 & 0.012 & 0.043 & 0
\end{pmatrix}
$$

matrix C.5

$$
\begin{pmatrix}
0 & 0 & 0.03 & 0.012 & 0 & 0 & 0 & 0 & 0.12 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0.018 & 0.043 & 0 & 0.015 \\
0.015 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.022 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.034 & 0.02 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.11 & 0.039 & 0 & 0 \\
0 & 0.11 & 0 & 0.15 & 0 & 0.013 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.12 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0.025 & 0 & 0.11 & 0 & 0 & 0.012 & 0 & 0
\end{pmatrix}
$$

matrix C.6

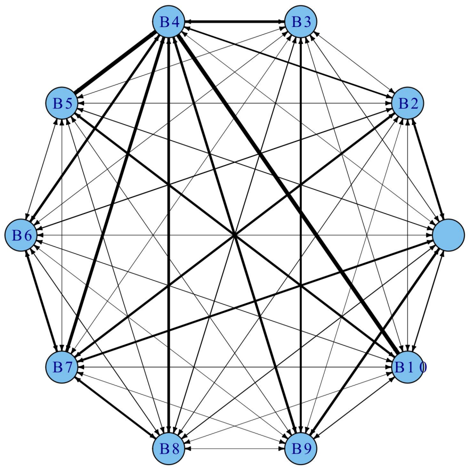
$$\begin{pmatrix}
0 & 0 & 0 & 0.012 & 0 & 0 & 0 & 0 & 0.12 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.021 & 0 & 0 & 0.13 & 0 & 0.021 & 0.018 & 0 & 0 & 0 \\
0.015 & 0 & 0.023 & 0 & 0 & 0 & 0 & 0 & 0 & 0.022 \\
0 & 0 & 0 & 0 & 0 & 0.015 & 0 & 0.034 & 0 & 0 \\
0 & 0.051 & 0 & 0 & 0 & 0 & 0.11 & 0.039 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.1 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0.023 & 0.025 & 0.2 & 0.11 & 0.015 & 0 & 0.012 & 0 & 0
\end{pmatrix}$$

matrix C.7

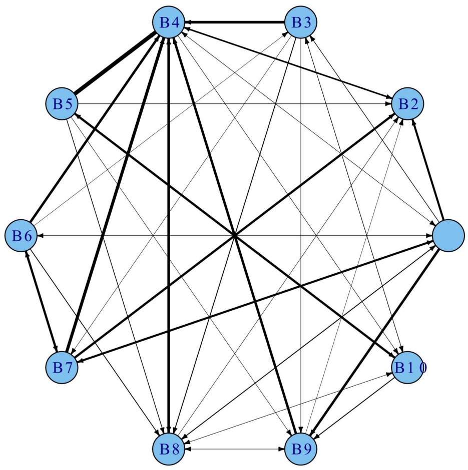
$$\begin{pmatrix}
0 & 0 & 0 & 0.012 & 0 & 0 & 0 & 0 & 0.12 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0.018 & 0 & 0 & 0 \\
0.015 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.022 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0.034 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0.11 & 0.039 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.13 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0.025 & 0 & 0.11 & 0 & 0 & 0.012 & 0 & 0
\end{pmatrix}$$

