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Monetary macroeconomic modeling, simulation and control

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Oppgavetekst

Build a macroeconomic model based on monetary stocks and flows.
Include a gvt. and a central bank. Include the possibility of asset bubbles. Simulate and check for crisis mechanisms.
Discuss alternative stabilisation measures.

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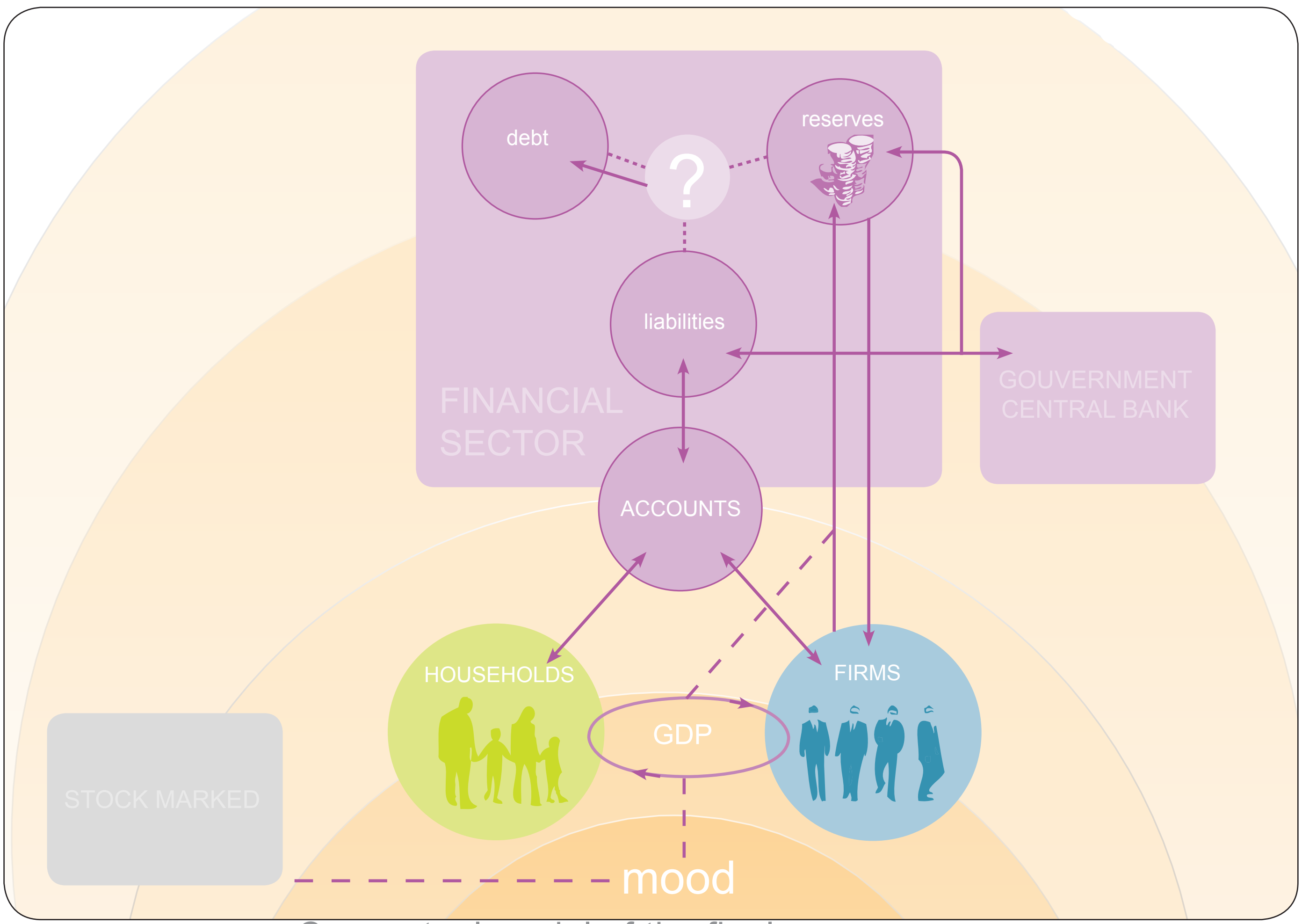
Macro economy

Monetary macroeconomic modelling, simulation and control



Conceptual model of the final macro economy

1. Abstract

In this report a dynamic macroeconomic model is built in an incremental manner. The economic units are built on an understandable tank analogy that can be described with the use of first order differential equations.

The units are realised in the form of block diagrams in Mathworks Simulink®. Simulink block diagrams gives an explicit mathematical formulation of the model, thereby making all the equations, the model consists of, readily available.

The economy's ability to service debt in different settings is tested. The first part of this model is kept simple, so as to make it understandable to people with different backgrounds. Then model realism gets increased priority, but still it is considered vital for the usefulness of the model that the reader truly understands it. However, the fundamental point of the thesis is made before model complexity should become an issue.

The foundation for the thesis, which is the work of Trond Andresen is represented in an oral manner, with simple mathematics at the base.

The model is built by adding new elements to the model throughout the report, giving an understanding of the individual parts of the model, before they are merged together and the complexity increase. A system that models economic mood is implemented, which has an amplifying effect on the current trend in the economy, and adds new dynamics because of its lag to the actual state of the economy. Real economy deposits are implemented as a “counterweight” to the financial sectors loan issuing. Insolvency in both the real economy and the financial sector is implemented. They both make up balancing loops, setting limits on real economy earnings on deposits, as well as bank’s earnings on issued loans. They both also prevent the model from displaying impossible dynamics under extreme conditions. Banks lending is limited by capital requirement, set by the bank of international settlements, BIS. An regulating agent is also implemented, to guide the economy and keep it on track. It imposes a reserve requirement on the financial sector, which it makes the bank sector uphold through open market operations. Finally a stock market with innate oscillations , developed by Trond Andresen, is implemented in the model. It is not connected to the economy via vessel dynamics, rather it influence the economy through the implemented mood system. This makes the economy more less robust, and induces oscillations in to the economy in otherwise static settings.

The economy appear as very fragile, just minor variations in interest rates makes for large fluctuations in the debt burden. The model exhibits path dependence. These variations makes the economy lock into states from which it does not recover.

Modelling dynamic systems, especially nontechnical is an imperfect try and fail science. The model will always contain flaws and shortcomings. The best we can do is try to minimize the flaws in the elements that are important for answering the questions we want answered.

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2. Preface

As a master candidate in technical Cybernetics writing an economic thesis without a background in classical economics or any other economic theory, it is safe to say I have had quite a challenge. It has however been great fun, and I have learned more the last couple of months than any of the years at the university. I am glad i took the challenge, and i would do it again in a heartbeat.

I would like to use the rest of this chapter to offer my gratitude to the people who helped me in this process. First I i would like to thank my teaching supervisor, Trond Andresen, who opened an entirely new door for me, and gave me my interest in system dynamics, and now also macroeconomics. I would also like to thank him for his guidance through this process. My next thanks goes to Unni at the "kyb" institute office, for being so understanding and helpful, when I needed to submit the masters graduation form prior to delivering my thesis. I would also like to thank John Sterman, simply for being so brilliant. At last, but by no means least, i would like to thank my darling girlfriend Helene. Thank you for pushing me through when I lacked the willingness to work, and for being such a fantastic girlfriend the last weeks before deadline. I am really thankful that you introduced me to Indesign™, and helped me with the layout of my master thesis. And of course for creating the fabulous conceptual model of the final macroeconomic model. I love you.

3. Introduction

1. THESIS
2. INTRODUCTION
3. STRUCTURE

3.1 THESIS

The problem and goal

Title: **Monetary macroeconomic modelling, simulation and control**

"Build a macroeconomic model based on monetary stocks and flows. Include a government and a central bank. Include the possibility of asset bubbles. Simulate and check for crisis mechanisms. Discuss alternative stabilisation measures."

The goal is to design a macro economic model that asserts the development of the debt burden in a modern economy, and examine any crisis mechanisms that might evolve as debt burden increases. Different factors and relations that might influence the debt situation, are implemented, examined and then discussed. It is important to emphasise that this is a model and is therefore, by the correct definition of the word, not meant to depict reality. Its purpose is to shed light on some issues, and perhaps provide some answers to these issues.

3.2 INTRODUCTION

The subject

A macro economy can be viewed as a collection units interfering with each other, with a relationship that evolves over time. What we call a dynamic system.

Conventional social economics, historically has seen and modelled the world as static, as derived by Adam Smith in the 1700s. We would like to remove ourselves from that way of thinking, as it is a gross simplification, and in many cases plain wrong. If this process has taught me one thing, it is that the economy is definitely not static.

Dynamic systems are, unfortunately, conceptually harder to understand. But they are *substantially* harder to predict the behaviour of. This tends to discourage traditional economist from learning and understanding this new way of thought. Terms like "path dependence" or "multiple equilibria" make neoclassical economists tremble. These terms will reappear in this paper. In system dynamics, the simple linear relations that we are used to employ in our daily life are rare. In system dynamics we cannot use algebraic equations to describe system's dynamics, instead we use differential equations. These equations generally don't give algebraic solutions, instead they depend on computer power and simulation tools. Neither do they give any particular help in the conceptual understanding of dynamic systems. It does not take much complexity for it to be extremely difficult to predict their behaviour. However block diagrams will help considerably (Andresen et al, 2003)

Block diagrams are not only used to create an overview, and help give a general understanding of a system, but can be programming language in it self.

There exist different tools of developing block diagrams, with properties that reflect their respective branches of business. These tools are used in everything from control engineering, software programming, economics, climate research and biological studies. They have a common thread, in that they create a interface between the user, developer or customer, and the differential equations that make up the system. One of these tools is Mathworks' Simulink® (Mathworks, 2008),which was the authors the tool of choice in the making of this thesis. Its most characteristic trait is that it explicitly show the mathematical equations making up the model. Very handy for technical uses. Others include Ventana Systems "Vensim" (Ventana, 2008), Isee's "iThink" (Isee, 2008) and Studio7's locally developed "Powersim" (Studio7, 2008). Many of these have a main emphasis on nontechnical applications, such as modelling production lines or organisational structures, they are used to model climate change or other climatic situations, as well as examining the course of an epidemic outbreak, or they can be used to model macroeconomic issues.

The master candidate chose Simulink®, because of previous experience through the course of his education, as well as it being the teaching supervisor's tool of choice.

3.2 STRUCTURE

The report structure

Introduction

This chapter is the introductory part of the report. Here the premise of the thesis presented, as well as goal and motivation behind it.

Foundation

This is where the very foundation of the thesis is made. It is where the building blocks of the model are introduced and explained. This chapter help give the basic understanding needed to benefit from reading the entire report. It does not form a part of the master candidate's work, rather it is a reformulation of the work of teaching supervisor Trond Andresen. Readers well versed in Simulink® and system dynamics, may omit this chapter.

Composition

This chapter is where the core of the thesis is found. In this chapter the foundation lain in the previous chapter is used to gradually build an economic model. This incremental way of building the model makes for a rational an easy to understand development, from start to finish. First simple models are examined, simulating different scenarios, and discussing the results, before adding complexity. This should give the reader an idea of what impact the addition of new loop, relationship, or economic agents will have on the model, throughout the process. This reflects the way the candidate went about building the model, thereby it might put the reader in the position of the candidate. After every new addition to the model, different situations are simulated and the results are subsequently discussed and if possible, ended with a concluding remark.

Further work

Possible measures to improve on the model will be briefly mentioned and discussed here.

Conclusion

Conclusions for the thesis as a hole are provided here. The problem definition will be revised and we will evaluate to what degree the report gives answers to the problem.

4. Foundation

1. BUILDING BLOCK
2. STRUCTURE
3. TOOL
4. AGGREGATION

FOUNDATION FOR THE THESIS

The following chapter builds directly on the work of amanuensis Trond Andresen's work in the papers; "A Block Diagram Approach to Macroeconomics, and why IS/LM is fatally flawed", "The Dynamics of Long-range Financial Accumulation and Crisis", and "The Macroeconomy as a Network of Money-Flow Transfer Functions",

The presentation of the material has been altered, and somewhat simplified to fit the scope of this paper, but is essentially the work of Andresen. The purpose being, in a plain and simple way, to give the reader the necessary knowledge and understanding to appreciate this paper.

4.1 BUILDING BLOCK

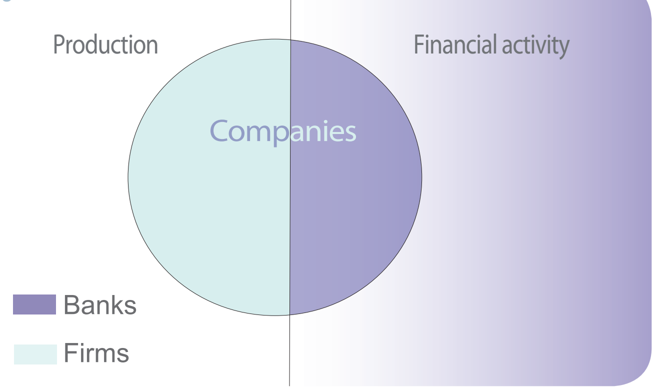
The economic agent

A firm, a household, a bank and a government acts as an agent in the economy, and will from now on be used to describe such economic agents.

A bank is an institution that deals in money and its substitutes and provides other money-related services. It is a financial intermediary, that accepts deposits and makes loans. It derives a profit from the difference between the costs of attracting and servicing deposits and the income it receives through interest charged to borrowers or earned through securities (Munn, 2008).

In the start of this paper however, it also includes other financial institutions and “all types of firms which make their profits solely from financial activities” (Andresen, 1999), such as finance companies, mortgage companies, insurance companies, pension funds, and investment banks. These often go by the name non-banks or NBFCs (Non banking financial company). Their functions are similar to that of a bank, but without meeting the legal definition of a bank (it does not hold a banking license), and cannot accept demand deposits.

Figure 1. Banks VS firms



A firm, in this paper, is simply a company that does not fit this definition of a bank.

A household comprises of all the economical aspects of a family, a couple or a private individual.

A government, or more specifically, *the* government is a regulative economic agent existing of both a government and the economy’s central bank. Their close relation makes it reasonable to model them as a single economic agent. The reasoning behind this simplification will be discussed in chapter 5.7

1) Fotnoter

We noe need a way to represent these agents, so that they display a qualitative behaviour that fits reality.

Money flows in to the agent, either in the form of wages for a household, or turnover for a firm. The money would have to accumulate in the agent, but after some time flow out as rent and daily expenses for the household, and as wage bills and debt service for the firm. There are to ways we can represent an equivalent behaviour.

One analogy is an open tank with a valve in the bottom: A fluid F_i flows in, and the tank starts filing up. As the tank fills up and M increases, the pressure on the valve rises and so the fluid F_o flows out of the tank.

The other analogy is represented by a pipe. Fluid F_i comes in one end and flows out the other (F_o). The amount of fluid in the pipe is termed M.

Figure 2. Tank analogy (Andresen, 1999)

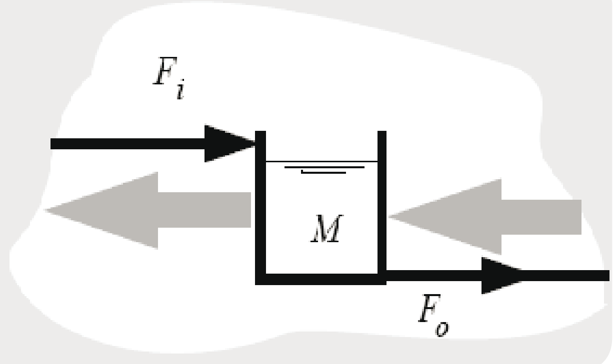
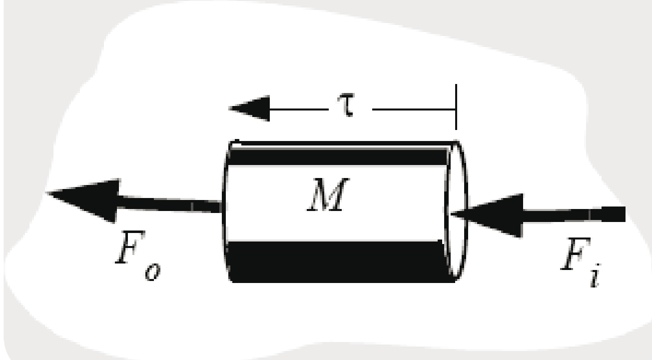


Figure 3. Pipe analogy (Andresen 2000)



Open tank analogy

If at a given time, a constant flow of fluid starts, the tank will gradually be filled. As it fills, the flow out of the tank will increase proportionally to the amount of fluid in the tank. At a certain level M, it will reach an equilibrium, where the inflow F_i will be equivalent to the outflow F_o.

To draw an economic parallel, this can be compared to your very first job. Your income suddenly goes from nothing to something. As you never have had any money before, it takes time to adjust your consumption, but gradually it reaches the level of your income, and we have equilibrium.

Now, if the flow of fluid suddenly was to stop, the tank would slowly be drained, at a falling rate, as the pressure on the valve drops. In the economic parallel, you would now have lost your job, and with it; your income. Even though your have no income, you are not able to stop your spending at once. As your account empties, you cut your expenses one by one, just to realize one day that you are broke.

Figure 4. Tank step response up (Andresen, In progess)

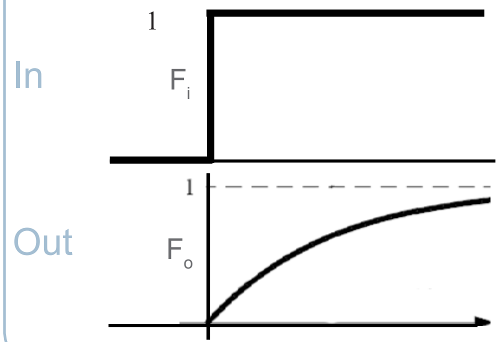
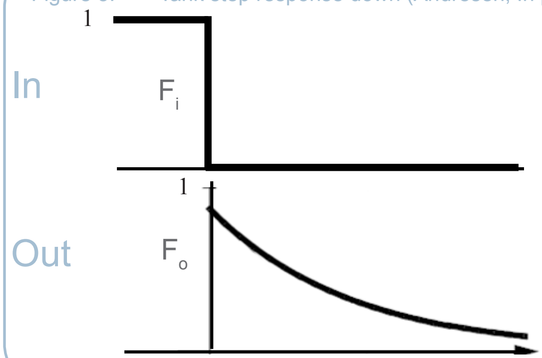


Figure 5. Tank step response down (Andresen, In progess)



Pipe analogy

An equivalent analysis for the pipe analogy: At a given time a constant flow of fluid F_i runs into the pipe, and it fills up gradually. When the water reaches the end of the pipe, it runs out at (F_o) the same rate as the inflow. We have instant equilibrium.

In the economic parallel, this would suggest that your income suddenly rises to a constant level. Instead of slowly increasing your spending, you contemplate a plan. Some time later you start spending the exact amount of money that you are earning (see figure 6.).

If the flow of fluid F_i into the pipe suddenly stops, the flow out F_o continues at the approximately same rate, until it instantaneously stops when the pipe is empty.

Economically this would mean that you maintain your consumption, even though you have lost your income. You continue like this until your account is completely empty. This corresponds to the responses with plain time delays.

The author is of the opinion that the tank representation has a far more appropriate dynamic, and gives an intuitively better understanding of how economic agents act. It is also easier to se that the level in the tank, represents the stock M. As a final remark, the dynamic of the tank can be represented by the use of differential equations (Ansresen,1999).

The tank dynamics are in principle only valid for continuous systems, but in the economy money is transferred in discreet packages, not in continuous flows. That being said, given the magnitude of the economical system (an entire nation or region) and its large time horizon, it is considered a reasonable approximation that money travels continuously.

As of now, all flows of money between agents are regarded as continuous.

Figure 6. Pipe step response up (Andresen, In progess)

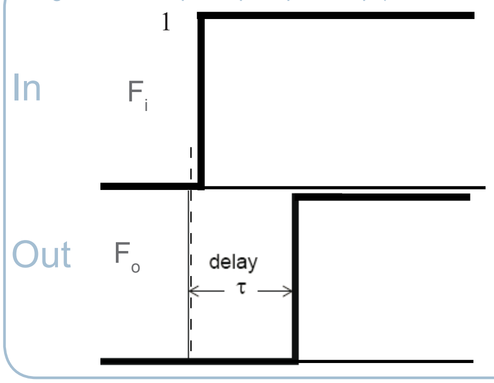
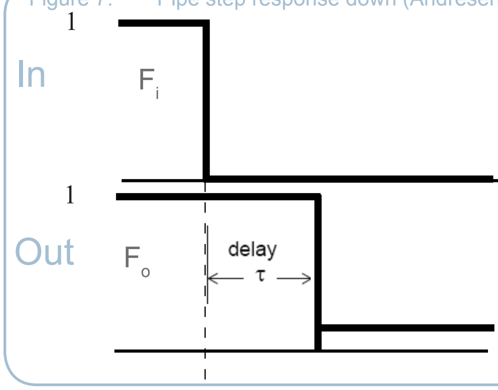


Figure 7. Pipe step response down (Andresen, In progess)



4.2 STRUCTURE

The mathematical formulation

Now we have a way of representing the agents in the economy, each with an inflow and outflow, and a stock of money. This stock has its origin in the delay between inflow and outflow. If money was spent the second it was acquired, the inflow and outflow would have been one and the same, and this buffer would not have existed. In reality there are limits to to how low this delay may become; the minimum time a firm or a person needs to make decisions or minimum time a purchase takes to be completed.

The delay can best be described as the time money spends in an agent, from arrival to departure. It also represents the time decision makers need to make their decisions and execute their tasks. Given that in- and outflow are equivalent we can conclude that the amount of money in an agent at a given time is $M=F\tau$

However, in general, inflow an outflow are different, therefore the equation is invalid. We want the economic agent to display the dynamic equivalent to a tank (Figure 4 and figure 5).

With the use a conservation law we get equation

[Change in total volume] = [inflow] - [outflow]:

(1): $$\dot{M} = F_i - F_o$$

Outflow F_o propotional to M:

(2): $$F_o = M \cdot \frac{1}{\tau}$$

(1): Change in volume equals the difference of what comes in and what goes out.

Each individual unit have no ability to control the inflow of money, they can only control the outflow, in other words their own consumption.

If we choose the outflow proportional to total volume we get equation (2),and the dynamic that we sought (see figure 4 an figure 5).

With this formulation we have now made τ a control variable: By changing τ we change the outflow from the agent. τ no longer signify time delay, but time lag or inertia. We can now also define the inverse of τ, which is $1/\tau$: the local velocity of money flow. The lower the time lag τ, the higher the velocity.

Lag is often denominated with a time constant T or τ. Since we no longer will use the term time delay, and there is no need to distinguish between the two, we will use τ to signify time lag.

τ is defined as the time where the tangent in t=0 crosses the functions convergence value (which often is zero). By one τ the stock is reduced by 63%, by 2τ its down to 86% and by 3τ it is 95% reduced. Mathematically the stock will never reach 100% and be entirely empty, but after 5τ the approximation is regarded as satisfactory.

By inserting the new outflow (2) into the conservation law (1), we get (3), the final dynamics of our economic agents. Which is the step response shown in figure 9 (Andresen, In progess)

Equation (3) is a linear differential equation. Linear differential equations can be Laplace transformed, so that they can be solved using simple algebra. The transfer function from input to output F_i to F_o is (4)

For a detailed procedure on how to find the Laplace transferred, see Andresen (2007).

In this paper, the notion of the transfer function will not be used further, as non linearities will be introduced at a later time, at which point the the frequency plane and transfer functions are of no use to us. Also, transfer functions are intuitively harder to understand for the untrained in linear system dynamics. The S-plane however, will be used further, to explain what will be the main tool of this thesis; the block diagram.

Figure 8. The time constant (Andresen, In progess)

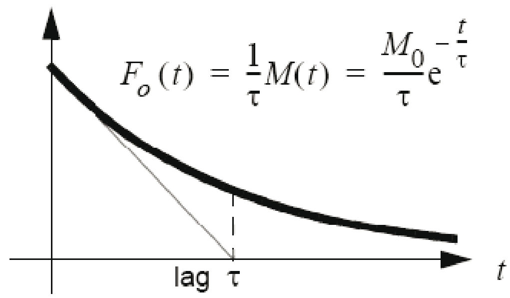
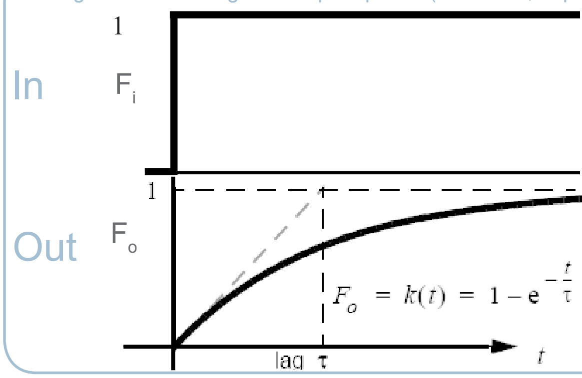


Figure 9. An agents' step response (Andresen, In progess)



Equation (2) inserted in (1)

(3): $$\dot{M} = F_i - M \cdot \frac{1}{\tau},$$

Laplace transformation of (3)

(4): $$H_{oi}(s) = \frac{1}{1+Ts}$$

4.2 TOOL

The block diagram

We want to represent an economic agent by the use of a block diagram, the software of choice is Mathworks' Simulink. We have the following framework in which an agent must be formed:

Conservation of money: $\dot{M} = F_i - F_o$

Proportional outflow. $F_o = M \cdot \frac{1}{\tau}$

Equals: $\dot{M} = F_i - M \cdot \frac{1}{\tau}$,

Which produce the dynamics of a tank with an inflow and outflow through a valve. A tank, or a stock may be represented by a integrator. Inflows and outflows are rates, that both over time are integrated to an amount, here represented by the hatched area under the graphs.

The difference between inflow and outflow, is the hatched area in figure 12. This area corresponds to the total amount (of fluid or money) in the stock at time T.

Figure 10. Integrating inflow

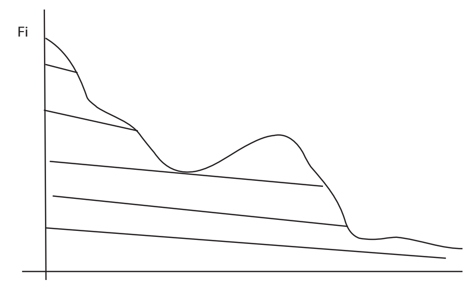


Figure 11. Integrating outflow

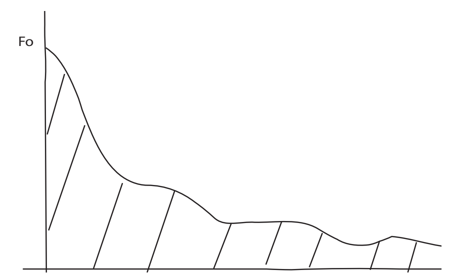
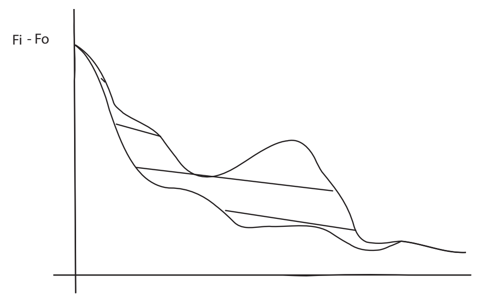


Figure 12. Integral inflow - Integral outflow



Which fits the tank analogy:

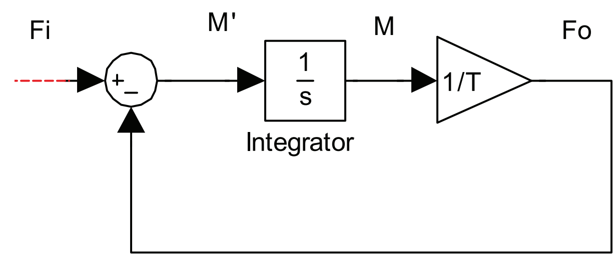
[Total fluid volume] = [Fluid flowing in over time] – [Fluid flowing out over time]. Which is equal to the integral of (3) and gives us (5)

Integrating (3):

(5): $$M = \int F_i - M \cdot \frac{1}{\tau} dt$$

Continuous time blocks are represented in the S-plane in Simulink. An integrator in Simulink, is therefore 1/S. This gives the simple model in figure 13.

Figure 13. Single agent block diagram



Only a 1/T part of the stock M leaves as outflow, and is therfore fed back to the integrator with a negative sign. In a system with many agents, the outflow F_o could and would be coupled with other agents, and eventually recirculate back to F_i as a part of an economic cycle.

Figure explanation:

M' signifies derivative M.

The triangle is a gain: [Output] = [input] • [gain]

What comes into the integrator changes the level M:

- F_i: Positive sign, increases M
- F_o: Negative sign, decreases M
- F_i - F_o: The total change on M

The output on the integrator measures the level M.

Based on the figure 13 and the figure explanation we can easily backtrack to the starting point. By setting M equal to all that comes in to the summation sign vi get (3): $\dot{M} = F_i - M \cdot \frac{1}{\tau}$,

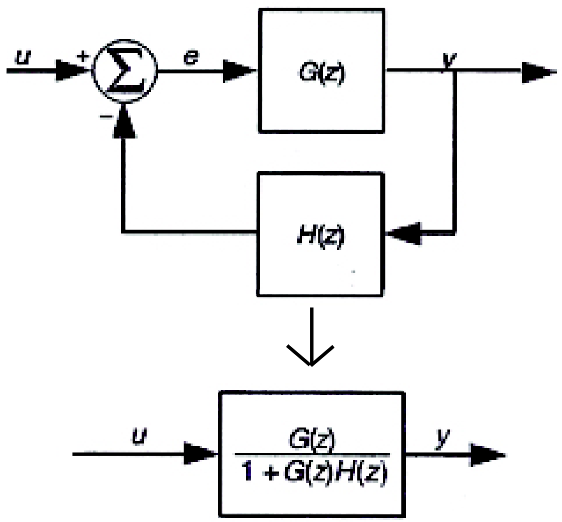
We can also reduce the block diagram by using the rule of collapsing feedback loops. Figure 14 shows how this is done. In this case we have:

$H(s) = 1$ and $G(s) = \frac{1}{s} \cdot \frac{1}{T}$

Which gives us the same transfer function we got by Laplace transforming (3):

Simulink does not differentiate between state-space models (time plane) and S-plane models (frequency plane), it can be used to represent both. In this paper however, we only consider state-space

Figure 14. Collapsing feedback loops (Westcott design, 2007)



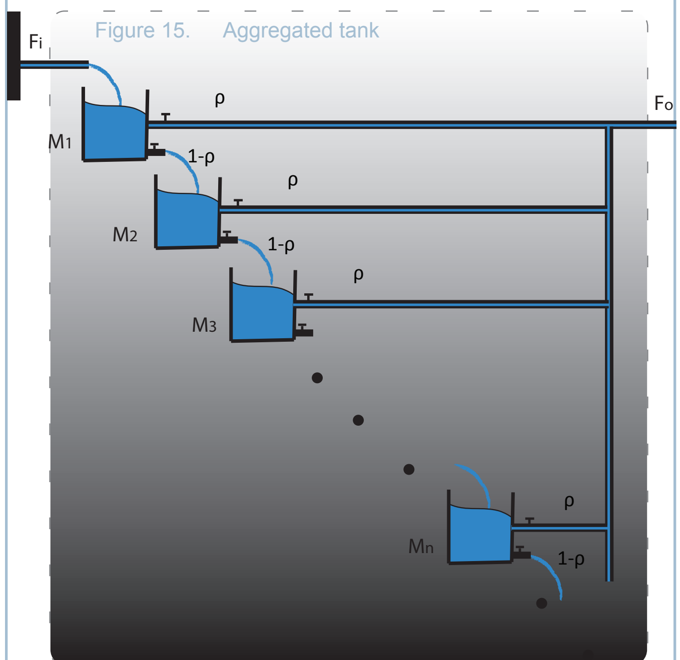
4.2 AGGREGATION

The economic sector

In order to make use of the economic agents (Andresen, 1999) derived in the previous sections, in a macroeconomic model, we need to aggregate them into economic sectors. An economic sector could be all households, banks, or firms within a confined economy, this could be a nation or an economic collaboration like EEA (European Economic Area) or even the entire world.

Each sector exists of agents of the same type, but different sizes. Both its stock, inflow and outflow may be different, as long as the ratio between them are alike, i.e they have the same time constant. With these assumptions Trond Andresen, showed that a single agent and a sector is qualitative alike. The only difference is that a sector, in general, has a larger inertia or lag τ than a single agent. For more on this proof refer to Andresen, 1998.

Figure 15. Aggregated tank



This figure shows the principle of aggregating the economic agents using a tank analogy. Since we are only interested in the input-output characteristics of the sector, we may say that each agents internal investments are made to one single agent in that sector.

5. Composition

1. FINANCIAL SECTOR
2. REAL ECONOMY
3. MERGING THE ECONOMY
4. MOOD
5. INSOLVENCY
6. BANK DEPOSITS
7. REGULATING AGENT
8. STOCK MARKET

BUILDING AND EXPLORING THE MODEL

In the following chapter a macroeconomic model that addresses the real economy's debt (burden) situation will be built. It is built in an incremental manner, starting with the most basic elements. This way the reader obtains an understanding of the individual parts of the model, before they are merged into one and the model complexity gradually increases.

The first two sub chapters 5.1 and 5.2 are recreations of Trond Andresens work in "The Dynamics of Long-Range Accumulation and Crisis" (1999) and "why IS/LM is fatally flawed" (In progress). The work is presented to suit the purpose of this paper and should be quite helpful in understanding and gaining confidence in the model that is built.

Keeping the model simple and understandable has been emphasized. It is considered vital for the usefulness of the model that the reader truly understands it. The consequences of assumptions and simplifications made throughout the process, will also be discussed. Although the complexity of the model increases throughout this chapter, the incremental manner in which this is done should make it manageable to comprehend. In addition, the fundamental point of the thesis is made long before model complexity might become an issue.

The model will abstract from production of both commodity and services. We only take the flow of money between economic sectors, and the different factors that affect these, into consideration. These factors might be a result of mental influences or definite rules or relations. The flow of money between the agents is considered instant, thus money can only exist in the agents of the economy, never in between.

5.1 FINANCIAL SECTOR

Banks and the accumulation process

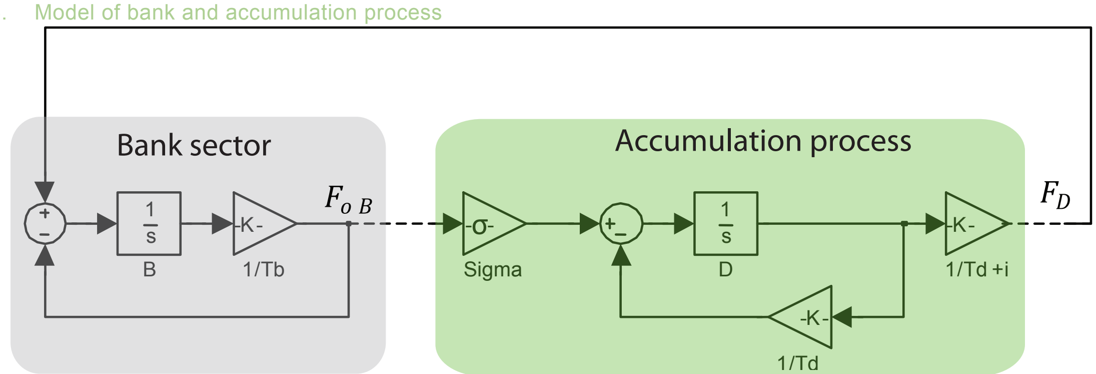
Banks have the ability to accumulate financial assets through lending money to firms or households in the real economy, and claiming interest on the debt service. In general, for the accumulation process, the term interest could be used to represent "any returns from savings or investments, including dividends on stock" (Andresen, In progress). In this paper however, we are only interested the debt burden situation. Therefore only financial claims similar or equal to loans will be considered.

In "long-range financial accumulation and crisis" (2000) Andresen calls agents with this behaviour economic "black holes". This is a fitting metaphor, in the sense that these agents drain money from the surroundings without giving much back to the economy. Black holes' hunger for profit on its every investment seems to form a self-reinforcing and potentially destructive process for the economy as a hole.

However, seeing as the term "black hole" carries a bias against these types of agents, implying that they have a negative effect on the economy, we will not use this term. Instead we will let time show if they are worthy of the title "black hole".

The following model, is based on a framework from the real world. With the chosen variables having exact meanings. The bank sector is comprised of actual banks, and the accumulation process is a written contract for the debt service, a loan agreement.

Figure 16. Model of bank and accumulation process



B	= The banks' reserves.	[currency]
D	= Accumulated debt, i.e. financial claims from the Bank sector.	[currency]
F_{oB}	= Money flow out of the bank; expenses and new loans.	[currency/time unit]
F_D	= Repayment of debt with interest.	[currency/time unit]
i	= Interest rate.	[%]
σ	= Financial reinvestment coefficient; determines share of F_{oB} to be reinvested.	[%]
T_B	= Circulation inertia; mean lag for the entrance and departure of money.	[time unit]
T_D	= Loans duration	[time unit]

In figure 16 we see a block diagram of the bank sector and the accumulation process ie. the loan agreement. The bank sector makes a profit based on the interest rate i. The accumulation process is connected to both to the banks inflow and outflow with a dotted line, "this is done to emphasize that there are no vessel dynamics with an actual money flow with between these" (Andresen, In progress b) The loan agreement determines the payment, but the actual money flow comes from the real economy, which is not yet included.

The gain σ determines share (0< σ <1) of F_{oB} to be issued as new loans. This value would not be static in a realistic economy, but increase as the total revenue increases, since a large part of the banks' expenses (1- σ) are fixed.

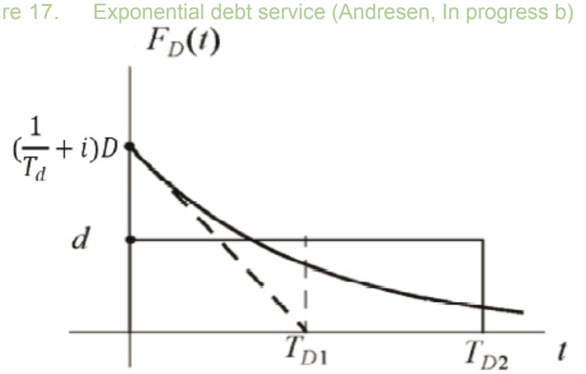
Increased revenue should increase funds for reinvestment. For simplicity however, σ is kept constant.

The accumulation process is similar to the bank sector. The difference is in the discrepancy between the outflow F_D, and the decrement of accumulated debt D. $1/T_D$ part of the debt is deducted, but $1/T_D$+i enters the bank sector. It is this discrepancy that assures the bank sector a profit.

This loan agreement does not give most common debt service, that is annuity loan. Where as the annuity loan consist of set payments where the sum of instalment an interest is constant over the duration of the loan. By studying the model, it becomes obvious that this is not the case here. Andresen named this type of debt service "exponential debt service"

The yearly payment starts at $(1/T_D + i)\cdot D$, and decreases as the size of the loan shrinks. There are no term instalments, the payment is continuous through the duration of the loan. In figure 17, Andresen shows the relationship

Figure 17. Exponential debt service (Andresen, In progress b)



between a traditional annuity loan, and exponential debt service.
In order to substitute the annuity loan with an exponential debt service, the area beneath both graphs must be equivalent. This gives us (8) as precondition to employ this debt scheme.

Andresen shows in Andresen (In progress b) that an approximate equivalence to (8) is achieved by demanding equal mean lags (9). The mean lag of the exponential scheme is T_{D1}. Therefore (9) holds true if the duration of the annuity scheme is twice the length of the exponential scheme. Figure 18 shows this relationship.

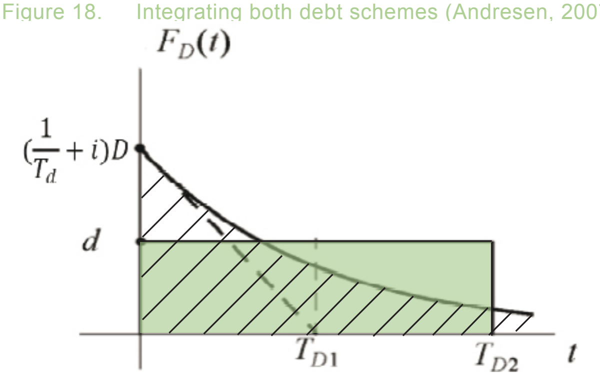
Integrating both debt service functions:

(8) $$\int_0^\infty \left(\frac{1}{T_d}+i\right)dt = \int_0^{t_{D2}} d \cdot dt = d \cdot T_{D2}$$

Comparing loan durations:

(9) $$T_{D2} = 2T_{D1}$$

Figure 18. Integrating both debt schemes (Andresen, 2007 b)



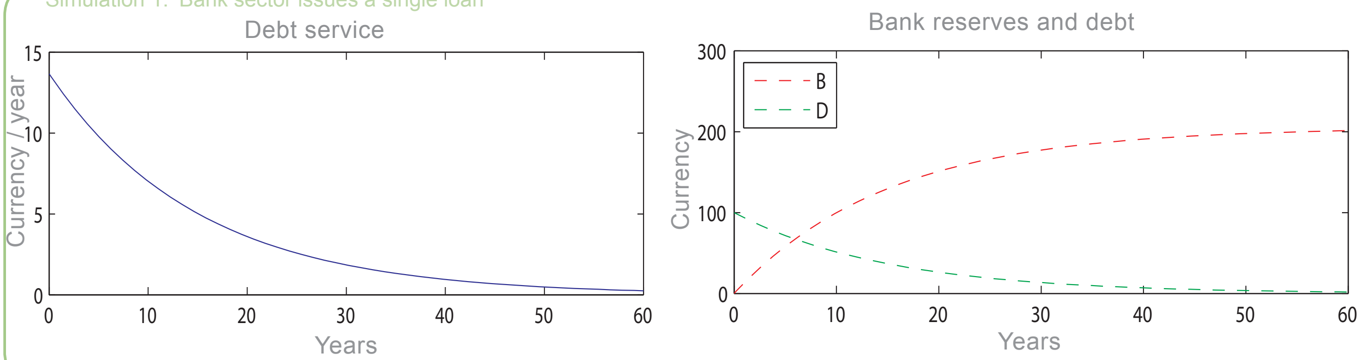
Simulations

We excite the system by allocating a single loan for 100 [currency] at t=0. In order to examine this one loan isolated, we do not wish the bank to spend any of the money it makes. We do this by removing the gain $1/T_B$ and creating an open circuit.

B init*	= 0	[currency]
D init*	= 100	[currency]
i	= 7	[%]
σ	= 30	[%]
T_D	= 15	[year]

*initial value

Simulation 1. Bank sector issues a single loan



The left graph shows the loan scheme from figure 17. From the right graph in simulation 1, we can se that the loan size starts at 100, and decreases exponentially with a mean lag of T_D= 15. By 60 years 95% of the loan is repaid. The banks' reserves increase drastically. by 10 years the initial loan value is earned back, by 15 years ROI (return on investment) is 1,3 and by 60 years it is doubled. In the real world inflation would restrain the earnings quite a lot.

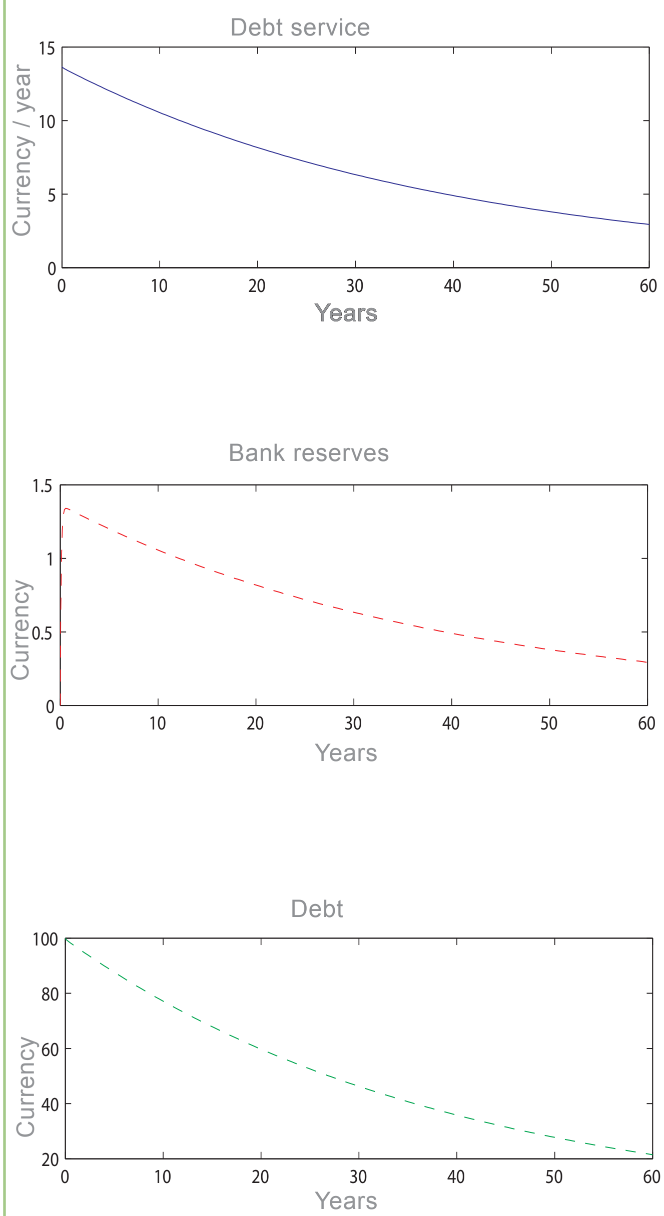
We repeat simulation, this time the bank sector is allowed to spend. 70% goes to expenditures and 30% is reinvested as new loans. The banks inertia T_B is nearly arbitrary. An increase would only slow the system down, the same response would unfold over a longer horizon. Later this choice is of greater concern, because it is the relationship between the different agents inertia that matters.

From the first graph we see the effect of the bank sectors reinvestment, the debt service now drops at a considerably lower rate. The second graph shows that the low inertia of the bank sector means that money nearly flows straight through the sector, without accumulating significantly. This money si spent covering expenses as well as allocating new loans for the public. Increasing T_B would result in higher accumulation of money in the bank sector, but less would be spent issuing new loans for the public, thereby earning less money.

Over time the banks money will dissipate through the high level of expenses, and eventually the bank will go bankrupt. The only way of changing

B init	= 0	[currency]
D init	= 100	[currency]
i	= 7	[%]
σ	= 30	[%]
T_D	= 15	[year]
T_B	= 0,1	[year]

Simulation 2. Bank sector consumes and reinvests



this, is by increaaing the inflow F_D from the accumulation process. This can be done either by enlarging the FRC, the financial reinvestment coefficient, or increasing the interest rate i.

We do another simulation with FRC at 50%, the remaining parameters stay the same.