b) Graphs

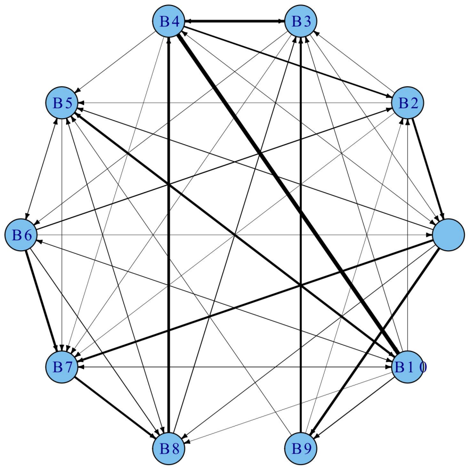
network C.0



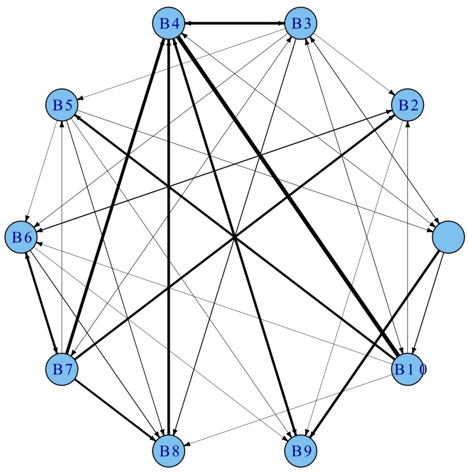
network C.1



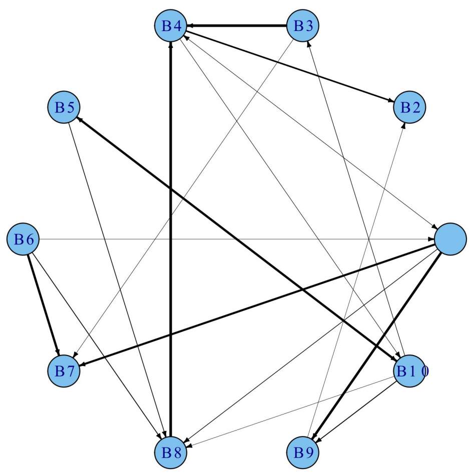
network C.2



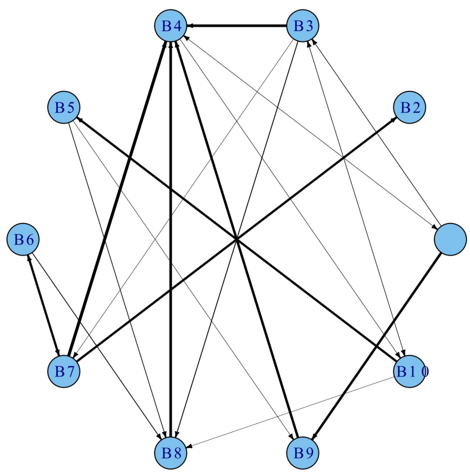
network C.3



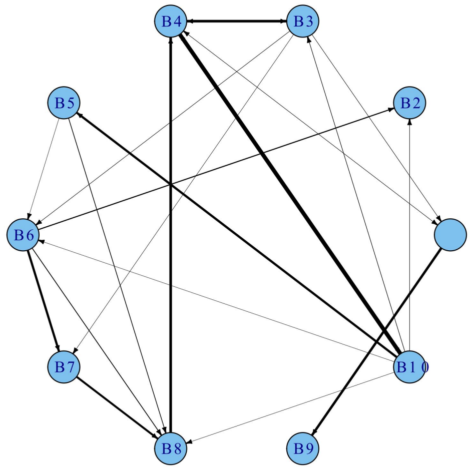
network C.4



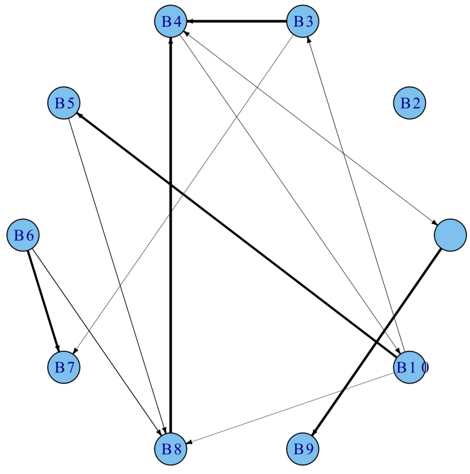
network C.5



network C.6



network C.7



c) Tables

Table 5.3.3.1

	matrix	first default	how many first defaults	average time gap till next default	and next default	overall number of defaults
SETI	A.0	21.02	2.19	3.55	2.72	7.15
	C.1	22.08	3.41	2.57	2.37	7.29
	C.2	23.14	4.12	2.13	2.89	8.09
	C.3	20.49	2.01	4.81	2.99	7.19
	C.4	23.27	4.58	2.17	2.8	8.06
	C.5	22.13	2.86	3.36	3.09	7.58
	C.6	22.6	3.07	2.98	2.25	7.92
	C.7	23.49	5.7	2.18	2.39	8.11
SETII	A.0	14.95	1.4	2.1	1.69	9.18
	C.1	16.36	2.85	1.51	1.31	9.12
	C.2	17.26	3.62	1.41	1.6	9.9
	C.3	14.8	1.16	2.8	1.74	9.2
	C.4	17.47	4.18	1.45	1.52	9.87
	C.5	16.49	2.13	1.88	1.71	9.38
	C.6	16.89	2.4	1.69	1.38	9.77
	C.7	17.84	5.47	1.39	1.53	9.9
SETIII	A.0	18.27	1.48	2.55	2.14	8.67
	C.1	19.69	2.77	1.87	1.72	8.62
	C.2	20.69	3.46	1.77	2.2	9.54
	C.3	17.89	1.3	3.49	2.4	8.69
	C.4	20.96	3.92	1.89	2.05	9.52
	C.5	19.71	2.13	2.56	1.83	8.98
	C.6	20.16	2.38	2.29	1.9	9.36
	C.7	21.4	5.21	1.91	1.86	9.55
SETIV	A.0	10.68	1.57	1.47	1.28	9.41
	C.1	11.71	3.37	1.22	1.18	9.48
	C.2	12.31	3.97	1.35	1.28	9.98
	C.3	10.69	1.23	1.85	1.34	9.52
	C.4	12.56	4.55	1.18	1.33	9.97
	C.5	11.84	2.59	1.44	1.29	9.66
	C.6	12.13	2.89	1.31	1.19	9.92
	C.7	12.85	5.96	1.19	1.24	9.99