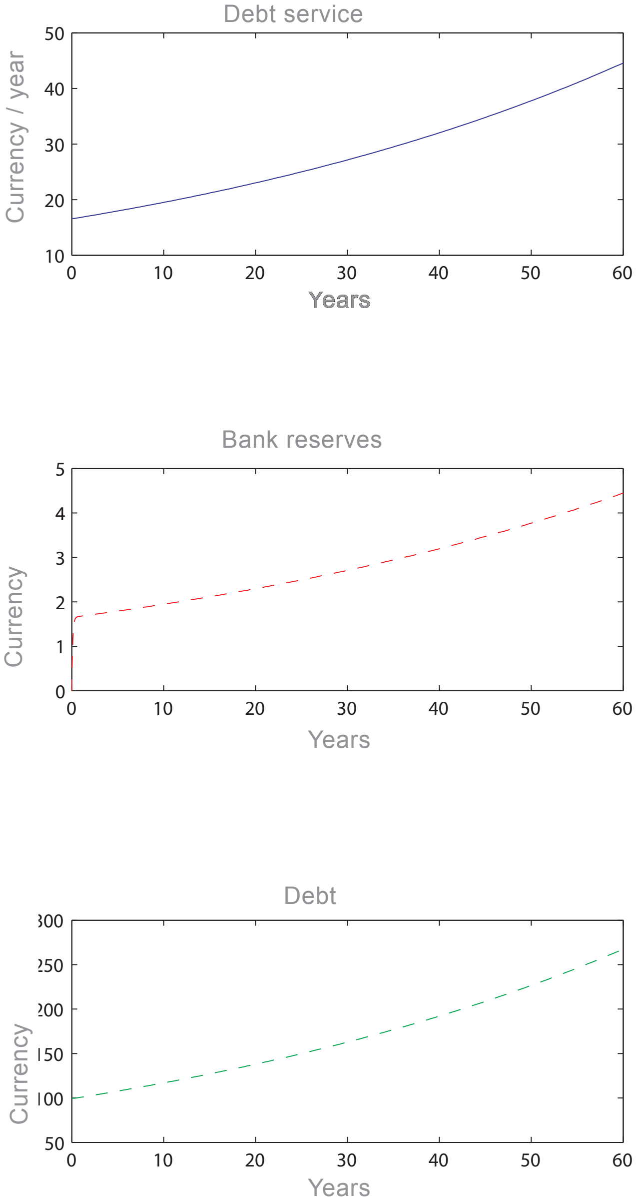
From all the graphs we se the same trend. By reinvesting half of the revenue, the bank sector sees an exponential growth. The public gets more and more indebted, while the bank sector increases its reserves.

Increasing FRC this much might not be possible in the real world. There are expenses to be covered before reinvestments can be done. But when the size of the banks increase a lesser part of their revenue will have to go to covering expenses, and a similar situation could actually occur.

A concluding remark on the system dynamics would be that the system is instable by nature. Either the bank sectors reserves will increase exponentially, or they will decrease in the same manner.

B init	= 0	[currency]
D init	= 100	[currency]
i	= 7	[%]
σ	= 50	[%]
T_D	= 15	[year]
T_B	= 0,1	[year]

Simulation 3. Bank sector, FRC= 50%

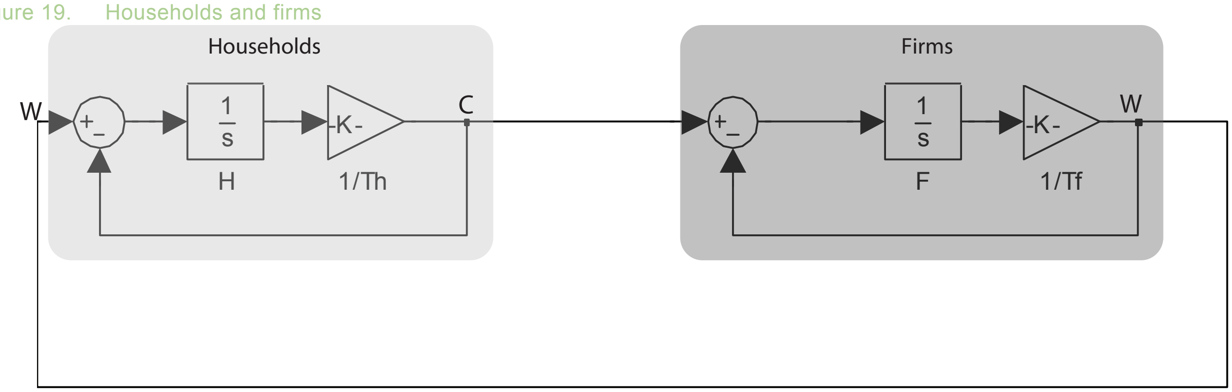


5.2 REAL ECONOMY

Firms and households

We will now look at the firm and household sectors, which were disregarded in the previous model. It is this part of the economy that receives loans from the bank sector, and repays it with interest. We call this part of the economy with households and firms “the real economy“. Andresen (1999) gave it this term seeing as “all the flows within this part of the economy are real flows, in the sense that they represent either wages, or purchase of consumption or investment goods”. Most of the agents in the economy falls into this category.

Figure 19. Households and firms



H	= Household money.	[currency]
F	= Firm money.	[currency]
W	= Wages .	[currency/time unit]
C	= Consumption.	[currency/time unit]
T_H	= Circulation inertia* Households	[time unit]
T_F	= Circulation inertia* Firms	[time unit]

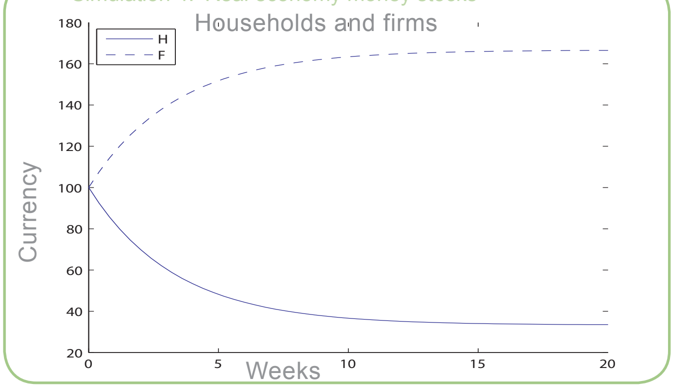
*mean lag for the entrance and departure of money.

The model in figure 19 is quite self explanatory. It consists of two economic sectors, where the sectors' money outflow, i.e. consumption, is the other sectors' inflow, i.e. earnings.

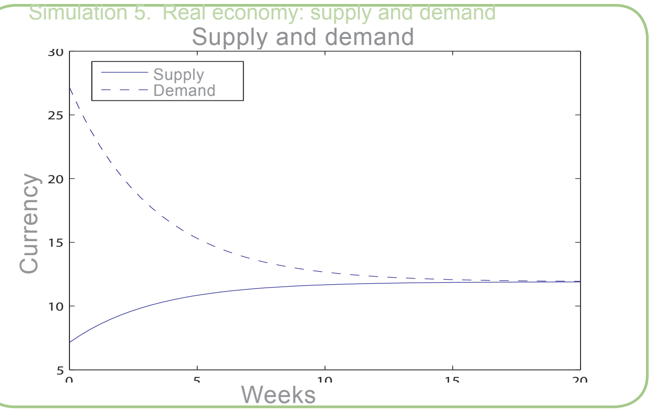
It would be reasonable to argue that not all of the firm sectors consumption goes directly to wages in the household sector. Instead some of that money flow should be reinvested in other firms in the sector. This is already accounted for, as transactions between individual firms are an internal part of the aggregated firm agent, as described in 4.4. Andresen shows, in Andresen (In progress), that there in fact is no difference in the system dynamics whenn investment loop is extracted from the sector.

H init	= 100	[currency]
F init	= 100	[currency]
T_H	= 4	[time unit]
T_F	= 20	[time unit]

Simulation 4. Real economy money stocks



Simulation 5. Real economy: supply and demand



Simulations

The size of the sectors time lag is arbitrary, the relationship between them however is not. The firm sector has to have a much larger time lag than the household sector, since households in general have a much smaller money reserve compared to consumption, than firms. Firms are dependent on having the ability to cover their losses in economic down periods. The alternative is bankruptcy. An average household has just about spent their monthly salary when the next one comes along. Andresen points out the most obvious reason; "the time lag of the firm sector is so much larger due to a high share of between-firm transactions" (Andresen, In progress). Households have little or none of these transactions.

From simulation 4 we can see that the system is stable. The sectors start out with the same money stock, and end up in an equilibrium with money stocks H and F proportional to their time lag. This is evident since equilibrium must mean that consumption=wages, and both wages and consumption are proportional to the money stock.

From simulation 5, we can se that the outflow from the firm sector and input to the firm sector, W and C respectively. Can be viewed as Supply and demand. High supply, low demand, and vice versa. At the end of the simulation we have equilibrium supply=demand.

We can conclude that “the real economy” consisting of households and firms make up a stable system, unlike the bank sector and accumulation sector. The system will keep in equilibrium as long as noise or other exogenous factors disturb the system.

From now on system dynamics and not equilibrium will be the focus of this thesis. This becomes evident in the next sub chapter.

5.3 MERGING THE ECONOMY

Financial sector and "the real economy"

We will now merge the two previous parts of the economy as one macro economy. The two separate parts are the financial sector, which is the creditor, and "the real economy" which is the debtor.

Until now the money flows have all been controlled by the sector which it exits, by adjusting its own time lag. We will now examine money flows that are not under direct control of its sector, but "imposed by other parts of the economy" (Andresen, in progress b). Andrese calls these money flows nondiscretionary flows. Such mandatory flows makes for really interesting dynamics. An issued loan can be responsible for economic growth for an economic agent, or it can make it bankrupt down the line.

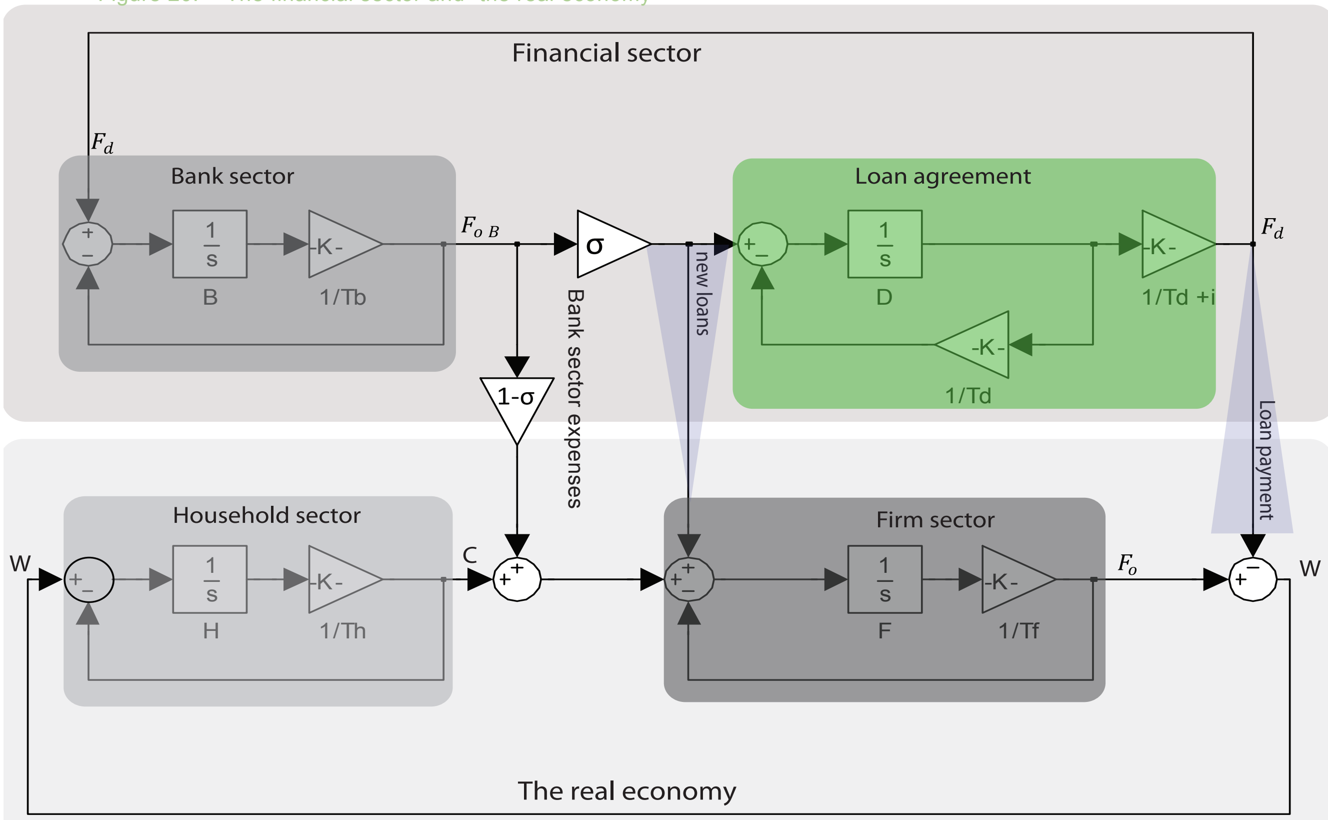
Figure 20 on the next page, is a model of this economy.

The flow F_D, which is payment on loans, is an obvious mandatory flow. It is actually represented by a negative flow from the financial sector, instead of a more "voluntary" positive flow into the financial sector. The actual flow of money goes upstream, with the shaded arrow. Since it is controlled exclusively by the loan agreement, it is deleted from F_O and added on the input of the bank sector.

In addition to F_D, there are two new money flows, going in the opposite direction. The newly issued loans, which later are repaid with interest and the bank sectors expenses. The financial reinvestment coefficient, σ, divides the proportion of money between these two flows. It should be evident that expenses are of higher priority than the issuing of new loans.

An interesting aspect that you can read from the model is that the financial sector is totally independent of "the real economy". There are no arrows in the direction of financial sector. This means that simulations made on this model will show the exact same result for the bank sector no matter what happens in "the real economy". "The real economy" on the other hand is equally *dependent* on the financial sector. A change in parameters in the financial sector could have large impacts on the rest of the economy. This underlines the power the financial sector has

Figure 20. The financial sector and “the real economy”



B	= The banks’ reserves.	[currency]
D	= Accumulated debt, i.e. financial claims from the Bank sector.	[currency]
H	= Household money.	[currency]
F	= Firm money.	[currency]
F_{oB}	= Money flow out of the bank; expenses and new loans.	[currency/time unit]
F_D	= Repayment of debt with interest.	[currency/time unit]
W	= Wages .	[currency/time unit]
C	= Consumption.	[currency/time unit]
i	= Interest rate.	[%]
σ	= Financial reinvestment coefficient; determines share of F_{oB} to be reinvested.	[%]
T_B	= Circulation inertia* Bank sector	[time unit]
T_D	= Loans duration	[time unit]
T_H	= Circulation inertia* Household sector	[time unit]
T_F	= Circulation inertia* Firms sector	[time unit]

*mean lag for the entrance and departure of money.

over the rest of the economy. Debt payments will always have priority to investments and even wages to employees. We wish to keep this skewed power distribution, as it seems to reflect todays situation.

Simulations

We kick start the economy by issuing a loan of 100 at t=0.

As discussed in 5.2 the relationship between the sectors time lags is important. The bank sectors mean lag is chosen larger than the firm sector. The reason for this is that we assume the bank sectors liquidity preference is higher than the firm sector. This is a reasonable assumption as the bank sector should be able to handle large economic fluctuations without getting liquidity issues. The bank sectors sole business is transferring money through the economy, a solid buffer should be therefore be required.

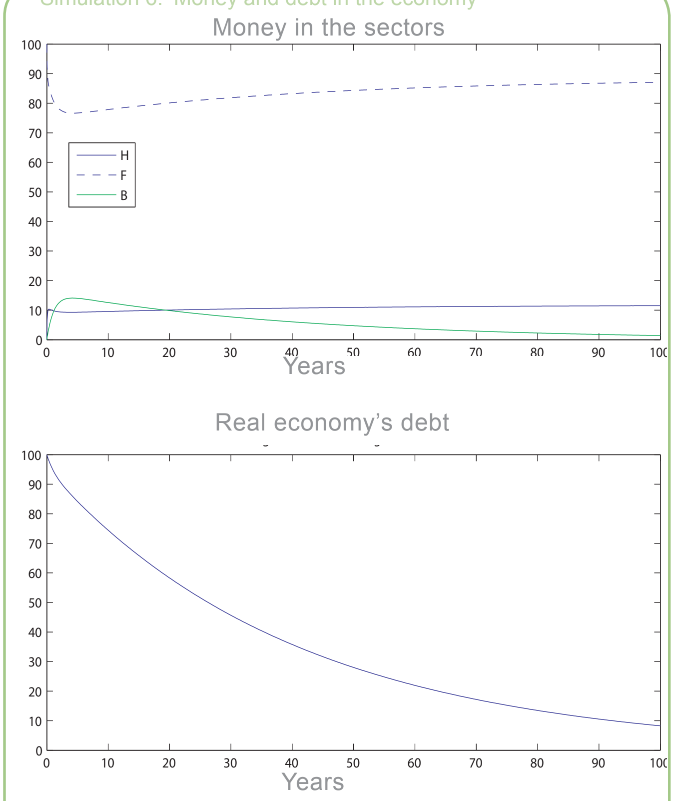
From the upper graph we se the relation between the three money stocks. The entire loan starts of in the firm sector, and is distributed through the other sectors over time.

There is a large drop in the firm sector at the beginning of the simulation. This is due to the high initial payments of the exponential debt service, but also is a result of establishing an equilibrium between the sectors in the real economy.

The high initial debt payments are the reason behind the initial boost of the bank sector.

B_init	= 0	[currency]
D_init	= 100	[currency]
H_init	= 0	[currency]
F_init	= 100	[currency]
i	= 7	[%]
σ	= 30	[%]
T_B	= 1,2	[year]
T_D	= 15	[year]
T_H	= 0,08	[year]
T_F	= 0,6	[year]

Simulation 6. Money and debt in the economy

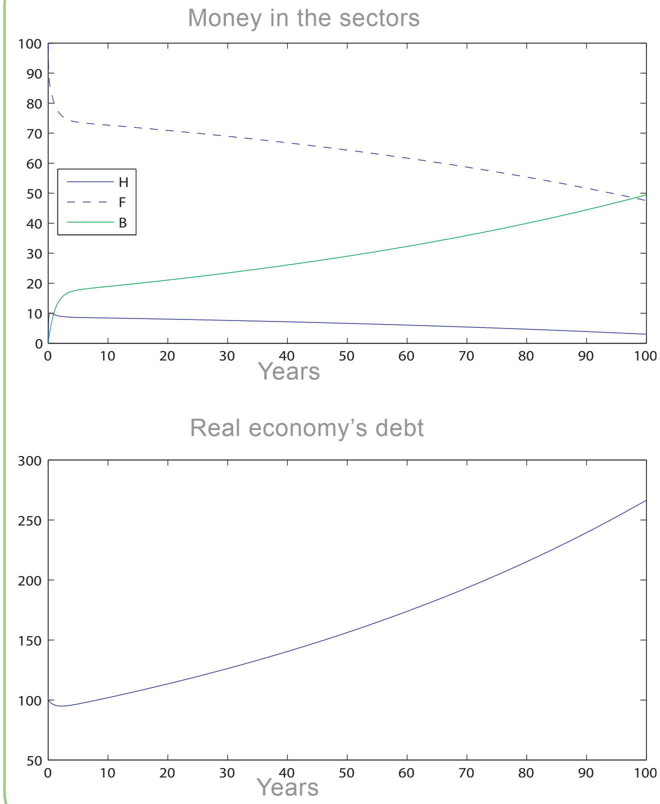


Though as the real economy debt decreases so does the payments to the bank sector, and as its expenses get larger than the debt payments its money stock gradually dissipates until the economy is debt free. This is much due to the fact that 70% of its output goes paying the real economy.

We repeat the simulation with FRC = 0,5
From the first graph we se, as with the last simulation, that the loan is distributed between the three sectors. The first couple of years resemble the simulation with FRC = 0,3, but after that, instead of repaying the loan it grows. The large reinvestment coefficient is responsible. New loans are issued before others are repaid, and the real economy collapses.

Although the real economy in this model cannot affect the financial sector, there are factors that do. This is what the next sub chapter discusses.

Simulation 7. Money and debt in the economy FRC=0,5



5.4 MOOD

The economic confidence

In the following we will model and examine the effects of economic mood. By mood we mean the agents confidence in the economy and its continued growth. Such a "mood factor" consists of a countless number of effects, and a complex connection between them. There would be time delays, positive and negative correlations, nonlinear relations, misinformation, and many small factors are easily (but wrongly) dismissed as noise. At least this is the case in the real world. In a virtual world we have the luxury of simplifying, and sometimes assuming. We do not have the opportunity nor the wish to take all these factors into consideration, but there are some important choices to be made.

There are a number different measurements in which we can base the economic mood. Common for them all is that they should be based on a ratio between a factor we wish to keep high, and a factor we wish to keep low.

(10) through (13) are examples on ratios that are relevant to the mood in the economy. They all give a picture of state of the economy. Some fit better than others, and it is the authors opinion that (13) is the most fitting for this purpose. Two rates divided by each other giving a ratio that shows how large part of GDP is actually used to service debt.

(10) Debt/GDP

(11) Debt/Export

(12) Debt/Assets

(13) Debt service/GDP

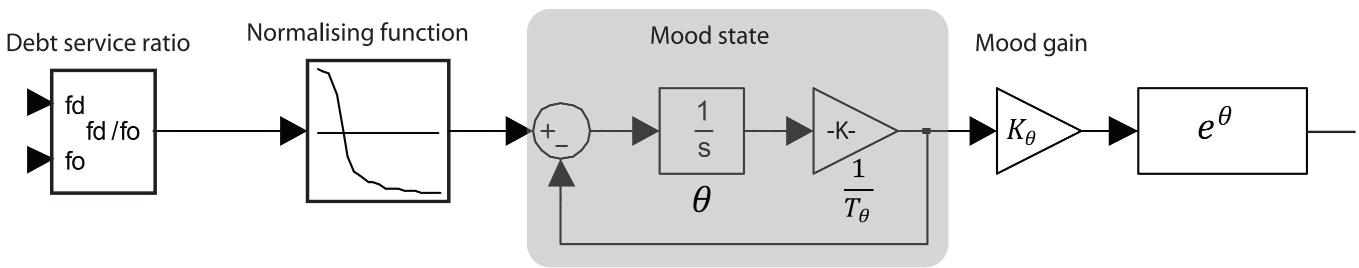
Using a ratio between a stock and a rate, might give a somewhat distorted picture of how an economy is doing. The recent high levels of private debt to GDP in countries like UK, USA and australia, reaching as much as 200% (Keen, 2008) has been growing for decades. These economies have only had minor setbacks the last couple of decades, despite the growing debt to GDP ratio. And even though many believe this will soon come to an end, it is important to recognize that factors like loan duration, interest rate and inflation are essential in calculating the actual debt burden.

Basing “Mood“ on a ratio that shows how much money is actually used servicing debt, seems to be a more reliable measurement. With this reasoning we choose (13) as basis for modelling economic mood. The term *debt service ratio* or *debt ratio* for short will be used to describe (13).

The relationship we initially wish to express with mood is quite simple:

High Debt ratio:	Low mood	Less spending
Low Debt ratio:	High mood	More spending

Figure 21. The Mood system



θ	= Mood state; accumulating mood	[dimensionless]
F_o	= GDP	[currency/time unit]
F_D	= Debt service	[currency/time unit]
F_θ	= Mood flow; current base Mood	[1/time unit]
T_θ	= Circulation inertia* Households	[time unit]
K_θ	= Circulation inertia* Firms	[dimensionless]

*mean lag for the entrance and departure of money.

Mood system: Part for part

Debt service ratio

Debt service divided by GDP, as described above.

Normalisation function

This function is included in order to normalize the debt service ratio from a fraction with values [0,1] to value range [-1,1]

The first condition for the function is that zero output shall define the debt service ratio that has no effect on the economy, i.e. neutral mood. Values over or under this defined value, will respectively increase or decrease the mood state. Which brings us to the most important issue. What debt service ratio should represent neutral mood.

The only reliable data to take into account when defining this value is history. By averaging the debt service for selected economies through history, through economic ups and downs, we should have a value that is applicable. The actual value of such a parameter is probably not constant, rather it would be dynamic and varying as the economy changes form through time. Economies goes through different phases, and today's modern economies work differently from those of the beginning of the last century. The federal reserve for instance was not even created until 1913 (Federal reserve, 2008).

It is however difficult to find reliable statistics on debt service ratio. Two different procedures are used. In the following i use data collected from Steve Keens Debtwatch. Unless mentioned explicitly, this data is from the Australian economy.