Table 5.3.3.2

		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
SET I	A.0	23.49	21.9	22.93	3.87	23.53	23.04	21.02	21.69	22.48	23.46
	C.1	23.16	14.9	23.33	7.01	23.23	23	22.08	23.04	23.4	23.39
	C.2	24.07	24.08	23.71	23.22	22.93	23.2	23.86	23.6	23.78	23.14
	C.3	23.49	20.56	23.45	6.13	22.94	23.49	20.49	21.31	23.67	22.78
	C.4	23.27	23.05	23.72	23.97	24.17	23.4	21.98	23.97	23.16	23.89
	C.5	23.68	21.16	23.54	9.91	23.43	23.64	22.13	23.43	23.7	23.66
	C.6	23.81	23.93	23.76	18.66	23.81	23.6	23.78	23.58	23.56	22.6
	C.7	23.77	23.95	23.62	22.7	23.72	23.49	23.23	23.84	23.5	23.78
SET II	A.0	20.38	22.17	20.87	10.04	18.8	17.12	14.95	22.49	16.53	18.07
	C.1	17.38	21.66	17.73	12.73	17.38	17.14	16.36	19.39	18.39	18.8
	C.2	18.48	18.36	19.62	19.71	20.05	17.29	19.16	19.78	17.99	17.26
	C.3	18.12	22.98	18.11	13.71	20.13	18.36	14.8	22.65	18.93	17.33
	C.4	17.47	20.24	17.97	19.18	18.93	17.72	20.25	18.73	20.02	18.31
	C.5	17.96	20.91	17.85	15.4	19.46	17.97	16.49	19.02	18.26	18.32
	C.6	18.31	19.59	18.02	20.51	19.45	17.84	18.36	19.97	19.95	16.89
	C.7	18.12	18.88	17.99	20.16	19.43	17.84	19.89	18.56	19.87	18.13
SET III	A.0	24.22	24.41	24.04	6.79	22.96	20.74	18.27	24.39	20	22.09
	C.1	20.98	19.85	21.38	9.7	20.87	20.59	19.69	22.64	22.15	22.33
	C.2	22.42	22.22	23.05	23.01	23.14	20.73	22.85	23.27	21.74	20.69
	C.3	22.01	23.88	22.03	10.01	23.66	22.25	17.89	23.86	22.88	20.8
	C.4	20.96	23.33	21.63	22.84	22.71	21.33	23.25	22.52	23.22	22.05
	C.5	21.67	23	21.58	13.61	22.94	21.72	19.71	22.72	22.02	22.1
	C.6	22.07	23.13	21.76	21.5	22.98	21.55	22.13	23.01	23.2	20.16
	C.7	21.77	22.54	21.62	22.98	23.01	21.4	22.98	22.32	23.06	21.79
SET IV	A.0	14.29	15.52	14.59	12.67	13.18	12.09	10.68	16.06	11.69	12.67
	C.1	12.4	20.33	12.66	15.21	12.39	12.25	11.71	13.87	13.14	13.42
	C.2	13.23	13.12	14.05	14.09	14.42	12.34	13.57	14.21	12.85	12.31
	C.3	12.97	18.03	12.88	17.12	14.37	13.08	10.69	17.05	13.55	12.35
	C.4	12.56	14.94	12.92	13.71	13.6	12.74	15.06	13.4	14.43	13.16
	C.5	12.89	15.67	12.81	17.44	14.13	12.88	11.84	13.65	13.09	13.12
	C.6	13.14	14.02	12.94	16.68	13.78	12.81	13.18	14.53	14.38	12.13
	C.7	13.05	13.52	12.96	14.77	14.03	12.85	14.39	13.3	14.42	13.06

6 Conclusion

We wanted to analyse systemic risk in different network structures and started our approach by establishing a system of financial networks based on the derived settings of the underlying paper "Market Procyclicality and Systemic Risk" by Paolo Tasca and Stefano Battistan. We searched for parameter settings in which we were able to observe the opportunity of systemic default. Based on this specific parameter constellations we were able to establish our simulation framework. We analysed 5 basis network structures and modifications of the fully interconnected system, which refers to incomplete networks. Our analysis was split into three parts. First we did a general analysis of the chosen array setting representing four possibilities on how banks and markets behave. We observed that in an environment where banks react faster on asset price changes and markets are more illiquid, first time defaults and upcoming defaults occur earlier and time gaps between those defaults are smaller than in the other cases. Those systems in a setting where banks react slower on asset price changes and markets are more liquid defaulted later. This results match to those presented in the underlying paper.
In the second part of the analysis we studied the different network structures and their behaviour on asset price changes. Overall due to the limited number of observations we saw some weak tendencies. We observed that banks which issued most debt defaulted preferred in the environment of highly liquid markets(set 1 and 3). On the other hand we saw that banks which held most debt preferably defaulted in a less liquid market settings(set 2 and 4). For those network structures representing the cases of a centralized bank we used the ratio of issued to held debt as an indicator for first defaults and observed a weak tendency that banks with low ratio default earlier.
The third analysis part dealt with incomplete networks. We derived networks with different degrees of interconnectedness. In those networks with low interconnectedness we observed that banks which held most debt default first and successively those bank with the most debt held in the remaining system defaulted thereafter. This behaviour can be seen in all environment settings except set 1 where banks react slower on asset price changes and markets are

highly liquid. The networks with high degrees of interconnectedness showed that the bank which issued most debt defaults first but for upcoming defaults we could not observe any tendencies.