By averaging "interest payment burden" in figure 22 a graph assembled by Steve Keen, we se that average interest payment is somewhere around 3% to 4% of GDP. However, this does not include the principal payment, which is a part of F_D in our model, and thereby a part of the debt service ratio. An annuity loan at the 8% interest rate, with 20 year duration has a accumulated interests equal to the original loan value. This interest rate is higher than the long time average calculated from figure 24 and the loan duration is in the upper range. This implies that average interest payment should at least be doubled in order to account for the principal

Figure 22. Interest payment with inflation (Keen, 2007)

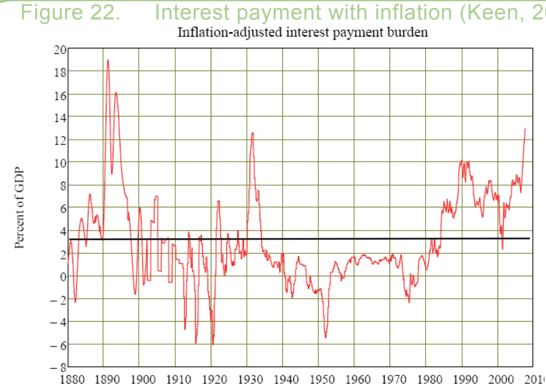
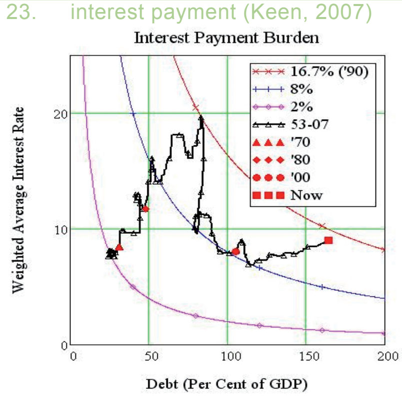


Figure 23. interest payment (Keen, 2007)



payments. Which would give us an average debt service ratio of about 8%.

The other approach involve averaging statistics for debt to GDP and interest rate individually. We can then calculate a reliable figure for average debt service ratio.

The average debt to GDP is about 70% since 1880 in Australia.

The average nominal interest rate, since 1880 depicted in figure 24 is about 7%

Using (14) with loan value expressed as debt to GDP and N being years, we can calculate debt service to GDP, i.e. the debt service ratio. With a average loan duration of 15 years, we get

P = 0.07*70% / (1-1.07^(-15)) = 7.69%

I have no statistics to back up the average loan duration. Accounting for both short and long term loans, it seems like a reasonable value. Increasing the loan duration will of course lower the debt service ratio, and vice versa.

In any case, having an accurate value for the *neutral debt service ratio* is of no importance for the points to made. Nor is it possible to say that more and better statistical data would give a more accurate value. Countries like the UK and US have had even higher debt to GDP ratios than Australia (Keen, 2007), but there are certainly countries with lower debt to GDP than Australia as well. We are creating a generic model, not trying to replicate a specific economy. As mentioned before, the neutral ratio is most likely not constant anyway, and so we are only after a ballpark figure. The Model will behave in the same qualitative manner with different values, only slightly shifted. *Neutral debt service ratio* is chosen to be 8% of GDP.

Figure 24. Historic interest rates (Keen, 2007)

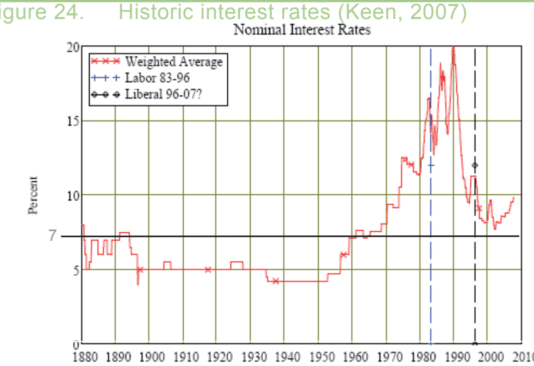
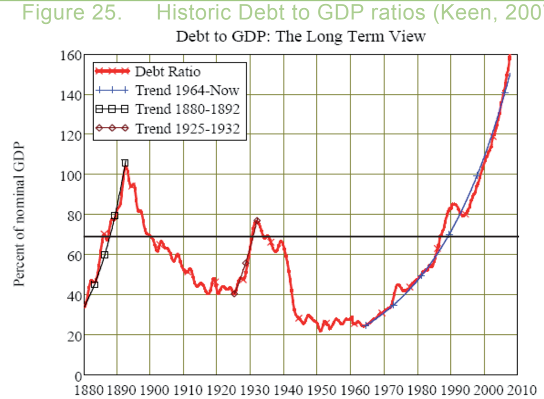


Figure 25. Historic Debt to GDP ratios (Keen, 2007)



Equation for calculating Annuity term payments

$$P = \frac{iA}{1-(1+i)^{-N}} \qquad (14)$$

A= loan value

N= number of terms

i= interest rate

P= term payment

We have now defined the two extreme values and the mid (neutral) value for the normalising function. Now we will decide how to form all the points in between. Two categories of functions can be used: Algebraic functions, or lookup tables. The advantage of algebraic functions is that they are smooth. The disadvantage is that it is confined by its mathematical formula and can therefore be difficult to manipulate and form. The opposite is true for lookup tables. Although they do not make for perfectly smooth functions, like algebraic functions, they are intuitively easy to manipulate in what way you wish.

In figure 27 we can se that with the use of lookup table, we can make use of the whole input area:

(15) $$-1+\frac{2}{1-e^{cx-\alpha}}$$

From =; no debt service, to 1; only debt service. The form in between we can choose freely, and iteratively change as new data or experience is available. We can do this knowing that we do not break the boundary conditions.

The algebraic functions take the form of (15) These functions are manipulated by changing the parameters c and alpha. Symmetry is the problem with these. In order to meet the conditions y(1) = -1, y(0) = 1 and y(0,08) = 0, the functions will have saturate at Mood input 0,2. Which means that there is no difference between 20% debt service ratio and 100%. This difficulty in manipulating the shape of the function resulted in choosing the lookup table as normalising function.

Figure 26. Algebraic functions

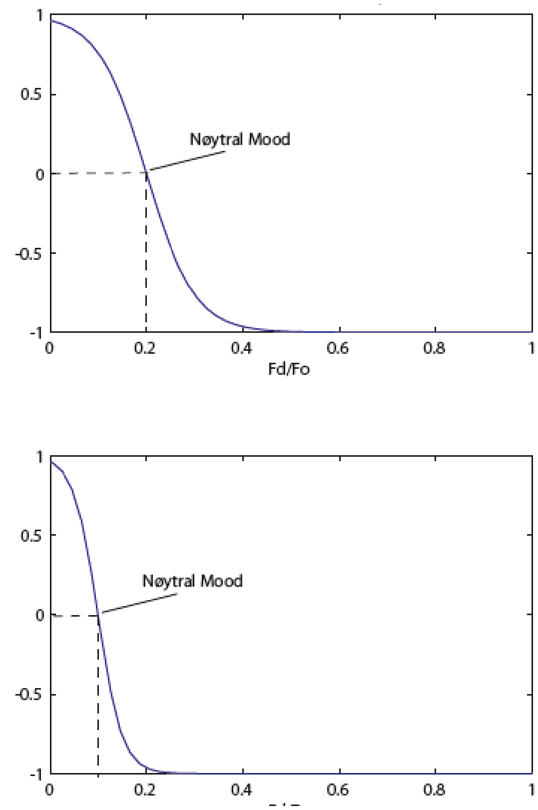
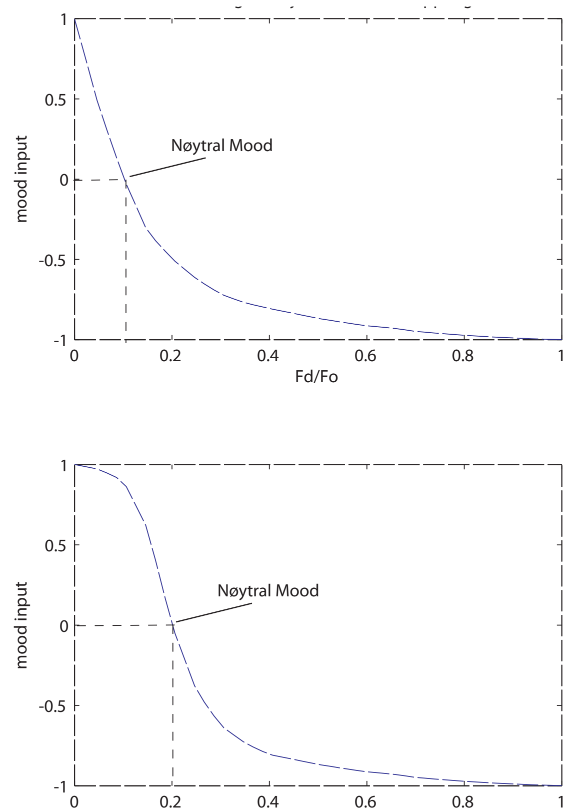


Figure 27. Lookup tables



Mood state

The output from the normalisation function is input for the mood state. By making mood a state, we can choose the lag in the economic mood, the same way we choose the economic agents lag. The lag represent the fact that the mood lags behind the actual state of the economy. Mood needs to accumulate before it effects the economy, and this takes time. Also by integrating the mood input, we smooth out noise and high frequency change in debt service ratio (F_D/F_O). The general roughness of the lookup table also gets smoothed down by the integration. To sum it up, it acts like a low pass filter.

Mood Gain

A simple gain to adjust the effect of mood on the economy.

Exponential function

This function is actually not part of the mood system. It is a way of translating the current mood [1,-1] to a factor [0, X] to be multiplied with the economic sectors' time lags. It is included here because it is shared by all the sectors.

Requirements for this function is:

- Positive mood: Factor>1: larger money flow
- Neutral mood: Factor=1: unaltered money flow
- Negative mood: Factor>1: smaller money flow
- Factor>0

The exponential function fulfil all of the above requirements. Equal mood inputs, above and below zero, changes the time lags equally. Which is a property we want. Equation (14) shows this quality. If mood changes in either direction, the effect on money flow will be the same.

(15) $e^x \cdot e^{-x} = e^0 = 1$

Examples:

e^1 = <u>2,72</u>

e^{-1} = 0,37 = <u>1 / 2,72</u>

We can conclude that we have a system that, with a certain lag, uses the debt service factor to control the economic mood. Change in mood leads to change in the sectors consumption. High, or good mood makes agents confident in the economy, thereby consuming more. Low, or bad mood lessens the confidence in the economy, agents are therefore more wary in their spending

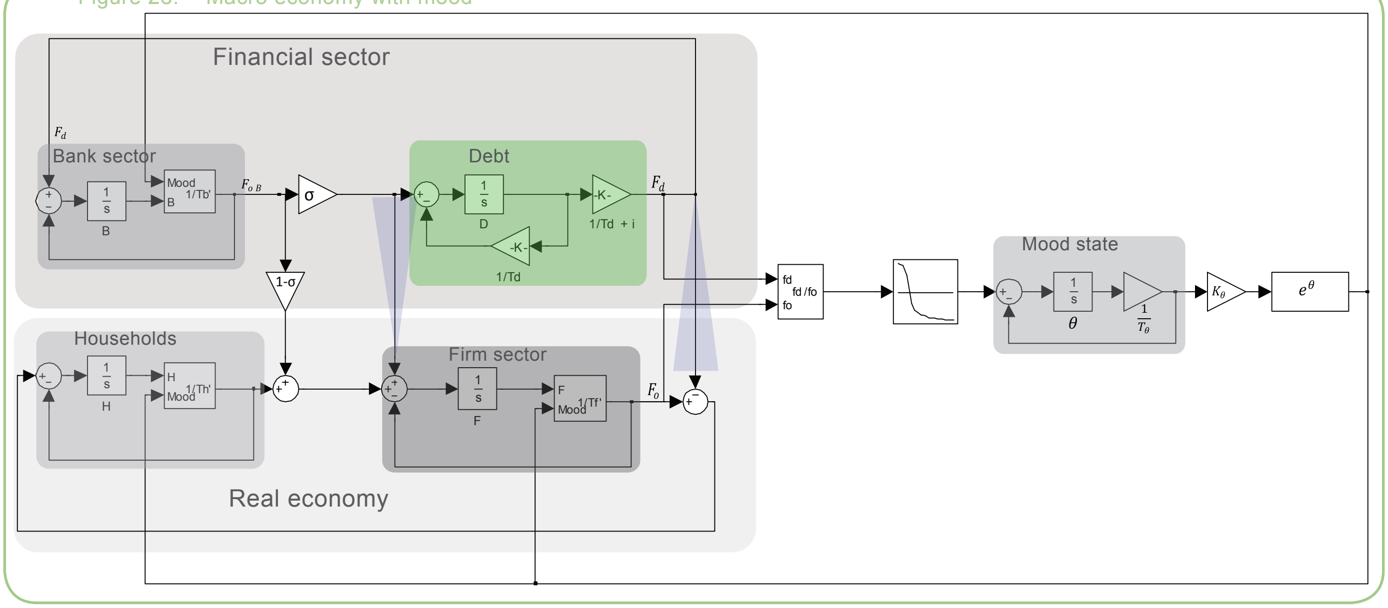
Macro economy with economic mood

In this sub chapter we include mood in the model from 5.3, with feedback to the economic sectors lag. By altering the on basis of the current mood we change the circulation speed of money. Figure 28 shows how this is implemented.

All parameters and variables, except for the altered time lags, are as described earlier, and need no further introduction.

Figure 29 shows how the time lag is modified.

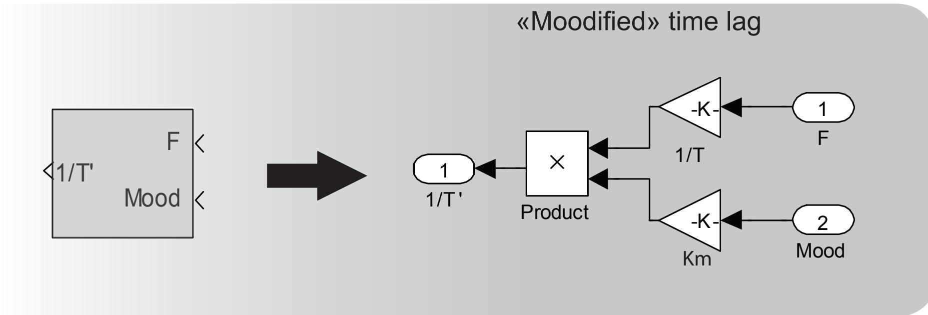
Figure 28. Macro economy with mood



T'_B	= Altered or “moodified“ Bank sector lag*; varies with economic mood	[Time unit]
T'_H	= Altered or “moodified“ Household lag*; varies with economic mood	[Time unit]
T'_F	= Altered or “moodified“ Firm sector lag*; varies with economic mood	[Time unit]

*lag == circulation inertia

Figure 29. Subsystem for modifying the agents time lag



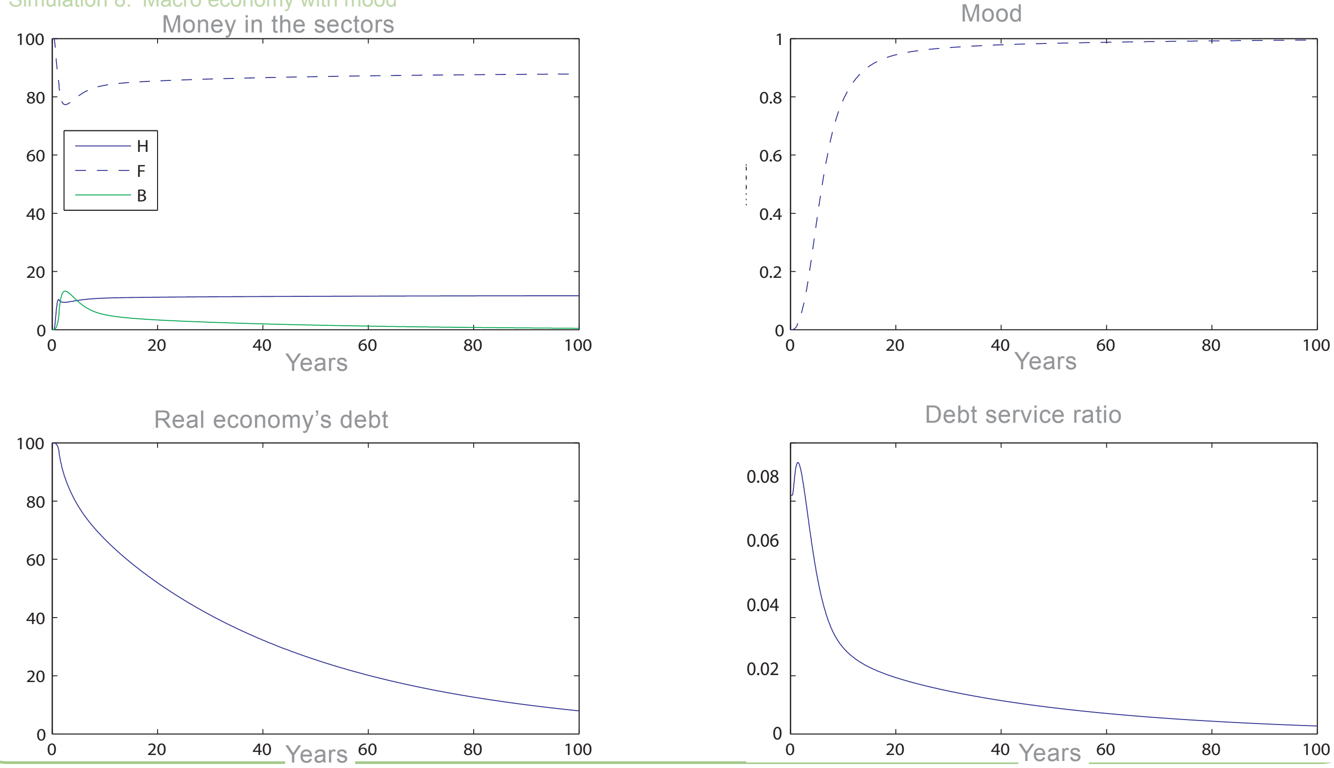
Simulations

We go through the same simulations to see what effects mood will have on the economy.

From the graphs to the left we see that the outcome is the same as without mood. Debt is repaid. The bank sector is emptied, and money si distributed between households and firms. The difference is that it happens even faster than before. Mood amplifies the current trend,

B_init	= 0	[currency]
D_init	= 100	[currency]
H_init	= 0	[currency]
F_init	= 100	[currency]
i	= 7	[%]
σ	= 30	[%]
T_B	= 1,2	[year]
T_D	= 15	[year]
T_H	= 0,08	[year]
T_F	= 0,6	[year]

Simulation 8. Macro economy with mood



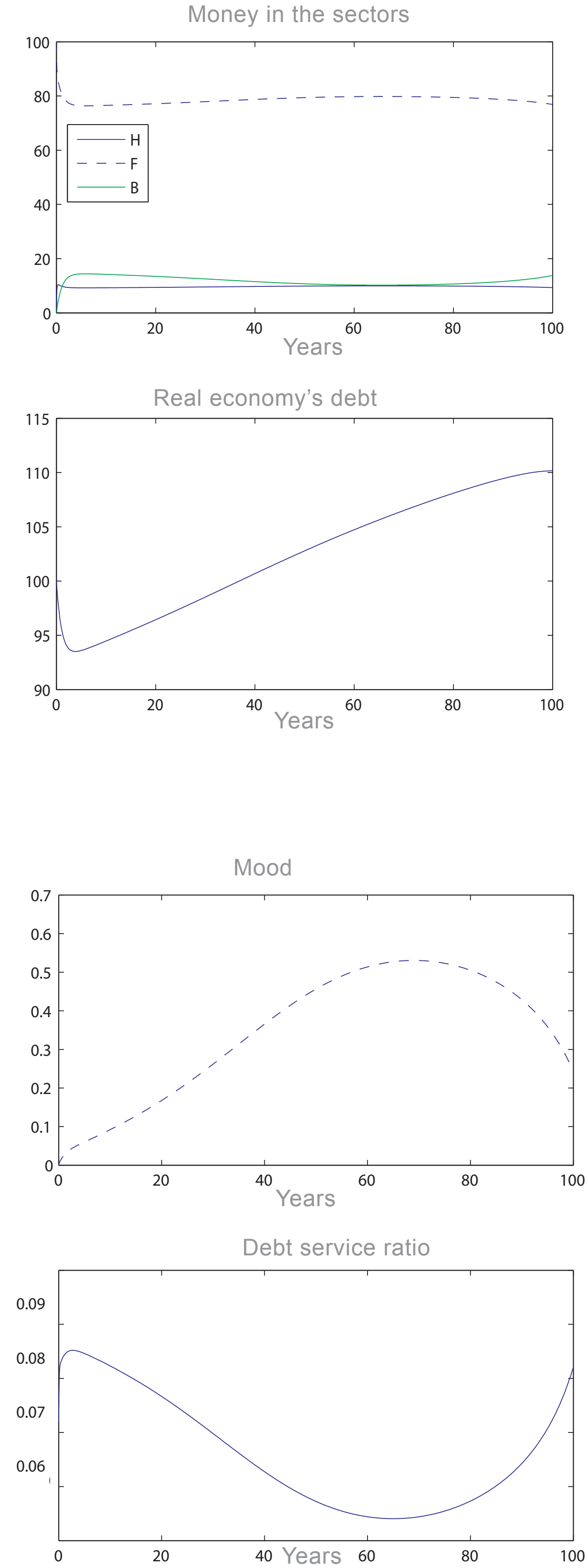
by increasing the local circulation speed in the sectors, thus debt is repaid even faster.

From the graphs to the right we see that mood rises to 1, as the debt service ratio converges to 0. The lag in the mood system makes sure that it takes time to be update to the actual conditions, thus it takes time to see the effects of mood.

We do an equivalent simulation with FRC = 0,5. From the first graphs we see that money is distributed among the three sectors as before, only instead of the instantaneous growth of the bank sector that we saw without mood, we have a gentle decline. At the end of the simulation the bank sector start growing again. The explanation for this is that while accumulated debt increases, we still have positive mood, because of the relatively low debt service ratio. This mood counteracts the growing bank sector, but at the end of the simulation mood catches up, and the bank sector starts growing. Positive mood leads to higher circulation speed, which means that the share of GDP that is used for debt service decreases, which in turn increases mood. We have a self reinforcing loop. However, as time goes by, the amount of debt keeps increasing and so the trend turns, and so does mood. It seems obvious that we have to increase the time horizon to see what dynamics we will have.

The simulation is the same as the former, with double the simulation time.

Simulation 9. Macro economy with mood FRC = 0,5



At t=100 the debt service ratio starts increasing, and mood sinks slowly to t=140. When debt service ratio passes 0,08, the economy reacts, with a degree of lag, with a collapse in mood, and the debt service ratio follows. This in turn worsens mood even more. Now the self reinforcing loop has the opposite effect to that of the start of the simulation.

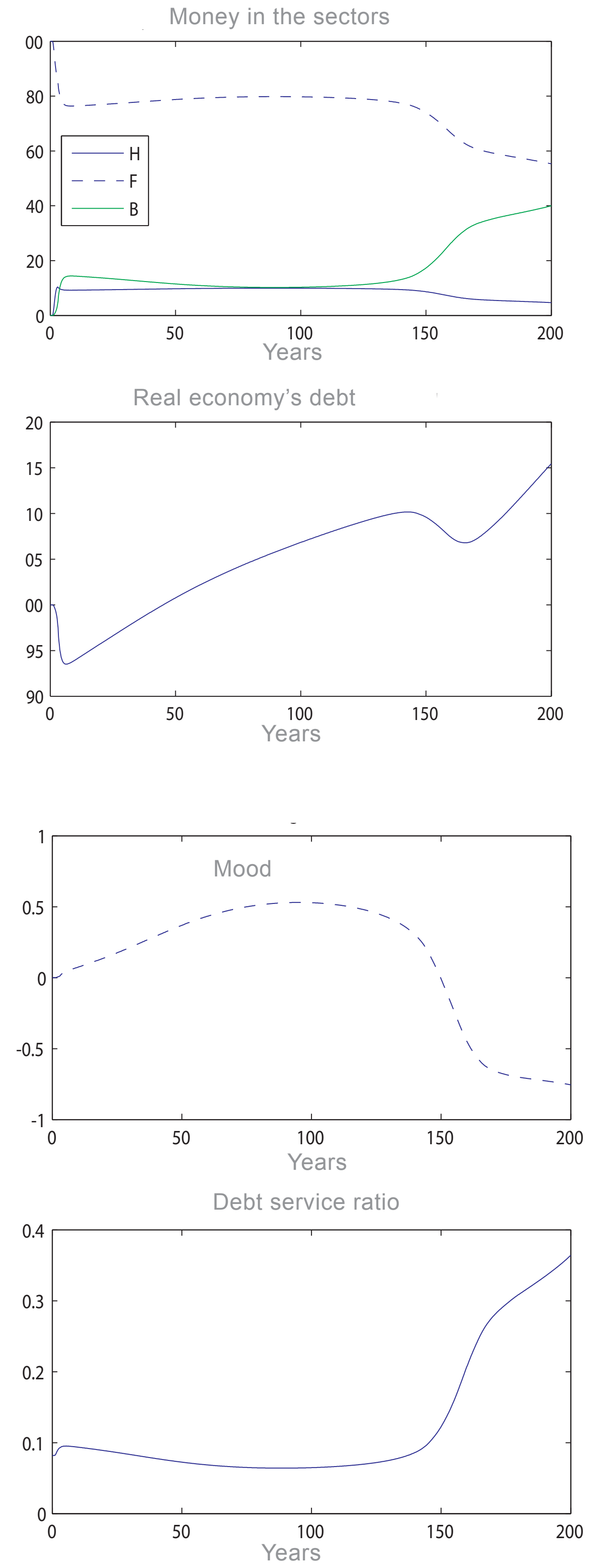
There is a small bump in the accumulated debt at about t=150, this is a result of mood making the bank sector sceptical of making new investments. However the trend turns quickly as we have a large shift in distribution of money. The bank sector's growth means that both a larger amount of new loans are issued, and GDP drops. This worsens the situation further.

The most important element mood contributes to this model is dynamics. It is the origin of oscillations and delayed reactions we could not have earlier. However, if the economy resides far from neutral mood, the economy locks into its current trend, and we see less exciting dynamics. The effect of mood is self reinforcing. When all is well, it gets better. When it is not, it gets worse.

However, as simulation 10 shows, mood can not read the trends of the economy. Even if accumulated debt increases, more is spent since the debt service ratio is under 8 %. In this example this only delays the inevitable , and even worsen the situation ones mood turns.

If the trend in periods of growth, for some reason were to turn, loans will still be issued in the transition to recession, because mood lags behind the current economic conditions.

Simulation 10. Macro economy with mood FRC = 0,5 2*t



5.5 INSOLVENCY

Bankruptcies and mutual agreements

In the previous sub chapter our model would let the debt service ratio F_o/F_d surpass 100%, which means that the economy has collapsed and that more than GDP is spent servicing debt. Which means the model is in valid. This limitation is physical. Debt service cannot under any circumstances surpass GDP. There must exist a balancing loop.

When the share of GDP being used to service loans in an economy is large, some households and firms have difficulties servicing their loans. Agreements are made with the respective banks to get better terms of payment, or reducing the size of the loan, in order to handle the payments and avoid going bankrupt. Some make use of public help, such as the norwegian "gjeldsordningslova" (forbrukerrådet, 2003), which entitles you to help from public organizations when in serious debt. In some cases debt is deleted entirely.

But when the crisis is at its gravest most people and firms go bankrupt. All these elements together make up a balancing loop called insolvency, and will to a varying degree delete some of the real economy's debt.

Deleted debt equals money lost for the bank sector. The size of this deletion increases as the debt service ratio rises. More and more firms an households can no longer service their debt.

An obvious relationship between insolvency and debt service ratio (debt burden) is a proportionate. When the debt service ratio increases, insolvency increase at the same rate. In most situations this relationship probably is valid. At neutral mood it is reasonable with 0,5-1% insolvency, but with only a proportionate relationship this would mean that with debt service ratio of 100 percent we would have less than 10% insolvency. It is clear that we need an nonlinear relationship.

At 100% F_o/F_d we want 100% insolvency. This will insure that we can never make the model invalid. But it should not rise to that until the debt service ratio is very high.

We therefore build an equation by combining a proportionate part and an exponential.

In the first graph of figure 30 we see the proportionate part of the equation. This will be the decisive part in most of the operation area, from 0 debt service ratio to 0,5.

In the second graph we se the exponential component. This part is negligible at $F_o/F_d<0{,}4$, but from there its exponential growth makes an impact.

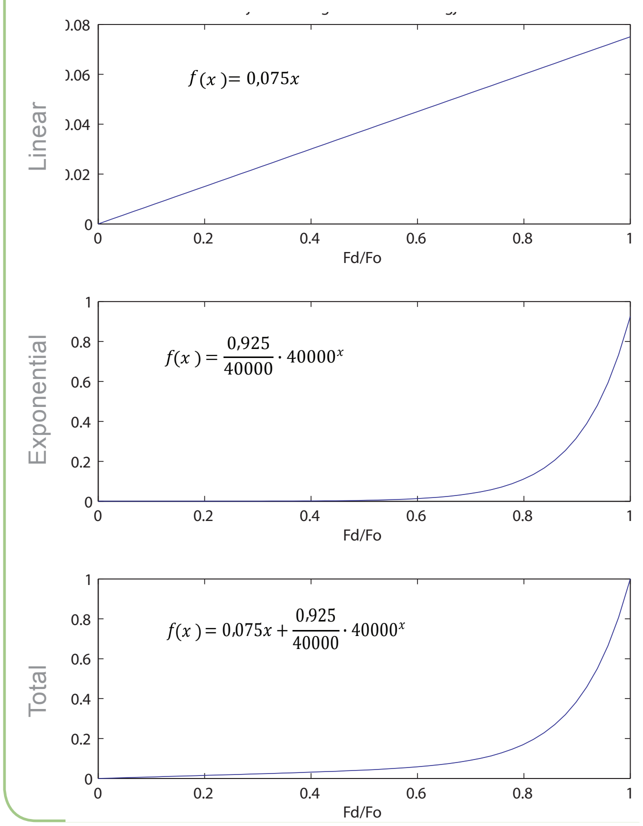
In the last graph we have combined the two. at first the proportionate component dominate, but as the crisis escalates the exponential part takes over.

From the equations (17) we can say:

- By increasing the base in the exponential component we make a steeper curve with low output for low x-values
- By dividing by the base make sure $F_e(1)=1$
- By multiplying by 0,925 we compensate for the linear component, so that $F_t(1)=1$.

In the next sub chapter we will se how insolvency is implemented, and examine its effect on the economy.

Figure 30. The Insolvency function



(16) Linear: $f_l(x) = 0{,}075x$

(17) Nonlinear: $f_e(x) = \frac{0.925}{40000} \cdot 40000^x$

(18) Total: $f_t(x) = 0{,}075x + \frac{0.925}{40000} \cdot 40000^x$

Macro economy with insolvency

In this sub chapter, we add insolvency to real economy agents, as previously introduced. This balancing loop makes sure that the higher the share of GDP is used to service debt, the more debt is deleted. How this is calculated and why it is done was the subject of the previous (see the start of 5.5).

Apart from this debt deletion resulting from insolvency the rest of the variables of the model in figure 31 has been discussed previously.

Figure 32 shows the subsystem where debt deletion is calculated. The debt service ratio F_D / F_O is input for the function described in the beginning of this sub chapter. Its output value [0,1] is then multiplied with current debt.

Figure 31. Macro economy with mood and insolvency

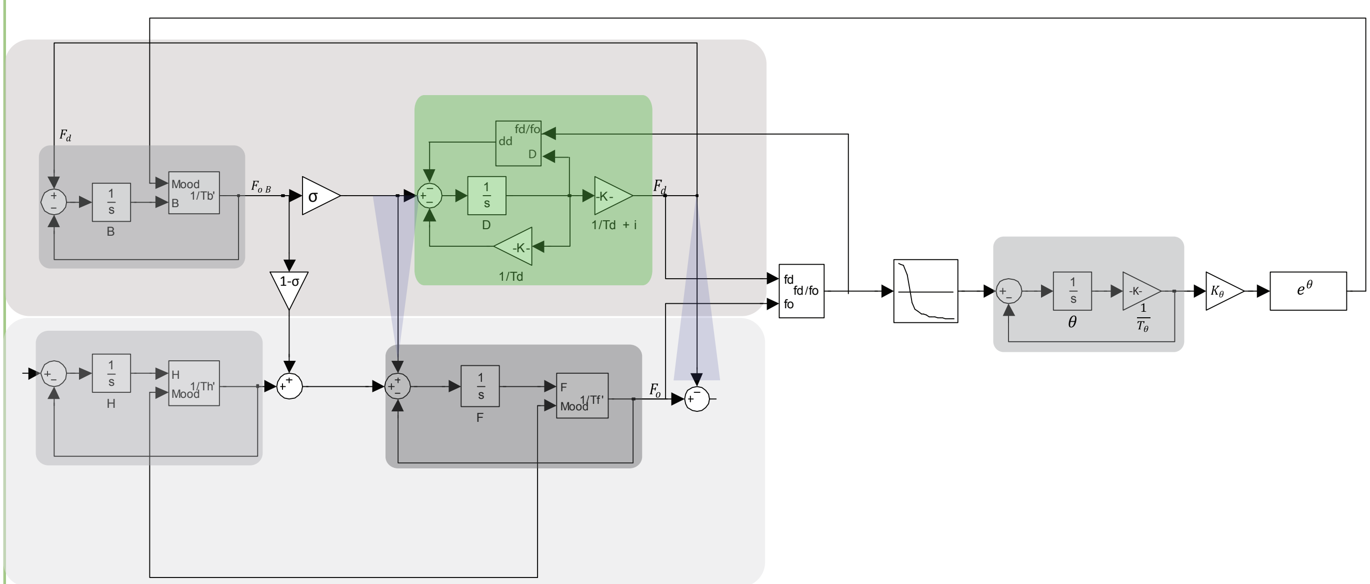
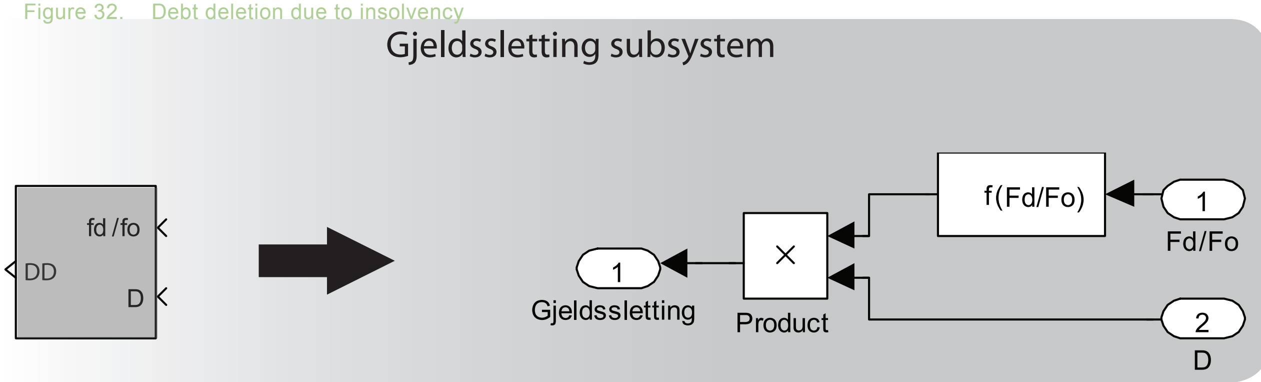


Figure 32. Debt deletion due to insolvency

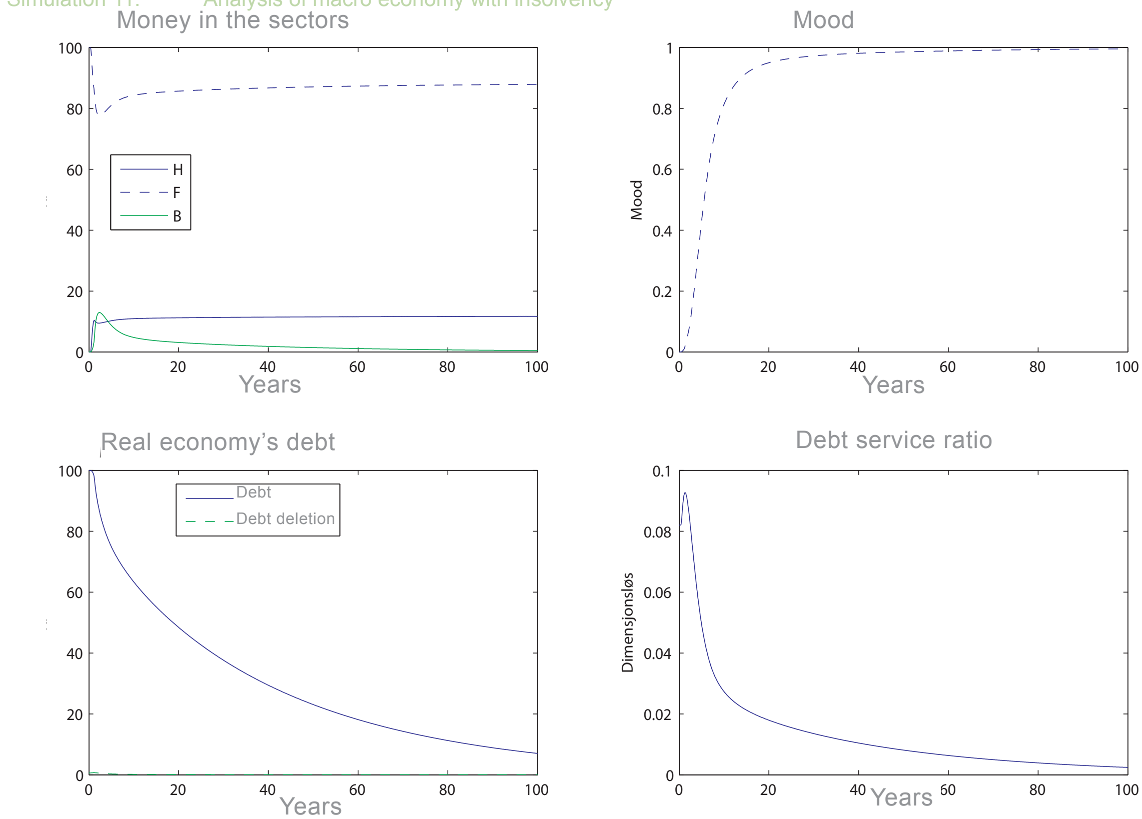


Simulations

We start with the standard simulations, so we can review the effect of this added loop. Debt deletion is shown in the same coordinate system as accumulated debt. Make notice that debt deletion is a rate, while debt is a stock.

B_init	= 0	[currency]
D_init	= 100	[currency]
H_init	= 0	[currency]
F_init	= 100	[currency]
i	= 7	[%]
σ	= 30	[%]
T_B	= 1,2	[year]
T_D	= 15	[year]
T_H	= 0,08	[year]
T_F	= 0,6	[year]

Simulation 11. Analysis of macro economy with insolvency



From the first simulation the new loop does not seem to have any effect on the economy. This is due to the low debt burden, which makes sure there are nearly no insolvency. Also since this was already a situation with falling debt burden, debt deletion would only amplify this trend, and change any qualitative behaviour.

We now simulate with FRC=0,5:

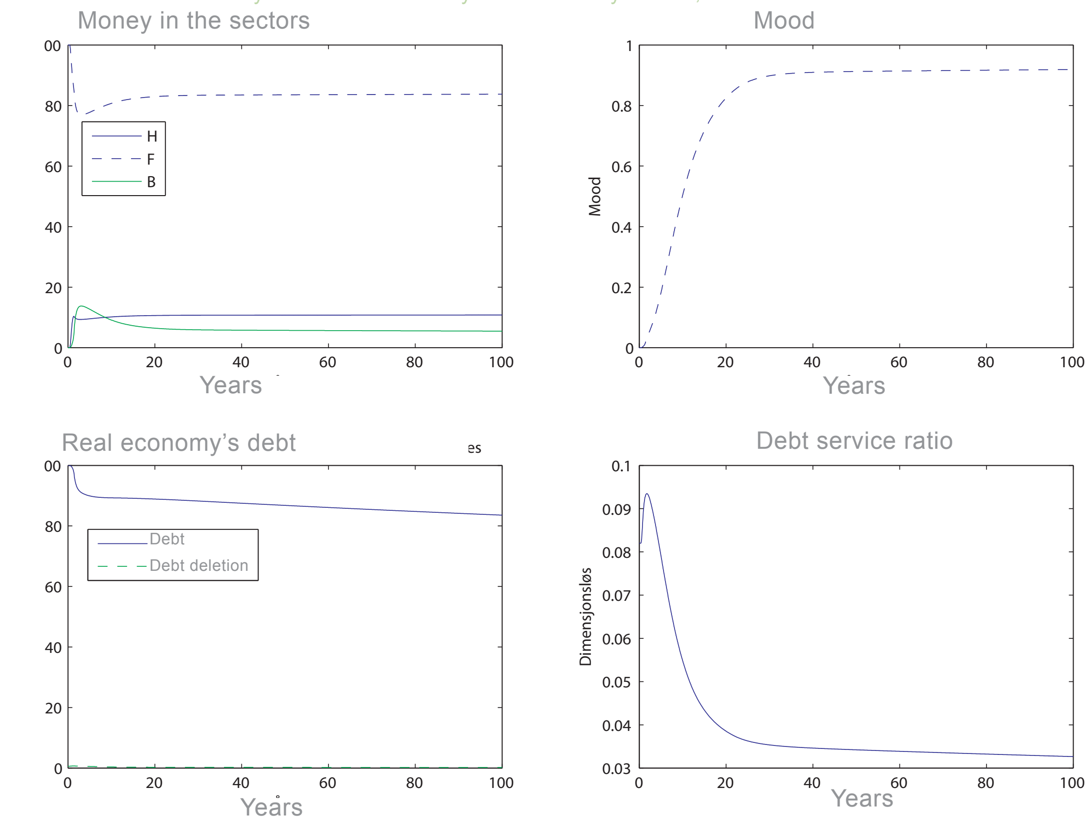
Here we see a distinct qualitative change in behaviour. Even with this much large reinvestment coefficient, accumulated debt do not increase, it is kept down by insolvency in the real economy. Although debt deletion seems negligeable, it is enough to stop the situation from escalating. The bank sector ends up with a share of the money, but does not manage to turn a profit on this. Aggressive investments consequently heightens debt burden, and insolvency increases, which "skim" of this profit. Normally this profit would be used to make an even higher profit, taking the economy "out of bounce". This does not happen any more.

In this next simulation (13) we increase the interest rate to 10%, and see wether or not this bring the economy out of balance.

The result is quite different from the previous. Although it does not manage to put the economy out of balance, it certainly sends i into a depression.

From the left graphs we see that the bank sector has had a quadrupling in size. And now, for the first time debt being deleted is actually visible. Accumulated debt does still not increase,

Simulation 12. Analysis of macro economy with insolvency FRC=0,5



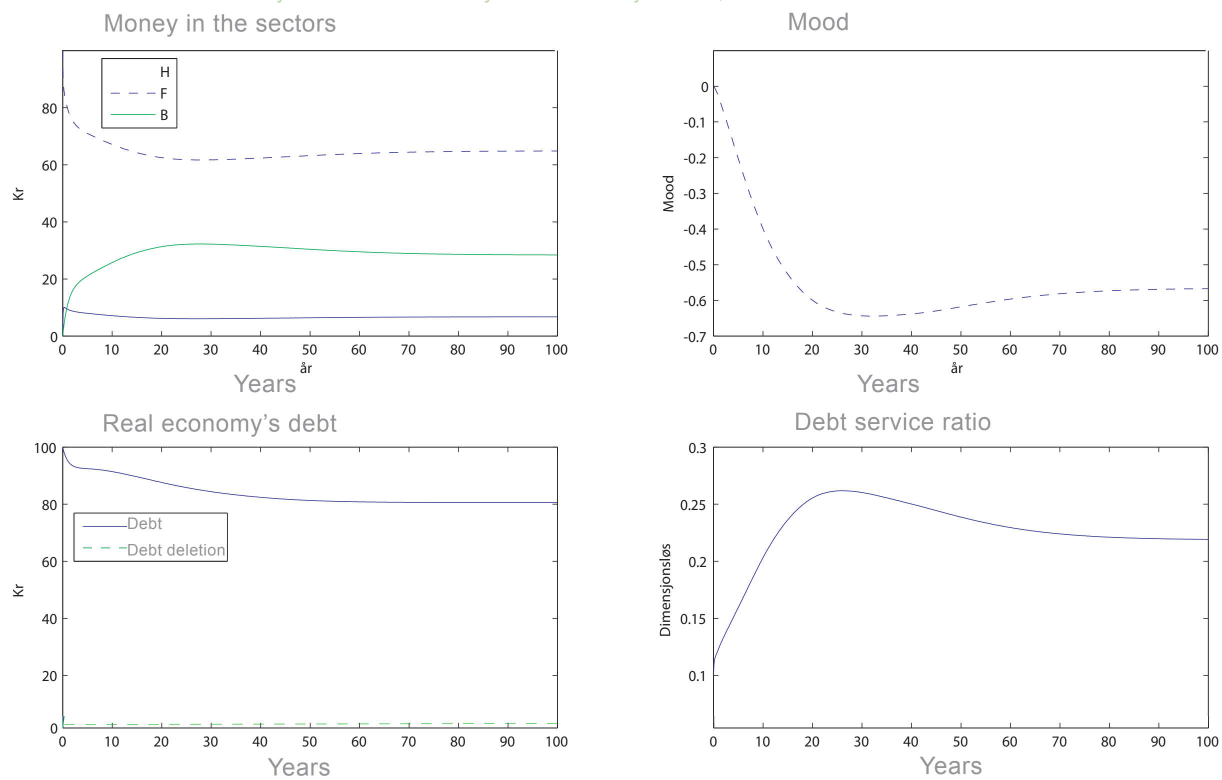
however the increase in the size of the bank sector consequently means that the real economy must shrink, due to the basic vessel dynamics of the system. So even though debt service does not increase, GDP decreases, which leaves less money for debt payments, hence increasing the debt burden and sending the economy into a depression. The economy locks into this position where the entire economy is vary, and is not inclined to spend more than necessary.

Could we possibly get the economy out of bounce? The answer is no. No matter how high the debt service gets, it never passes 100% of GDP. Insolvency makes sure of that. However the model easily locks into "good" or "bad" situations, which with the current dynamics, it can never get out of.

We will now go through a series of simulations, with different reinvestment coefficients; FRCs, and range of different interest rates in order to map out models dynamics. The debt service ratio is the most describing measurement we have, for the state of the economy. Therefore we make use of this through the simulations. Based on what we know about the model, we can say that it should be able to reach a form of equilibrium with neutral mood, or debt service ratio in the area of 8%. We now put this hypothesis to the test.

From the three following simulations we have a range different interest rates repeated for different FRCs.

Simulation 13. Analysis of macro economy with insolvency FRC=0,5 and iD=10%



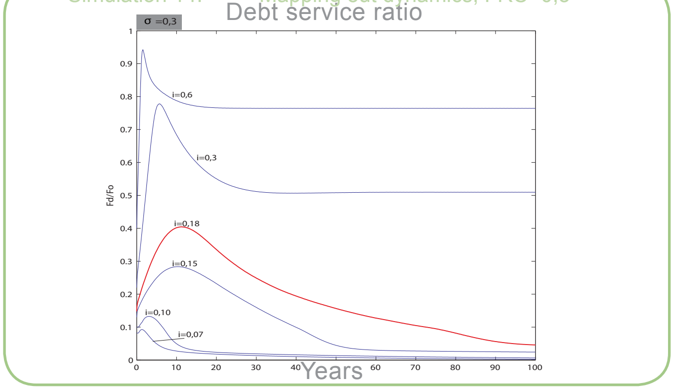
The different simulations are quite similar, a result of the exponential increase of debt deletion. Investing more money as little purpose, as the increased profit is lost due to insolvency. In the area below 50% debt service ratio, the advantage of increasing investment is more pronounced.