A Numerical approach

A.1 Algorithm

To establish a solid simulation procedure we first want to explain the underlying algorithm. Further we discuss some parts of the used code and explain the used predefined R-packages. Starting with our initial conditions in a first step we want to calculate with (22) the corresponding asset price $s_l(0)$. In our simulation we use just one asset. Similarly if we consider various assets we compute in this first step not the asset price, but some kind of portfolio price, which we have to split up into the different assets.
This calculated asset price $s_l(0)$ suffers an initial unique shock, in our case we shocked the asset price with -10%. According to this shocked asset price we have to recalculate the corresponding ϕ_i with (22), which we then use to compute the change in quantity of the external asset via (23). Furthermore we compute with (24) the change in quantity for external debts. With these changed quantities we are now able to compute the resulting asset price via (25).
This procedure is repeated t times. We refer to $t = 50$ which simulates 50 weeks or almost one year, assuming that banks are only able to react ones a week to changes, which also occur just once a week.
In every repetition we have to check whether our new calculated ϕ_i is still below 1 or not. If one or more ϕ_i exceeded 1 we say that the corresponding bank i run into default and is from now on not able to react any more in the financial system. In practice we set all values corresponding to the ruined bank i equal to zero. All other banks are left untouched.
After this modification the procedure runs as usual, meaning with the modified system we recalculate the change in quantity of external debt and external asset and furthermore the resulting asset price.

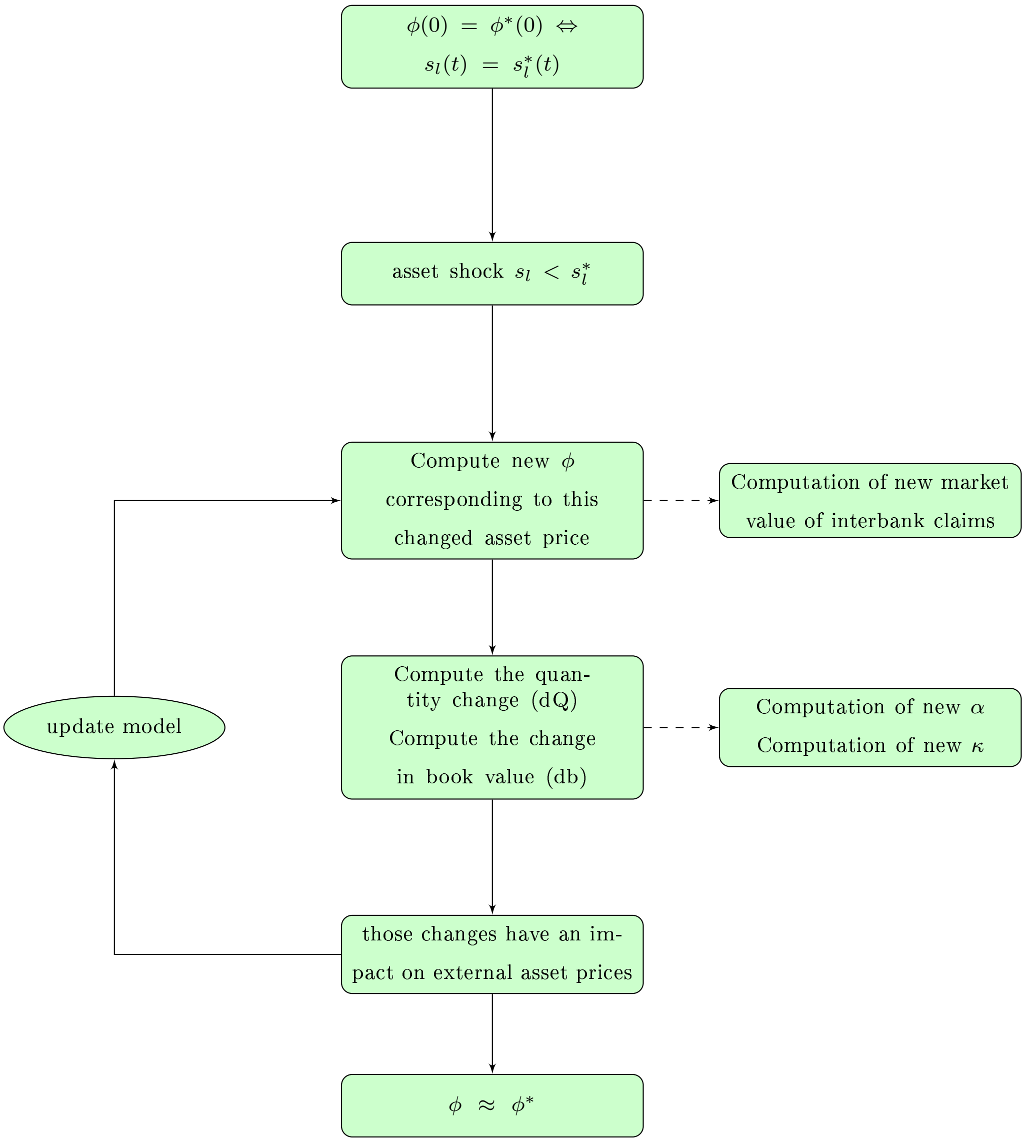


Figure 11: Algorithm[1]