In every plot, there is a graph outlined with a different colour, that has an interest rate turning out the debt burden closest to 8%. At FRC=0,5 this interest rate is considerably lower than at FRC=0,3. This is obvious since a higher degree of reinvestment needs a lower interest rate to make a profit. Each of these interest rate represent a crucial point. A small change up, or down from this marginal value, yields a large change in debt burden.

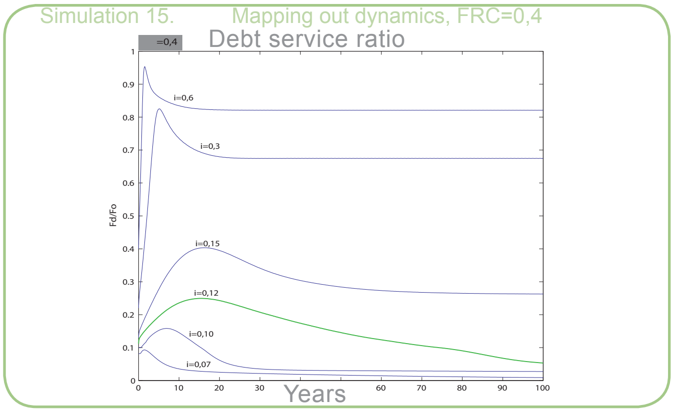
By extracting these graphs into a single plot, and considerably increase the time horizon, we see that the debt service ratios oscillate around 0,08, with equivalent periods and amplitude. Only the initial debt service ratio differs significantly.

If interest rate is decreased these graphs would fall to a debt service ratio far below 8%, as can be seen on the graphs for the interest rates just below the marginal rate. The opposite is true for the rate above. These interest rates where the only ones tested, which made the debt burden oscillate. This means that events within the economy, or influences from the outside, with seemingly little effect, may have severe consequences later in time. Such nonlinear phenomenons are often called path dependencies. We will discuss this at a later point.

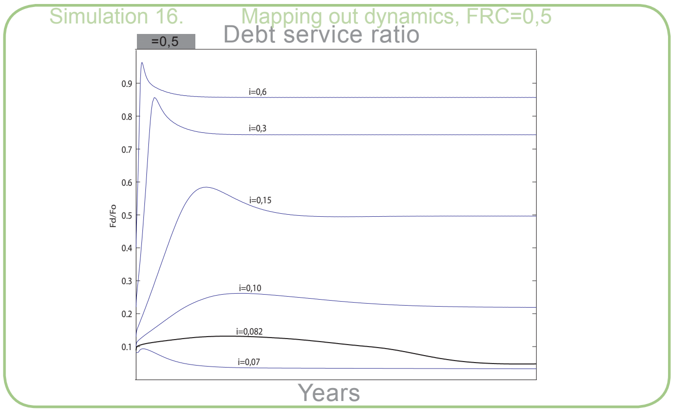
Simulation 14. Mapping out dynamics, FRC=0,3



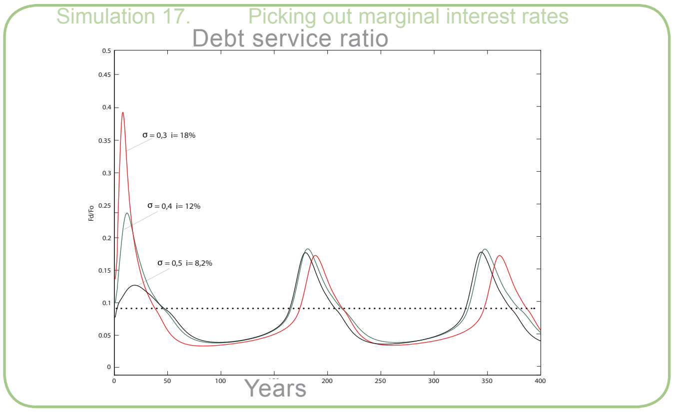
Simulation 15. Mapping out dynamics, FRC=0,4



Simulation 16. Mapping out dynamics, FRC=0,5



Simulation 17. Picking out marginal interest rates



5.6 REAL BANKS

Capital and reserve requirements

Until now we have assumed that banks will cover all their expenses in the real economy (wages, equipment purchases and so on), and the rest of their output goes to issuing new loans. In this respect we have treated the banks as "non-banks". Of course the reality is not this simple. We will now change the banking sectors lending policy.

When a bank lends money, it has no effect on a bank's own capital. It does not drain the bank of money. Instead bank lending is limited by the capital ratio requirement set by the Central bank. If a bank has sufficient capital, to meet the requirement, it can expand its balance sheet by issuing more loans. If it can not meat the capital requirement, it can issue new stock or sell more subordinated debt, although this is not a possibility for small banks. If the bank cannot increase its capital, it can reduce its assets in order to improve the capital ratio. It can simply stop issuing loans, or even sell loans to other banks, but shrinking the balance sheet like this is not desirable since it would hurt profitability (Hummel, 2004).

Bank lending can also by limited by a reserve requirement. This sets a limit on how much liabilities a bank can have compared to its reserves. The original point of this requirement was to make sure that banks could meet the withdrawal of deposits.

Increasing reserves to meet reserve requirement can be done by getting personal current accounts, with little or no interest to pay, (banks preference) or long term savings accounts, with a moderate to high interest rate. But most often, pressed with time, the banks will borrow from other banks (with excess reserves) in order to meet the requirements. If sufficient reserves is/are not available, the central bank will buy securities from the public, thereby injecting what is needed to restore the balance. The same applies to the opposite. If the banking sector has excess reserves, the central bank will drain it by selling securities to the public (Federal reserve, 2008).

In the short term, this "back and forth", buying and selling game is only meant to stabilise. In the long term however, its course depends on the central banks' monetary policy.

For example, by not draining excess reserves the "overnight interbank rate" will fall, as the pressure on acquiring funds diminishes. If the central bank does not inject funds, when there is a shortage, the interbank rate will rise due to the upwards pressure of acquiring reserves. This interbank interest rate in turn determines the interest rate banks charge on loans to the public. Influencing this interest rate is the primary monetary policy tool of a central bank.

It is a common misconception by the general public, that the central bank actually SETS the interest rate, rather than being an effect of their day to day open market operations.

It is worth mentioning that some countries use other guides to determine their day to day operation. Net domestic assets have been used as a sort of intermediate guide in Poland (National Bank of Poland, 2008) and Mexico (Bank of Mexico, 2008), base money in Brazil (Central Bank of Brazil, 2008), M3, which is the broadest measure of money, in India (Reserve Bank of India, 2008), and the foreign exchange rate in Egypt (). Still in most modern and well working economies the interest rate is the guiding tool.

When a bank creates a deposit to fund a loan, its assets and liabilities increase equally, as mentioned earlier, with no increase in capital. That causes its capital to asset ratio to drop. Thus the capital requirement limits the total amount of credit that a bank may issue.

So instead of a money flow going from the banking sectors "reserve stock" to the "debt stock", the amount of newly issued loan will be determined by a capital ratio requirement.

New financial sector

We will now introduce the new financial sector, which operates as described above. Each new component will be discussed and the choices that has been made will be accounted for.
Figure 33 shows the new financial sector. New components include the Liability stock, the BIS capital ratio requirement and the banks decision rules, or control action to keep capital/asset ratio close to the required minimum.

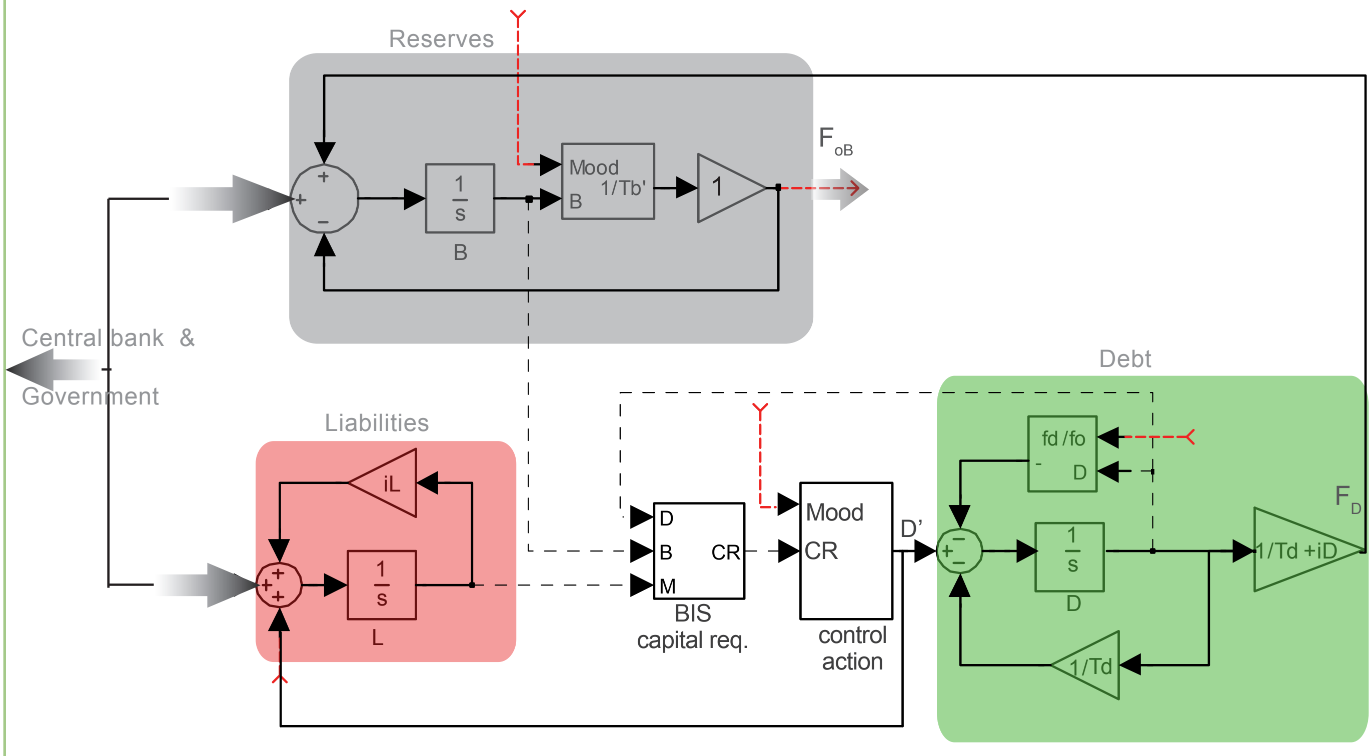
We have also vaguely suggested money flows from and to a regulating central bank / government. This will be included and discussed at a later point. The dotted lines signify that there is no money flowing through, instead there is a flow of information gathered from elsewhere in the model.

Bank sector expenses are somewhat different than before. It made perfect sense, when banks where treated as non-banks, to make expenses to the real economy a percentage of the money outflow (revenue) with the rest going to reinvestments.

Without these vessel dynamics, banks can cover expenses by issuing a bank draft in payment. If the recipient deposits the draft in the same bank, he receives a deposit which increases liabilities, while assets and reserves remain unchanged. If the recipient deposits it in another bank, assets and reserves decrease while liabilities remains unchanged. In both cases, the capital ratio and reserve ratio of the issuing bank decrease. These to ratios will from now on be the main units of measure of the financial sectors health.

As seen on the model, expenses are only drawn from the reserves. This makes sense because we will later include a reserve requirement on the banks. While draining reserves to cover expenses, the aggregate bank sector will have to borrow reserves. This can either be done directly in the central bank discount window or in the interbank funds market. For the latter, the central bank must first purchase treasury securities from the public, thereby injecting what is needed to restore the balance. Either way there will be an interest rate on the borrowed reserves close to the target central bank funds rate. We will not differentiate between the two,

Figure 33. The new financial sector



B	= The banks' reserves.	[currency]
D	= Accumulated debt, i.e. financial claims from the Bank sector.	[currency]
L	= Accumulated liabilities, to central bank or the real economy	[currency]
F_{oB}	= Money flow out of the bank; expenses in the real economy	[currency/time unit]
F_D	= Repayment of debt with interest.	[currency/time unit]
D'	= Flow of newly issued loans	[currency/time unit]
iD	= Interest rate on debt.	[%]
iL	= Interest rate on Liabilities.	[%]
T_B	= Circulation inertia* Bank sector	[time unit]
T_D	= Loans duration	[time unit]
CR	= Capital (to asset) ratio	[Dimensionless]

*mean lag for the entrance and departure of money.

and we will use a common interest rate for all of the bank sectors liabilities.

Because covering expenses with reserves will inn effect increase liabilities we only use this one form of payment. Also the size of reserves will be proportionate to the size of the bank, and thereby its expenses. This is considered a necessary simplification.

The BIS rule

The Bank for International Settlements (BIS) have issued a set of rules which set limits with a framework on how banks and depository institutions must handle their capital. The rules enforces them to keep a minimum capital/asset ratio (three different sorts), which is a measure of a bank's financial health. BASEL I, which is what this framework is commonly known as, has recently been replaced by the newer and far more complex BASEL II. BASEL I (BIS, 2008) was chosen for its simplicity, and seeing as a nation like the United States still uses it, we consider it sufficient for this purpose.

There are three different capitals used to make capital requirements. Tier 1 capital, tier 2 capital and total capital (tier 1 + tier 2). Seeing as the simplicity our model does not let us differentiate between tier 1 and tier 2 capital, we use total capital in our calculations (BIS, 2008)

The measure of a bank's solvency is its capital, i.e. assets minus liabilities. The BIS rules imposes a lower limit on a bank's capital relative to its risk-weighted assets to provide a margin against insolvency. That ratio is what ultimately limits a bank's deposit creation through lending.

In our model in figure 28, there is a subsystem called BIS capital req. This is where real-time calculations of the weighted capital/asset ratio are done.

In this model capital consist of **reserves** plus **loans** minus **liabilities.** The assets in BASEL I, are weighted as described the table above.

By using this table for our simplified model, we se that the only assets with any weight in this model are the ordinary loans; stock D in our

Asset	Weighing
Cash and equivalents	0
Government securities	0
Interbank loans	0.2
Mortgage loans	0.5
Ordinary loans	1.0
Standby letters of credit	1.0

Capital ratio: Total CAPTIAL / ASSET =

(Reserves+loans-liabilities)/
(cash+loans+securities)

Weighted capital ratio: CAPTIAL / ASSET=

(Reserves+loans-liabilities)/
(Ordinary loans)

model. Therefore the ratio used to impose a lower capital requirement in our model is
(B+D-L)/D

The Control Action

This is the banks effort to keep the capital/asset ratio above its required minimum. Or put in an other way: it is the banks effort issue as many loans as possible, increasing its balance sheet, without "breaking" the BIS rule.

What can be done to alter the capital/asset ratio has already been discussed, but many of the options of the real world, are not available in this model. Issuing new stock for example i not possible here. By investigating the actual ratio in our model, we can decide which variables can be altered:

(Reserves+loans-liabilities)/(Ordinary loans)

Decreasing the ratio:
Can be done by lowering capital or increasing weighted assets. Although throwing away reserves or Increasing liabilities without corresponding commitments will lower the ratio, increasing assets by expanding the balance sheet is of course the favourable way of achieving this. There is no upper constraint on the capital/asset ratio, thereby no legal reason to lower the ratio. It will however, increase your earnings, which is every banks principal goal. A bank with a particularly high ratio is probably not a very successful bank.

Issuing a loan will either increase assets, beeing loans (D), and liabilities equally, if the client has an account in that bank, or decrease reserves if lender withdraws the loan. By that account a new loan will not affect capital, but it will increase assets, thus lowering the capital asset ratio.

Figure 34 shows the effect of raising both assets and liabilities equally. The ratio converges to zero. Which goes to show that increasing loans indefinitely is not possible. In reality however, debt and liabilities will not increase equally. While debt is being serviced, interest is paid. This interest rate must be higher than the average deposit interest rate for the bank to make a profit. This means that, over time,

Figure 34. Increasing assets and liabilities equally

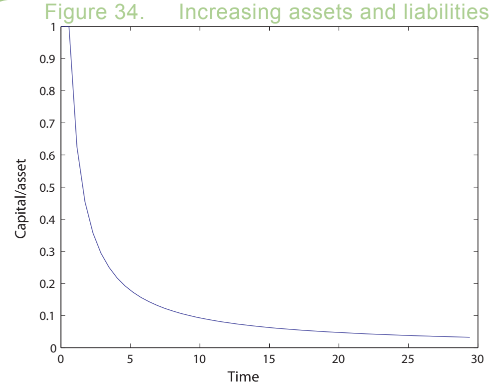
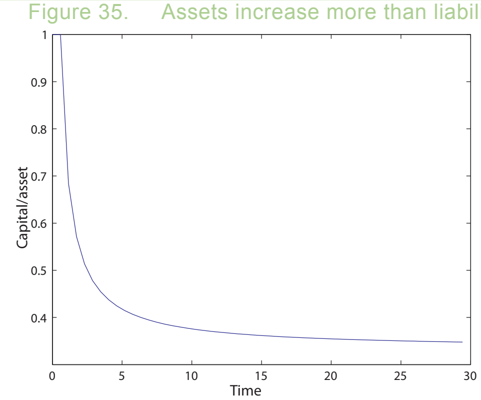


Figure 35. Assets increase more than liabilities



assets will increase more than liabilities (or the lowering of reserves). Figure 35 shows an example where assets increases considerably more than liabilities. Now the ratio converges to 35%, far above the requirement from BASEL I.

Increasing the ratio:
Can be done by increasing capital or decreasing assets. An increasing Capital to Total Assets ratio is usually a positive sign, showing the banks liquidity is improving over time. By studying the ratio we see that increasing the ratio by increasing capital is difficult in this model. We cannot issue new stock as is common in the real world., or seek a merger with a stronger bank . Remember we model an aggregate bank sector.

Normally we cannot increase reserves without increasing liabilities equally, which in time will lower the ratio since reserves gain no interest, but clients deposit accounts do. So receiving reserves from the central bank has no effect, as this money rarely comes without obligations. Similarly we cannot decrease liabilities without decreasing reserves or loans, and thereby decreasing the balance sheet. While not being favourable, it is the only option in this model. Since this is an aggregate model selling loans to other banks does nothing to help the economy. However, suspending the issuing of new loans, while debt payments gradually lower assets will help.

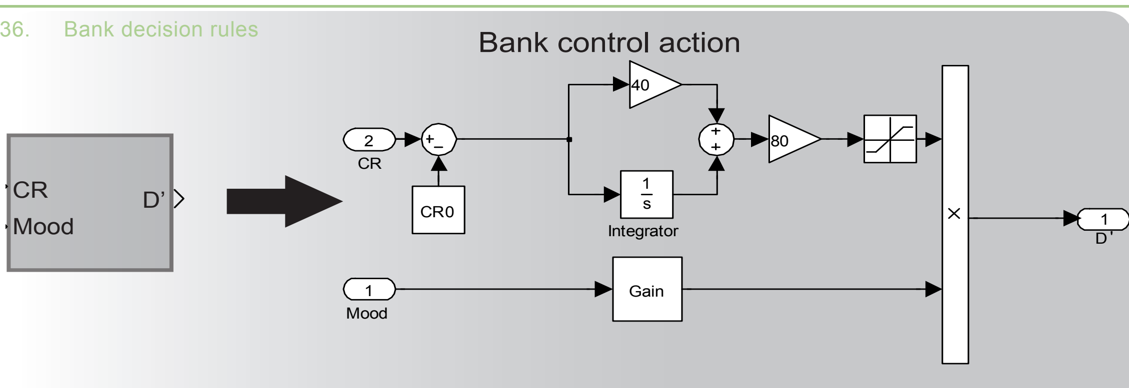
Figure 36 shows the banks control action to keep Capital Ratio CR close to the minimum required CR0.

The minimum required total capital to weighted asset ratio is set to 8% (BIS, 2008) as a guide for central banks. This is also the value chosen in this model.

The first part part model in figure 31 takes the difference CR - CR0 and attempts to minimize it by issuing loans to the real economy. Issuing loans is the only control output the bank sector has. It has no other means itself of affecting the capital ratio.

The control action is implemented with a PI-regulator. The integral effect “punishes“ long time deviation from the reference point CR0, and the proportionate effect minimizes the present

Figure 36. Bank decision rules



deviation. The gains where chosen through a trial and error process, in an attempt to get the desired performance. The lower saturation indicates that we do not have the option of selling loans to banks not within the economy. Which means, banks in this model have no other means of increasing the capital ratio than the passive action of not issuing more loans.

The control action works perfectly as it is, but to increase realism, we added the effect of mood on the willingness to issue new loans. Low mood should leave banks less willing to issue loans. i.e. sub prime lenders. High mood should have the opposite effect.

The Gain sub system is as shown in figure 37. Its only purpose is to magnify or weaken the effect of Mood. However since the input is not really mood, rather exp(mood), we need to take the natural logarithm of this value before adding a gain. We want the amplified value to revolve around zero, so that the effect of the gain is equal for both positive and negative mood. After the gain we bring it back to exp(mood), so that neutral mood is 1 rather than 0 (see **5.4 exponential function** for details on this)

The Bank Liabilities

The last element introduced in the new financial sector (in figure 33) is the bank liability stock, which si depicted in figure 38. It consists of all deposits from the real economy as well as borrowed reserves from the central bank or subordinated debt. The interest rate iL makes the liabilities increase over time. It is crucial for

Figure 37.   Amplifying mood sub-system

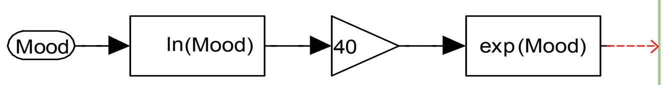
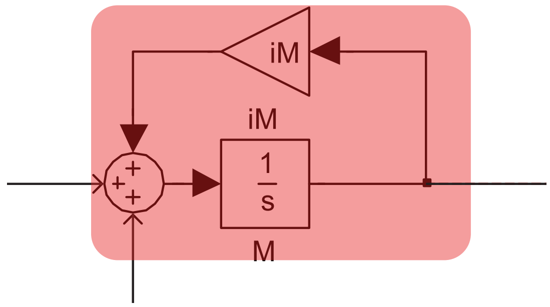


Figure 38.   Bank liabilities



the survival of the bank sector that this is lower than the interest rate for loans. The purpose of introducing this stock has already been discussed.

Simulations

We will now examine the financial sector by doing some simulations. We decouple The financial sector totally from the real economy. This means that we must default mood to neutral, since it depends on F_d. Bank expenses to the real world are also set to zero. It is also important that we set debt service F_d as a negative input to liabilities, since there is no Central bank to remove surplus reserves yet.

We start simulating with a loan of 100, as before. This amount is added to the liabilities, simulating that the loans are deposited in the bank sector. We also start with 12 in reserves, i.e. 12% reserve to liability ratio. The interest rate on debt is set one percent higher than for the liabilities.

From the first graph we se that both debt and liabilities grow, but debt grows faster, which means the 1% difference in interest rates makes the bank sector grow. Reserves remain constant, as they are not connected to the money flow of the rest of the system

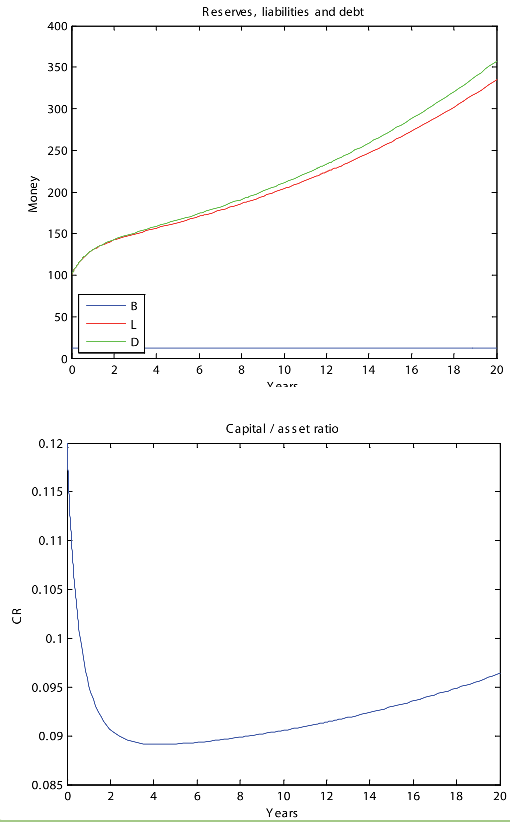
The capital / asset ratio drops at first, but as debt grows faster than liabilities, it starts rising.

This situation will escalate indefinitely, since there si no balancing loop, no mood connected to the insolvency function, only a constant percentage of debt is deleted.

In the next simulation we sett the interest rate equal iD = iL = 4%, and examine what happens

B_init	= 12	[currency]
D_init	= 100	[currency]
L_init	= 100	[currency]
iD	= 5	[%]
iL	= 4	[%]
T_B	= 1,2	[year]
T_D	= 15	[year]

Simulation 18. Financial sector iD=5% iL=4%



We first notice that both the stock and liabilities fall, instead of rising. And this time debt is lower than liabilities. Since the interest rates are equal, the small amount of insolvency is enough to make sure that the bank sector looses money, and will reach insolvency.

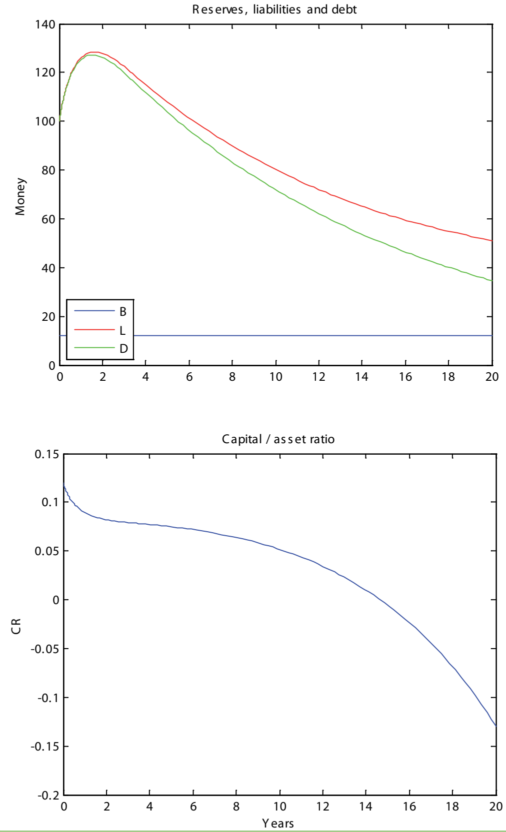
From the next graph we see that the capital ratio plummets as liabilities become larger than debt. This means less new loans are issued, and the bank sector is heading for a sure death. At t=15 we se that capital / asset ratio is zero, the bank sector has less assets than liabilities, and is thereby insolvent.

In the last simulation we have chosen iD 4.65 % and iL 4%

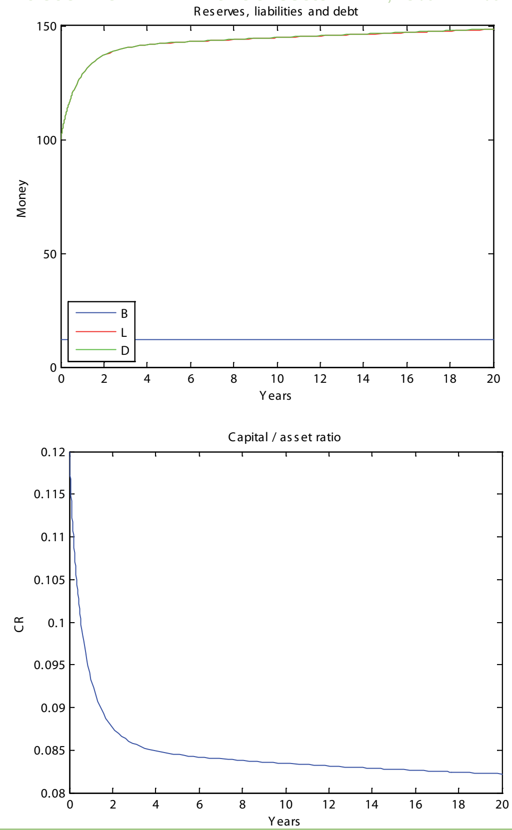
From the first graph we can almost only see two curves. Now liabilities and debt overlap and reaches a equilibrium at about 150. This happens because the difference iD and iL is just enough to counteract the loss of assets through insolvency.

The last graph shows that BASEL I and the banks control action works. Capital / Asset ratio converge to 8%. But the The system as it is now is not robust at all. It is inherently unstable for most parameters. Just a small change will break the fine balance.

Simulation 19. Financial sector iD=4% iL=4%



Simulation 20. Financial sector iD=4,46% iL=4%



5.7 REGULATING AGENT

Government and central bank

Until now, we have assumed that economy runs its course based solely on the personal interests of the agents of the real economy and the banking sector. There is no supervisory control agent imposing on the economy, trying to steer it in a desired direction. Nor is there any monetary agency, guiding the economy, helping it to keep on course. Every modern economy has one, it would therefore be a gross simplification not including one in this model.

These monetary agencies come in various forms, but in most developed countries today, they come in the form of an “independent” central bank.

A central bank regulates an economy’s money supply and credit, it issues currency, and manages the rate of foreign exchange. The principal objectives of a modern central bank are to maintain a high level of employment and production, a reasonably stable level of domestic prices, and an adequate level of international reserves (Encyclopædia Britannica, 2008). Central banks have several means to these goals, which will be discussed later on.

Figure 39. The Federal Reserve crest (Federal reserve, 2008)

Some central banks are publicly owned, some privately. Some are tightly bound to their governments, some loosely. Some take a more active role in the economy, while others are more passive. To illustrate some of the differences, take the American central bank; the Federal Reserve, “The Fed“ for short.

The goals of the US’s monetary policy are spelled out in the Federal Reserve Act (1913), which specifies that the Board of Governors and the Federal Open Market Committee (FOMC) should seek “to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates.” (FOMC 2008)These three simple goals are what governs the policy of The Fed. Actually, these are only the preconditions for the actual goal, which is; maximum sustainable output growth, which simply put is: growth in potential GNP. With these ground rules laid down in 1913, and the addition of ten or so similar acts, The Fed has been operating independently from the US government.

In the other end of the spectrum, we have the central bank of North Korea, which actually is also a commercial bank. In fact it's the only bank, with more than 200 branches. All other banks were either shut down of incorporated into the central bank in 1947(Heritage, 2007). The country has no private financial sector, the central bank, i.e the government, single-handedly controls the economy. Solely based on the definition, you might be able to call "The Central Bank of the Democratic People's Republic of Korea" an actual central bank, though it would be more suitable simply calling it the government, or perhaps Kim Jong-il, the distinction is vague at best.

There are more subtle differences between the central banks in most developed economies, but the goals are roughly the same even though their means differ. In this paper the role and the modelling of the central bank will be simplified, so as to be cover all different variations of a central bank.

Unlike the commercial banks in "our" banking sector, central banks are operated for the public welfare and not for maximum profit. This should mean that it will form one or more stabilising loops in the model, guiding the economy clear of a potential crisis.

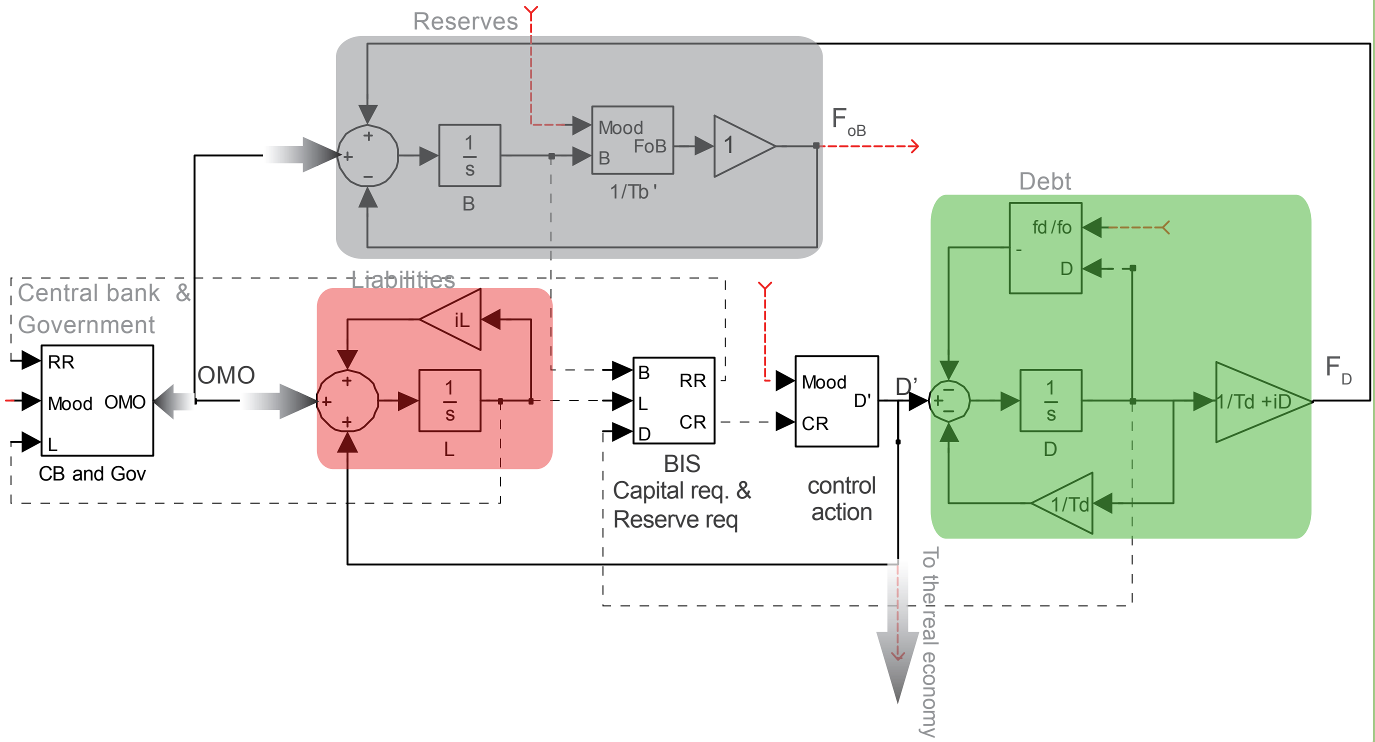
An important responsibility for many central banks is servicing the nation's largest banking customer; the government. As the government's bank or fiscal agent, the Fed processes a variety of financial transactions.

Just as an individual might keep an account at a bank, a nations Treasury keeps a checking account with the central bank through which incoming federal tax deposits and outgoing government payments are handled. As part of this service relationship, central bank sells and redeems government securities such as savings bonds and Treasury bills, notes and bonds. In order to minimize variations in aggregate banking system reserves, the Treasury maintains a nearly constant balance in its central bank account. In effect, Treasury payments are simply transfers from its commercial bank accounts to the bank accounts of the public.

Which means that the government and the central bank operates much as a single agent in the economy. This simplification is made in the model in figure 40.

In this new model of the financial sector there are few differences to the one introduced in 5.6. The obvious difference is the including of a regulating agent; a central bank, as just discussed. A more subtle difference is that we now calculate a reserve to liability ratio in the capital req. subsystem. This reserve ratio is used by the central bank to conduct its Open Market Operations.

Figure 40. The financial sector coupled with a regulating agent



B	= The banks' reserves.	[currency]
D	= Accumulated debt, i.e. financial claims from the Bank sector.	[currency]
L	= Accumulated liabilities, to central bank or the real economy	[currency]
F_{oB}	= Money flow out of the bank; expenses in the real economy	[currency/time unit]
F_D	= Repayment of debt with interest.	[currency/time unit]
D'	= Flow of newly issued loans	[currency/time unit]
OMO	= The central banks Open Market Operations	[currency/time unit]
iD	= Interest rate on debt.	[%]
iL	= Interest rate on Liabilities.	[%]
T_B	= Circulation inertia* Bank sector	[time unit]
T_D	= Loans duration	[time unit]
CR	= Capital (to asset) ratio	[Dimensionless]
RR	= Reserve (to liabilities) ratio	[Dimensionless]

*mean lag for the entrance and departure of money.

Open Market Operations

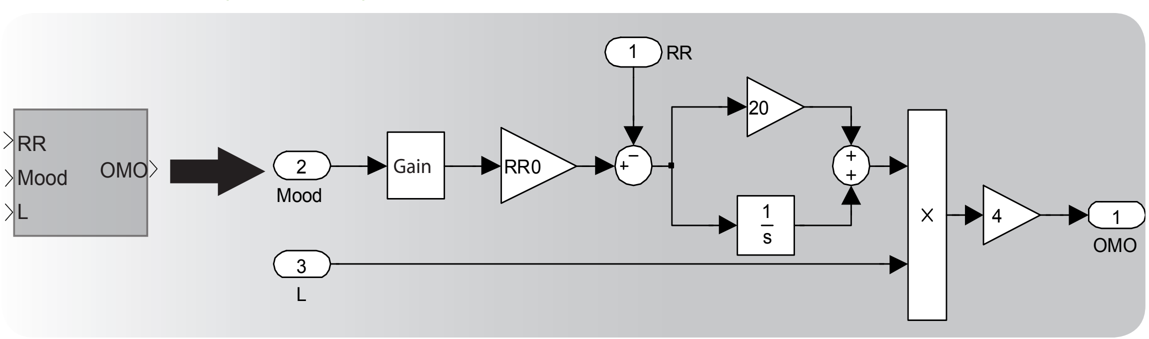
Or "OMO" for short, is the act of buying or selling bonds, bills, and other financial instruments in the open market. A central bank can expand or contract the amount of reserves in the banking sector and can thereby influence an economy's money supply. When the central bank sells such instruments it absorbs money from the sector. Conversely, when it buys it injects money into the it. Today the operations are conducted simply by electronically increasing or decreasing the amount of money that a bank has in its reserve account at the central bank, instead of selling or buying financial instruments. The effect is has is the same though.

Today Open market operations are the major instrument of monetary control in industrial countries. For countries that use interest rate as guide for their monetary policy, for example Australia (RBA, 2008) open market operations is the main tool. Although there is still dispute surrounding the use of OMO it does provide a means of avoiding the inefficiencies of direct control. Developing indirect controls is important to the process of economic development because, as a country's markets expand, direct controls tend to become less effective, and markets eventually find a way around them, especially in a global world economy (New York Fed, 2007)

Open market operations affect the money supply through their impact on the reserve base of the banking system. As a matter of monetary policy in controlling these reserves, open market operations can be conducted in one of two ways: actively, by aiming for a given quantity of reserves and allowing the price of reserves, i.e. the interest rate, to fluctuate freely; or passively, by aiming at a particular interest rate, allowing the amount of reserves to fluctuate

Figure 40 shows that reserves received through open market operations are far from charity. The OMO flow accumulates in both the reserve stock and the liability stock, which obviously means that they are borrowed. However, this also means that the central bank in this model cannot help banks increase their capital ratio (se 5.6 for capital ratio), in fact, over time, borrowing reserves from the central bank will lower the capital ratio, as liabilities gain interests

Figure 41. Central bank Open Market Operations



and reserves do not. The central bank can also remove reserves when there is a surplus of it in the economy

The model in figure 41 shows how Open market operations are implemented in this paper. Its shape is very similar to that of the banks decision rules in 5.6. The goal of the central banks, through OMOs, is to provide to bank sector with sufficient reserves to meet the reserve requirement, so that investments can be made.

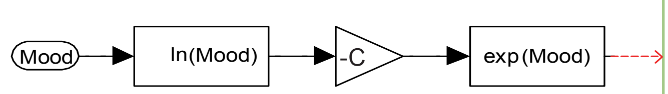
As with the bank decision rules we use the difference between the reference ratio RR0 and the current reserve ratio RR to establish the open market operations. The PI regulator uses a proportionate part an a integral, for the same reasons as with the bank decision rules. A major difference is in the way we include Mood. Mood actually changes the reserve requirement. Low mood makes the reserve requirement lower, thereby freeing up reserves. This expanding policy is is traditionally used to combat unemployment in a recession by lowering interest rates, lowering reserve requirement should have this effect. Contrary, high mood will increase reserve requirement, so as to bind up more reserves. Such a contractionary policy has the goal of raising interest rates to combat inflation or cool an otherwise overheated economy.

Having variable interest rates would have no particular effect on this model, since this macro model only aims to shed light on the relationship between sectors. And in this model the financial sector controls the real economy's lending entirely, and changing the interest rate would not affect the real economy's lending. Therefore the interest rates are kept constant.

From figure 41 we also se that the amount of reserves injected or removed is based on the liabilities of the bank sector. This is meant to help prevent liabilities from reaching zero and creating a singularity in our model. Otherwise the dynamics of the model seemed unaffected by this.

The Gain sub system in figure 42 is equivalent to the one in figure 37. It is used to amplify the "original" mood before transforming it back. In this case the amplification is negative in order to work as described above.

Figure 42. Amplifying mood



Simulations

We will only have a short discussion of some simulations here, as the results are very similar to that in 5.6, without a regulating agent.

Simulation parameters are the same as in 5.6 and we start with iD=5% and iL=4%

From the first simulation We se that both liabilities and debt increase as before, but the difference between them is limited. The central bank's reserve requirement makes sure that some of that profit is sat aside as reserves. We se the same trend from the capital / asset ratio, it almost stabilizes just above at the required level.

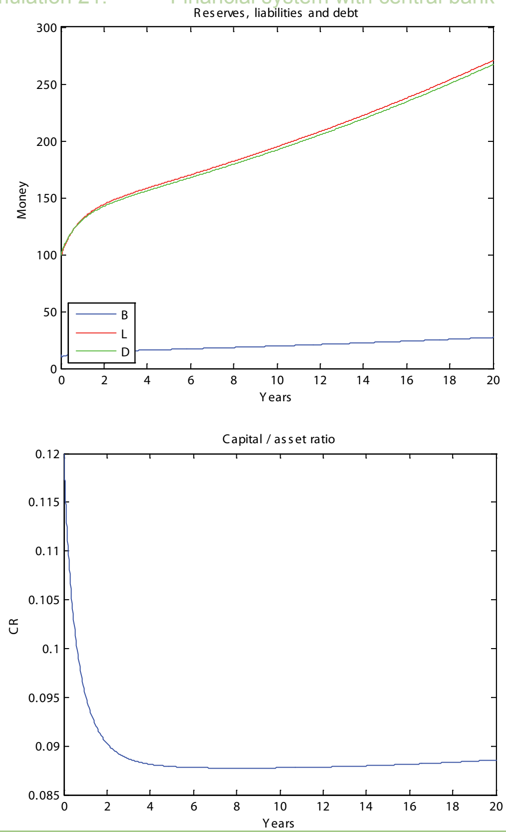
We now simulate with iD=iL=4%.

Here we see the same effect. The regulating agent or central bank remove excess reserves, thereby somewhat lowering the bank's liabilities and minimizing its' losses. Although the bank sector still heads for insolvency-

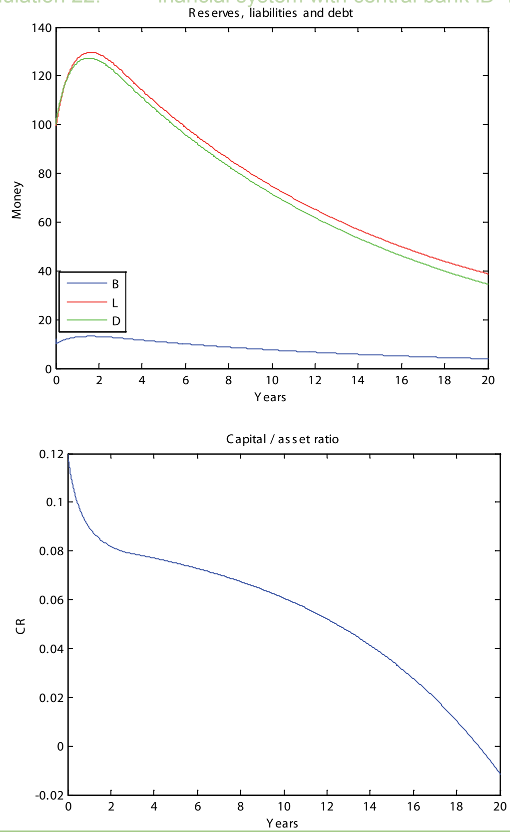
It becomes clear that the central bank / government stabilizes the system, and makes it more robust than before.

B_init	= 12	[currency]
D_init	= 100	[currency]
L_init	= 100	[currency]
iD	= 5	[%]
iL	= 4	[%]
T_B	= 1,2	[year]
T_D	= 15	[year]

Simulation 21. Financial system with central bank



Simulation 22. inancial system with central bank iD=iL=4%



5.8 DEPOSIT ACCOUNT

The new real economy

A deposit account is a current account at a banking institution that allows money to be deposited and withdrawn by the account holder. The transactions and resulting balance is recorded on the bank's books. Some banks charge a fee for this service, while others may pay the customer interest on the funds deposited (Britannica, 2008 b).

This account, however includes any high liquidity, low risk investment in the financial sector. Aggregate invested money always make a small profit, and the money should be readily available for withdrawal. This is how the deposit account in the model in figure 43 functions the interest rate being equal to that of the bank liabilities.

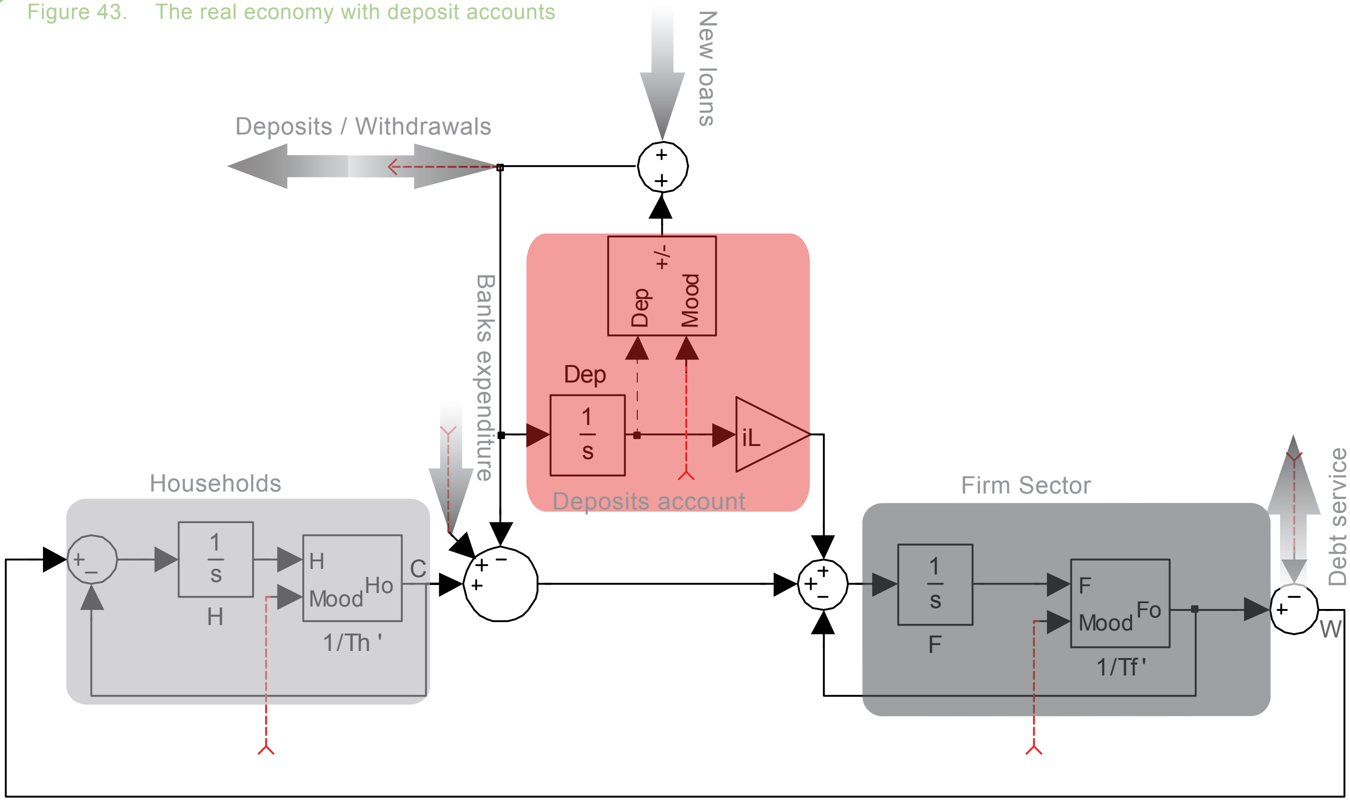
The "value" of new loans enter this account but the money do not get into circulation in the real economy before it is withdrawn, at which time they are also removed from the bank sectors liabilities. This account is a mirror image of the share of bank liabilities that consist of deposits. Every change her gives an equal change in the bank liabilities.