A.2 Code

For simulation purposes we used 'R' as it is open source and provides sufficient features. As we wanted to solve systems of n equations in n unknowns we used the R-Package *rootsolve* by Karline Soetaert [9] and in particular the *multiroot*-function. This function can be used to solve our problem of n equations in n unknowns, it estimates the root of the equations, i.e. variable values where all function values are zero. The function assumes a full Jacobian matrix, and uses the Newton-Raphson method. The Newton-Raphson method or Newton method is a root-finding algorithm, that starts with an initial guess which is hopefully close to the true root, from this point we approximate the tangent line and calculate the intersection with the x-axis. Normally this point on the x-axis is a better approximation to the true root of the function than the previous guess. This procedure can be iterated to find the root.

The dynamics of the asset price has an underlying geometric Brownian motion and hence we derived a stochastic differential equation which consist of a deterministic and a stochastic part. We implement the stochastic part in the usual way, that means we assume that it is related to some noise. It is assumed that the noise follows a Gaussian behaviour, which means the noise is normally distributed.

A.3 Detailed Description and Explanation of the R-Code

As we did our simulation framework for $n = 10$ financial institutions the following code is written for $n = 10$ banks and $l = 1$ asset, but in principle its no problem to extend the code to n financial institutions. Furthermore if one wants to extend the number of assets, there have to be made some more modifications regarding the calculated portfolio values.
First we use the command

```
set.seed(123)
```

to generate reproducible output. Furthermore we define our initial variable

```
probstore()
```

with which we store all data points generated during a simulation run.
Our simulation starts with number of simulations N and the outer loop:

```
N<-2000
for (k in 1:N){
library(rootSolve)
setwd("D:/...")
data<-read.csv("xxx.csv")
```

Number of banks i and assets l

```
n<-10
l<-1
```

Assign values from loaded csv-file to variables

```
eps<-data$eps
gamma<-data$gamma
b<-data$b
h<-data$h
beta<-data$beta
r<-data$interest
```

```
targetphi<-data$leverage
sigma<-data$sigma
sigma<-sigma[!is.na(sigma)]
u<-data$u
v<-data$v

factor<-1
R<-rep(1,n)+r
beta<-0.5
T<-50
Dt<-0.01

shock<-0.9
price_begin<-rep(1,l)

W1j<-data$W1j
W2j<-data$W2j
W3j<-data$W3j
W4j<-data$W4j
W5j<-data$W5j
W6j<-data$W6j
W7j<-data$W7j
W8j<-data$W8j
W9j<-data$W9j
W10j<-data$W10j
```

Preparation of those variables, which store the changing values and which we need in the end to produce graphics

```
b_null<-b
B_all<-c(b_null)
as.array(B_all,dim=n)
b<-numeric(n*(T+1))
b<-as.vector(b_null)
```

```
phi_all<-c(targetphi)
as.array(phi_all,dim=n)
```

Now we are able to calculate the initial portfolio/asset value, therefore we set $\phi = \phi^\star$ and prepare the matrix W_{ij}.

```
phi<-targetphi

W<-data.frame(W1j,W2j,W3j,W4j,W5j,W6j,W7j,W8j,W9j,W10j)
W<-W*factor
W1<-W1j*h
W2<-W2j*h
W3<-W3j*h
W4<-W4j*h
W5<-W5j*h
W6<-W6j*h
W7<-W7j*h
W8<-W8j*h
W9<-W9j*h
W10<-W10j*h
ww<-data.frame(W1,W2,W3,W4,W5,W6,W7,W8,W9,W10)
ww<-ww*factor

portfolio_value<-(h+b-(phi*rowSums(ww/(R+beta*phi))))/phi
```

As we now know the initial price of our single asset we are able to calculate the quantity of the asset held by each bank i.

```
quantity_begin<-portfolio_value/price_begin
```

In the next step we shock the portfolio-value and then we have to calculate the corresponding ϕ to this shocked portfolio-value with the help of the earlier introduce *multiroot*-package:

```
pneu<-shock*portfolio_value
```

```
model<-function(x){
 F1=-x[1]+(h[1]+b[1])/ (sum(pneu[1])+ (W1[1]/(R[1]+beta*x[1]))+ ...
  + (W1[10]/(R[10]+beta*x[10])))
 ...
 F10=-x[10]+(h[10]+b[10])/ (sum(pneu[10])+ (W10[1]/(R[1]+beta*x[1]))+ ...
  + (W10[10]/(R[10]+beta*x[10])))
c(F1=F1,F2=F2,F3=F3,F4=F4,F5=F5,F6=F6,F7=F7,F8=F8,F9=F9,F10=F10)
}
ss<-multiroot(f=model,start=c(0,0,0,0,0,0,0,0,0,0))
phi<-ss$root
phi_all<-c(phi_all,phi)
```

Now we define $N * T$ normally distributed random variables and start to calculate the next book value and quantities in asset

```
Z<-rnorm(N*T)

kappa<-b/(b+h)

mu<-(eps/kappa*phi)*(targetphi-phi)/(1-targetphi)

##Calculation of next bookvalue##
#################################
B_next<-b+mu*b*Dt+u*sqrt(Dt)*Z[k]

##Store the calculated bookvalue##
##################################
B_all<-c(B_all,B_next)
b<-B_next

pp<-matrix(pneu,n)

w<-W*h/(R+beta*phi)
sumw<-t(matrix(rep(colSums(w),each=l),l))
```

```
sump<-t(matrix(rep(rowSums(pp),each=l),l))
alpha<-pneu/(sump+sumw)
alpha

qmu<-(eps/alpha)*(targetphi-phi)/(1-targetphi)

##Price-shock##
###############
price<-rep(1,l)*shock

##initial quantity##
####################
Q<-pneu/price

##Store calculated price, Declaration of variables##
####################################################
price_null<-price
price_all<-c(price_null)
as.array(price_all,dim=l)
price<-numeric(n*(T+1))
price<-as.vector(price_null)

##Store calculated quantity, Declaration of variables##
#######################################################
Q_null<-Q
Q_all<-c(Q_null)
as.array(Q_all,dim=n)
Q<-numeric(n*(T+1))
Q<-as.vector(Q_null)

##Calculation of next quantites##
#################################
Q_next<-Q+qmu*Q*Dt+v*sqrt(Dt)*Z[k]
```

```
Q_all<-c(Q_all,Q_next)
Q<-Q_next

Qas<-colSums(qmu)

##Calculation of price##
########################
price_next<-price+gamma*Qas*price*Dt+sigma*sqrt(Dt)*Z[k]
price_all<-c(price_all,price_next)
price<-price_next
```

After a first calculation of our initial portfolio-value and corresponding new ϕ_i we calculate the book values b_i , quantities Q_i and finally the resulting asset price. With those values we start now our "simulation"-year, meaning that we now go into the loop representing the upcoming $t = 50$ time steps:

```
for (i in 1:T){

p<-matrix(c(Q*price),n,1)

model<-function(x){
 F1=-x[1]+(h[1]+b[1])/ (sum(pneu[1])+ (W1[1]/(R[1]+beta*x[1]))+ ...
  + (W1[10]/(R[10]+beta*x[10])))
 ...
 F10=-x[10]+(h[10]+b[10])/ (sum(pneu[10])+ (W10[1]/(R[1]+beta*x[1]))+ ...
  + (W10[10]/(R[10]+beta*x[10])))
c(F1=F1,F2=F2,F3=F3,F4=F4,F5=F5,F6=F6,F7=F7,F8=F8,F9=F9,F10=F10)
}
ss<-multiroot(f=model,start=c(0,0,0,0,0,0,0,0,0,0))

phi<-ss$root
```

[13] In every time step we have to check if one of the ϕ-values reached 1 representing systemic default. If one or more banks run into default all

[13]we reduced the code of this function to keep it readable

corresponding values have to be adapted. Finally we proceed calculating the new book values, the new quantities of external asset and the asset price

```
check<-(phi<1)*1
Wz<-W*check
Wneu<-t(check*t(Wz))
wwz<-ww*check
wwneu<-t(check*t(wwz))
W1<-wwneu[,1]
W2<-wwneu[,2]
W3<-wwneu[,3]
W4<-wwneu[,4]
W5<-wwneu[,5]
W6<-wwneu[,6]
W7<-wwneu[,7]
W8<-wwneu[,8]
W9<-wwneu[,9]
W10<-wwneu[,10]

phi_all<-c(phi_all,phi)
b<-b*check
h<-h*check
eps<-eps*check
kappa<-b/(b+h)

kappa<-rapply(as.list(kappa),f=function(x)ifelse(is.nan(x),0,x),
how="replace")
kappa<-t(matrix(as.numeric(kappa),10))

mu<-(eps/kappa*phi)*(targetphi-phi)/(1-targetphi)

mu<-rapply(as.list(mu),f=function(x)ifelse(is.nan(x),0,x),
how="replace")
mu<-t(matrix(as.numeric(mu),10))
```

```
B_next<-b+mu*b*Dt+u*sqrt(Dt)*Z[i]
B_all<-c(B_all,B_next)
b<-B_next

w<-Wneu*h/(R+beta*phi)

price_null1<-matrix(rep(price,each=n),n)
price_null1<-price_null1*check

pp<-matrix((matrix(Q,n)*price_null1),n)

sumw<-t(matrix(rep(colSums(w),each=l),l))
sump<-t(matrix(rep(rowSums(pp),each=l),l))
alpha<-pp/(sump+sumw)
alpha

alpha<-rapply(as.list(alpha),f=function(x)ifelse(is.nan(x),0,x),
how="replace")
alpha<-t(matrix(as.numeric(alpha),10))

qmu<-(eps/alpha)*(targetphi-phi)/(1-targetphi)

qmu<-rapply(as.list(qmu),f=function(x)ifelse(is.nan(x),0,x),
how="replace")
qmu<-(matrix(as.numeric(qmu),10))

Q_next<-Q+qmu*Q*Dt+v*sqrt(Dt)*Z[i]
Q_all<-c(Q_all,Q_next)
Q<-Q_next

Qas<-colSums(qmu)
```

```
price_next<-price+gamma*Qas*price*Dt+sigma*sqrt(Dt)*Z[i]
price_all<-c(price_all,price_next)
price<-price_next
}
```

After this inner loop we need a function which allows us to store those values of the particular run, where each of the banks run into default, for further analysis.

```
probphi<-t(matrix(phi_all,n))
l1<-Position(g<-function(d){d>1},probphi[,1])
l2<-Position(g<-function(d){d>1},probphi[,2])
l3<-Position(g<-function(d){d>1},probphi[,3])
l4<-Position(g<-function(d){d>1},probphi[,4])
l5<-Position(g<-function(d){d>1},probphi[,5])
l6<-Position(g<-function(d){d>1},probphi[,6])
l7<-Position(g<-function(d){d>1},probphi[,7])
l8<-Position(g<-function(d){d>1},probphi[,8])
l9<-Position(g<-function(d){d>1},probphi[,9])
l10<-Position(g<-function(d){d>1},probphi[,10])
temp<-c(l1,l2,l3,l4,l5,l6,l7,l8,l9,l10)
temp
probstore<-c(probstore,temp)
```

If we want an graphical output we make some further lines of code, here as an example if we want to draw just the behaviour of ϕ_i. In the same manner we could draw the change in book values or quantities of assets of bank i.

```
phis<-as.list(paste('phi',1:n,sep=''))
PHI<-matrix(phi_all,nrow=n,dimnames=list(phis))
phi1<-as.vector(PHI[1,])
phi2<-as.vector(PHI[2,])
phi3<-as.vector(PHI[3,])
phi4<-as.vector(PHI[4,])
```

```
phi5<-as.vector(PHI[5,])
phi6<-as.vector(PHI[6,])
phi7<-as.vector(PHI[7,])
phi8<-as.vector(PHI[8,])
phi9<-as.vector(PHI[9,])
phi10<-as.vector(PHI[10,])


plot(phi1,type="l",col="aquamarine",ylim=c(min(phi_all),max(phi_all)),
xlab="t",main="epsilon=0.2/gamma=0.3",sub="leverage=0.6",ylab="phi")
lines(phi2,type="l",pch=22,lty=2,col="green")
lines(phi3,type="l",pch=22,lty=2,col="blue")
lines(phi4,type="l",pch=22,lty=2,col="brown")
lines(phi5,type="l",pch=22,lty=2,col="red")
lines(phi6,type="l",pch=22,lty=2,col="green")
lines(phi7,type="l",pch=22,lty=2,col="blue")
lines(phi8,type="l",pch=22,lty=2,col="brown")
lines(phi9,type="l",pch=22,lty=2,col="red")
lines(phi10,type="l",pch=22,lty=2,col="green")

abline(h=1)
```

We use the following lines of code to store the generated data points in a txt-file, which we can use later on for more statistical analysis.

```
get<-probstore
gmat<-t(matrix(get,nrow=10))

gmat[is.na(gmat)]<-0
allstep.default<-gmat
allstep.default
prob.step.no<-colSums(gmat)/(N*T)
prob.step.no
```

```
mgm<-apply(gmat,2,g<-function(x){x>0})

mg<-mgm*1
prob.default<-colSums(mg)/(N*T)
prob.default

write.table(c(allstep.default,prob.step.no,prob.default),"xxx.txt")
```

Statistical analysis
We load the generated txt.file in R again and modify it in the following manner: We just use those data points referring to default time steps. In a next step we arrange those data points in an $N \times i$-matrix and count how many defaults happened in each of the N simulations. In this matrix we substitute all zeros by 1000 and sort the rows of the matrix in an increasing order. After that step we re-substitute all 1000s with zero again.

```
x1<-read.table("xxx.txt", header = TRUE, nrow =
nrow(read.table("xxx.txt", header = TRUE)) - 20)
N<-2000
x2<-(matrix(x1$'',N))
x2[x2==0]<-1000

x3<-10-floor(rowSums(x2)/1000)

reihenfolge<-c()
for (k in c(10,9,8,7,6,5,4,3,2,1)){
for (i in 1:N){
xx<-sort(x2[i,],TRUE)[k]
print(xx)
reihenfolge<-c(reihenfolge,xx)
}
}

neus<-matrix(reihenfolge,ncol=10)
```

```
zaehler<-c()
for(j in 1:N){tempi<-sum(neus[j,]<=neus[j,1])
zaehler<-c(zaehler,tempi)
}
number<-zaehler

neus[neus==1000]<-0
```

With the upcoming function we are able to identify the time step of initial default, how many banks run into this initial default and after how many time steps the next default happens.

```
differ<-c()
for (j in 1:N){ifelse(neus[j,]==0,temp<-diff(append(0,neus[j,])),
temp<-diff(append(0,neus[j,])))
differ<-c(differ,temp)
}
write.table(differ,"differ1a.txt")
y1<-read.table("differ1a.txt",header=T)
y2<-matrix(y1$'',10)
y3<-t(y2)
y3[y3<0]<-0
step<-colSums(y3)/(N-sum(y3[,2]<1))
steps<-step[2]
steps[is.na(steps)]<-0

step2<-colSums(y3)/(N-sum(y3[,3]<1))
steps2<-step2[3]
steps2[is.na(steps2)]<-0

write.table(c(y3[,1],number,rep(steps,N),rep(steps2,N),x3),"xyx.csv")
```

We end up with a csv-file which stores the first default, how many banks are run into this first default at the same time, average time step till the second default, average time step till third default and the total number of defaults

per simulation N.
To display the analysed data in a good looking way we have use the following:

```
setwd("D:/...")
t1a<-read.table("xyx.csv",header=T)
A1<-matrix(t1a$'',N)

allin<-data.frame(A1,...)
f <- function(x) c( mean = mean(x))
erg<-t(matrix(apply(allin,2,f),3))
```

References

[1] Tasca P., Battiston S.: *Market Procyclicality and Systemic Risk*, Chair of Systems Design, ETH Zurich, Switzerland

[2] Kaufman George G.: *Banking and currency crises and systemic risk:Lessons from recent events*, Federal Reserve Bank of Chicago

[3] Jean-Pierre Landau: *Procyclicality - what it means and what could be done*, Remarks by Mr Jean-Pierre Landau, Deputy Governor of the Bank of France, at the Bank of Spain's conference on Procyclicality and the Role of Financial Regulation; Madrid, 4 May 2009

[4] Adrian Tobias, Federal Reserve Bank of New York, Hyun Song Shin, Princeton University : *Liquidity and Leverage*, Version: May 2008

[5] Adrian Tobias, Federal Reserve Bank of New York, Hyun Song Shinm Princeton University: *Procyclical leverage and Value-at-Risk*, Staff Report No. 338, July 2008, Revised August 2013 Staff Reports

[6] Alexander J. McNeil, Rüdiger Frey, Paul Embrechts: *Quantitative Risk Management: Concepts, Techniques and Tools*, Princeton University Press, 2005

[7] Iacus Stefano M.: *Simulation and Inference for Stochastic Differential Equations*, Springer Series in Statistics

[8] Shreve S.E.: Stochastic Calculus for Finance II, Continuous-Time Models, Springer Science + Business Media New York, 2004

[9] Soetaert K.: *Package 'rootSolve'*, 24. April 2013, Version 1.6.4

Abstract German

Ziel dieser Arbeit ist es systemisches Risiko in unterschiedlichen Netzwerkstrukturen zu untersuchen. Stellen Sie sich ein Dominoreihe vor, wenn ein Stein umfällt, könnte, die richtigen Parameter vorausgesetzt, der sogenannte Dominoeffekt auftreten. In dieser Arbeit möchten wir analysieren, ob und wie unterschiedliche Netzwerkstrukturen diesen Dominoeffekt beeinflussen. Diese Analyse findet anhand von Finanzinstituten statt, welche unsere Grundlage bilden. Diese Banken haben zumindest ein Finanzinstrument (z.B. eine Anleihe) gemeinsam und halten gegenseitig Forderungen. Diese Interbankenforderungen wurden anhand von Matrizen dargestellt, welche der Schlüssel der Systemvernetzung der Banken waren, denn die unterschiedlichen Matrizeneinträge vertreten wie individuell und unterschiedlich Banken miteinander verbunden sind. Weiters, wurde eine Abwertung der Anleihe simuliert und analysiert, wie unterschiedlich die Banken in den verschiedenen Netzwerkstrukturen über einen gewissen Zeithorizont hinaus reagieren.

Abstract English

In this thesis we wanted to model systemic risk and how it works in different network structures. Imagine a row of dominoes, if one stone falls there might be a cascading effect such that (parts or) all other stones will fall sooner or later, depending on how close they are related to each other. In this thesis we wanted to analyse if and how different network structures influence such cascading effects. Our basic setting considered financial institutions, also known as banks. Those banks have at least one financial instrument (asset) in common and also hold some claims on each other. We described these interbank claims with the help of a matrix, which is the key to the interconnectedness of the banks in the system, because the different entries of the matrix represent how the individual banks are related to each other. Furthermore we simulated a single shock on the common asset and analyse how the different network structures of financial institutions behave afterwards during a certain time period.

CV

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