When withdrawing money the bank liabilities shrink but as do its reserves, the money supply in the real economy however increases. When depositing the bank reserves of course increase, but its liabilities do too. And the money supply of the real economy diminishes.

As we can se from the model in figure 43 withdrawal/deposit has opposite input signs on the account and the real economy. thereby working as described above. There is a continuous flow of interest paid to the real economy, base on the stock "Dep".

The deposit account acts like buffer between the real economy and the financial sector. This will become even clearer when we discuss the subsystem where the amount of withdrawals and/or deposits are decided.

Figure 43. The real economy with deposit accounts



H	= Household money.	[currency]
F	= Firm money.	[currency]
Dep	= Money in deposit accounts	[currency]
W	= Wages .	[currency/time unit]
C	= Consumption.	[currency/time unit]
iL	= Interest rate on deposits (same as bank liabilities)	[%]
T_H	= Circulation inertia Households	[time unit]
T_F	= Circulation inertia Firms	[time unit]

The decision to deposit or withdraw could, or should be based the trend of change in F, i.e. the (lowpass) filtered derivative of F. This would be rational behaviour, however since we are modelling aggregate agents of an entire economy, it si unlikely that they know the exact change in the real economy's money supply. This is something even the central banks struggle measuring. Simulations done with this solution lead to very unlikely, and static dynamics, not especially representative of the economy we know.

Mood however is a universal feel that every single agent is affected by. Mood and the current level of deposits was therefore chosen to determine the amount to be withdrawn or deposited as seen in figure 45. $e^{(Mood)}$ Must be transformed back to its original form, with values ranging from-1 to 1, as done in 5.7.

Multiplying mood with current "Dep" makes it impossible to overdraw the aggregate account. This translates into increased savings with increasing mood, and net withdrawal with negative mood. People save in anticipation of a coming recession, and start withdrawing when the debt burden. i.e. Mood, becomes to high to handle.

Simulations

We will have a brief examination of the new real economy's dynamic, almost decoupled from the financial sector. No loans received, thus no debt service. No expenses paid by the financial sector. But the real economy does have a deposit account,

Figure 44. Discarded decision rule for saving and withdrawing

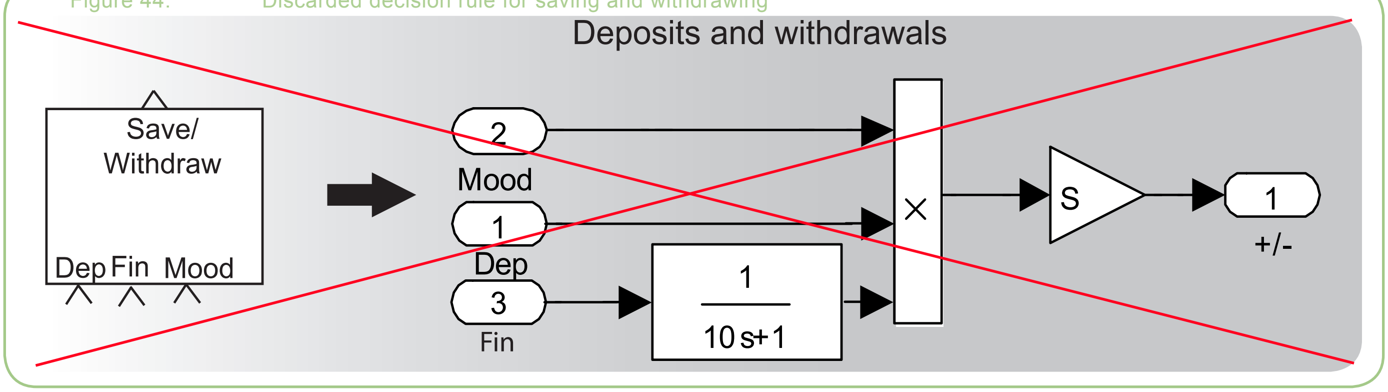
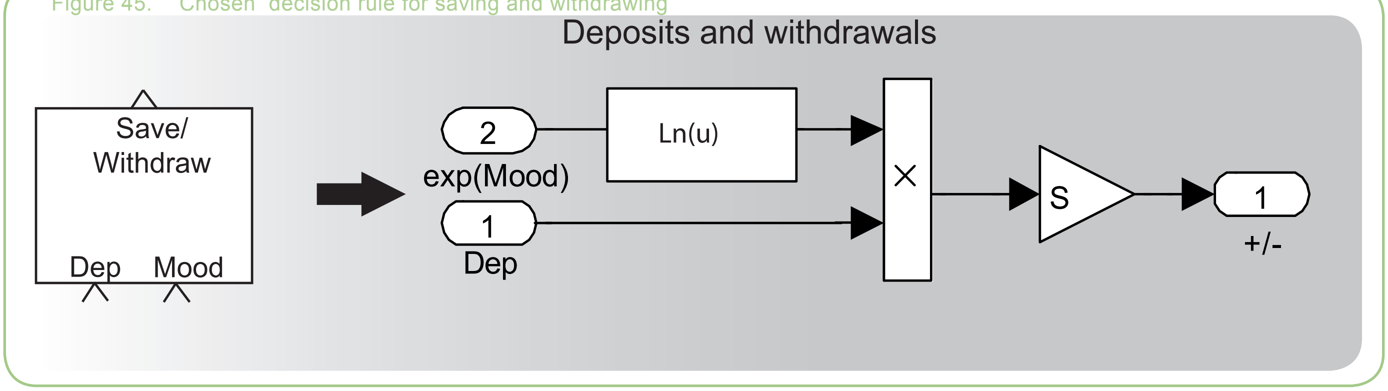


Figure 45. Chosen decision rule for saving and withdrawing



that start of at 10. The rest of the parameters are as described to the right.

We start of with a simulation of the discarded decision rule with neutral mood. From this we se that it does not take the real economy long to establish equilibrium. Every interest deposited back to the account. This is how an untouched savings account would look like, none of the returns are withdrawn
with this decision rule the financial sector, the real economy's dynamic is quite static.

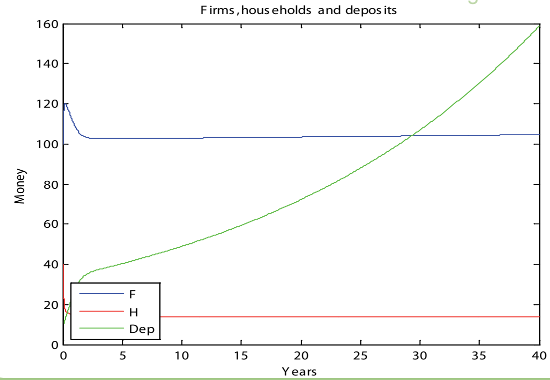
In the next simulation we impose a sinus mood (input with 0,5 amplitude and no bias) to this discarded deposit / withdrawal - control action. We can now se that the it is more or less indistinguishable from the former. It is unmoved by economy's mood. This is the action of a cold and calculating investor, not an aggregate economy.

From the last simulation we see that the chosen control action makes deposits oscillate with mood. The economy withdraws most of the returns, instead of reinvesting, therefore money in the real economy gradually increase by having deposits. It of course increases more in periods of optimism, when the agents deposit more and interests increase. It seems however to rise the most when agents are withdrawing since more money comes into circulation.

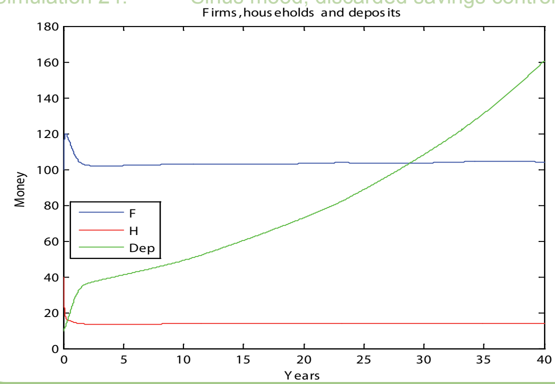
The fact that saving/withdrawal is not dependent on money in circulation, might seem like an error. But later, when new loans are issued this money needs to go through the deposit account, and the issue thereby resolves itself.

F_init	= 100	[currency]
H_init	= 40	[currency]
Dep_init	= 10	[currency]
iL	= 4	[%]
T_F	= 1,2	[year]
T_H	= 0,08	[year]
S	= 0,7	[dimentionless]

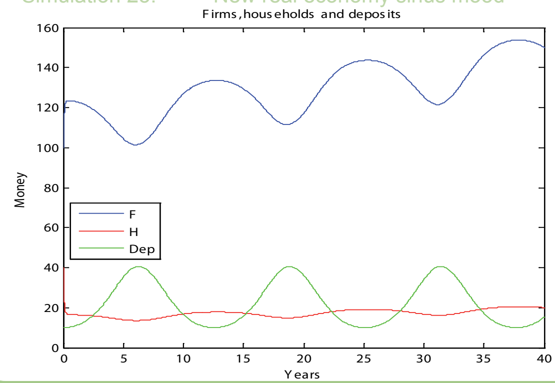
Simulation 23. Neutral mood discarded savings control action



Simulation 24. Sinus mood, discarded savings control action



Simulation 25. New real economy sinus mood



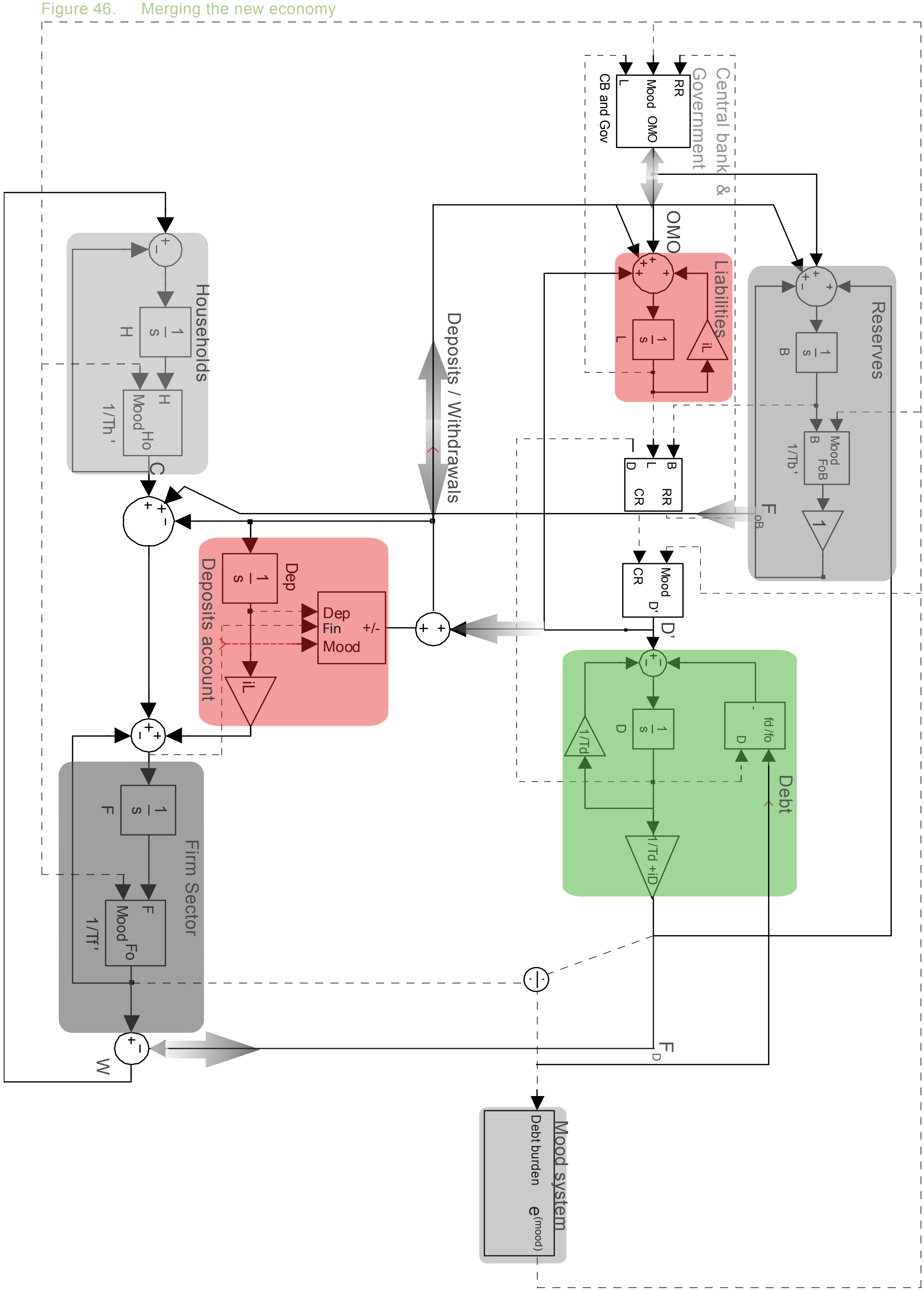
5.8 NEW MERGER

The new macro economy

In the following we will merge the real economy with the financial sector, in a similar manner as in 5.3. The models variables and parameters will not be examined, as they have been discussed in the previous sub chapters.

By examining the model in figure 46, on the next page, we se how money flows between the real economy and financial sector and how the various aspects of the economy interacts.

Figure 46. Merging the new economy



Simulations

We will now examine the model by going through a series of simulations. We cannot, as before, kick start the economy with be issuing a single loan. This would induce singularities, since many control actions depend on ratios between stocks and flows. We therefore start the economy in a reasonable state, and examine its evolvement from there. It is important to keep in mind the vessel dynamics when setting the initial conditions. For example Dep can never surpass L.

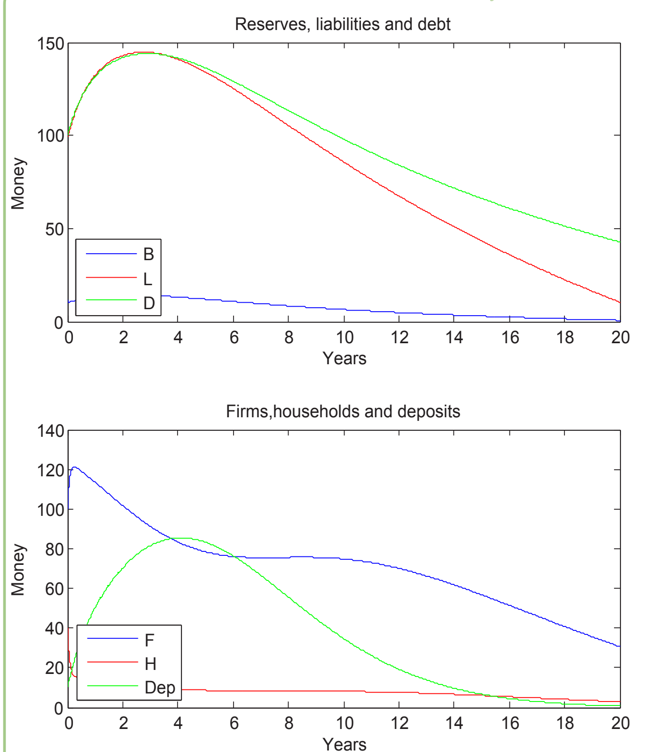
All initial values and parameters are as before, in order to make reasonable comparisons. In the first simulations we set iD 3 percent over iL, at 7% and 4%.

From the first graphs we see the stocks of the financial sector. At first glance we recognise that they are all decreasing. We are not to worried about this. As long as the ratio between the different sectors are kept within reason, it can be said to be the result of deflation, the money increases in value. Deflation comes with problems, but that is not a discussion for this paper. By increasing payments to the real economy, i.e. increasing reserves circulation speed (lowering T_B), and at the same time increasing loan interest rate, we could easily have had inflation instead. It is the relationship between these stocks that should be the point of interest.

By having three percent higher interest rate on loans, than deposits, debt decreases at a much

B_init	=12	[currency]
D_init	=100;	[currency]
F_init	= 100	[currency]
H_init	= 40	[currency]
L_init	=100	[currency]
Dep_init= 10		[currency]
Theta_init= 0		[mood]
iL	= 4	[%]
iD	= 7	[%]
T_F	= 1,2	[year]
T_H	= 0,08	[year]
Td	= 15	[year]
Tb	= 1,2	[year]
Ttheta	= 12;	[year]
CR0	= 8	[%]
RR0	= 10	[%]

Simulation 26. Stocks in new macro economy iD=7%, iL=4%

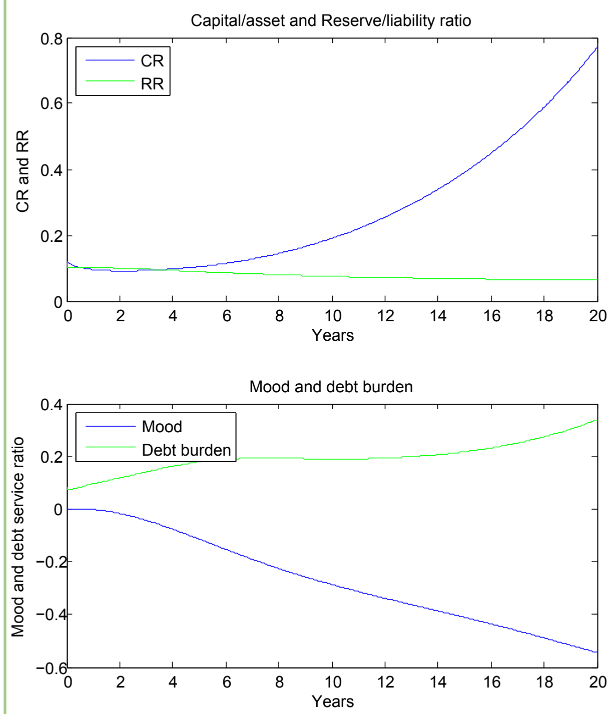


lower rate than liabilities. The reserves fall at the same rate as liabilities, as the central banks's open market operations keep reserves roughly at the target reserve requirement, which depend on the current mood. As debt service increase bank reserves, OMOs will reduce liabilities further, but never past zero. Liabilities will hit zero, at which point reserves start increasing. However, with reserves higher than liabilities we are outside the realm of what is reasonable.

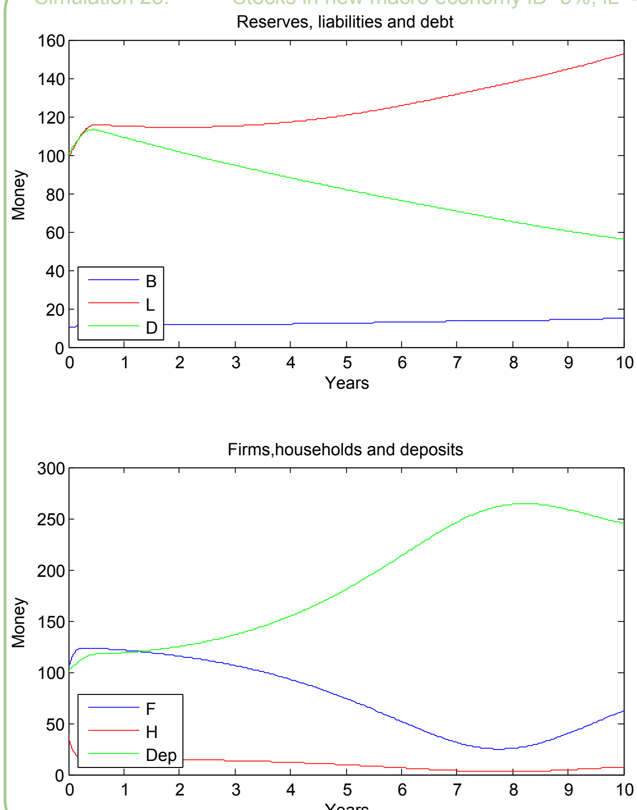
The firm household and deposits graphs are also decreasing, except for the first months, when firms and households establish the right stock ratios according to their circulation time lags (se 5.2). Deposits increase as the first large loans are received, but due to bad economic mood, they are swiftly withdrawn, to help cover debt payments. This eases the debt burden in the short run, but as we se from the two last simulations, the debt burden keeps increasing after a while, and the ever decreasing mood makes the debt burden even worse. We also see that the bank sectors fantastic capital / asset ratio ought to worsen the real economy's debt burden even more, however the dropping mood, keeps the bank sector from making too many risky investments. However, the debt burden keeps increasing even so, and soon insolvency in the real economy will bring the bank sector to its knees.

We now try reducing the difference in interest rates to iD=5% and iL=4%. And the difference is obvious. Liabilities actually surpass real economy debt. This is both due to the bank sectors shortage of reserves, which forces it to borrow from the central bank, and also real

Simulation 27. Ratios in new macro economy iD=7%, iL=4%



Simulation 28. Stocks in new macro economy iD=5%, iL=4%



economy agents' optimism which inspire them to save/invest in the bank sector, both of which increases liabilities.

This simulation is not worth examining for too long, as it becomes invalid after only two years. The point of it is to see that by setting the two interest rate as close we drive banks to insolvency, i.e. liabilities surpass assets. It seems clear that we will have to take this into account before continuing.

As firms and households can become insolvent, so can banks. When approaching the point where this happens, either the financial community gather round and organize a rescue, and, or the government set up compensation arrangements, directly or via the central bank. In very few cases do actual insolvency occur, but when it does banks go bankrupt, like the agents of the real economy, and may be unable to pay any of the amount owed. In most economies however, there are insurances on deposits, so if no one buys the bank and assume their liabilities, or a bridge bank is established, depositors will still be paid off (Pelgrave, 2007).

A single simplified representation of these options

Simulation 29. Ratios in new macro economy iD=5%, iL=4%

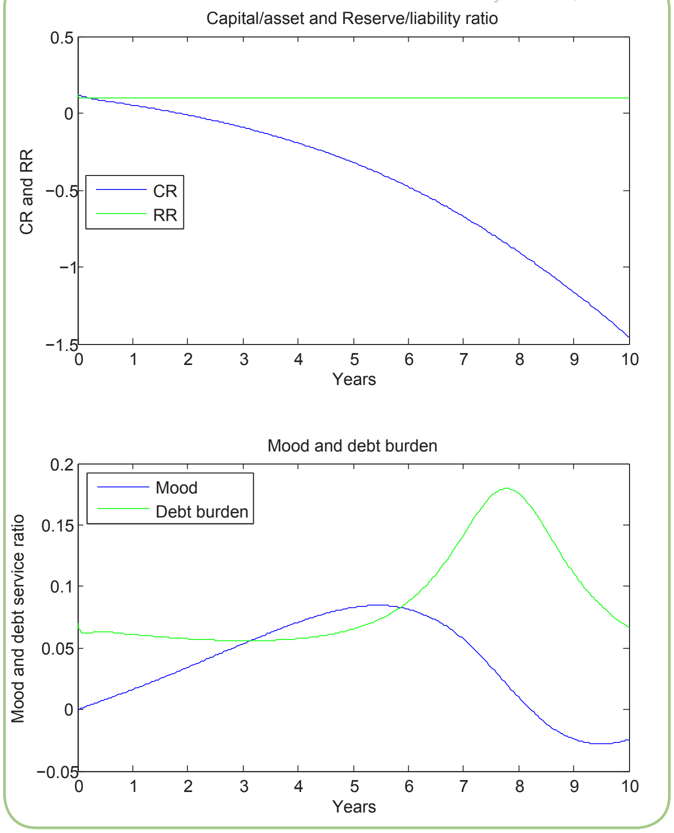


Figure 47. Including Bank insolvency

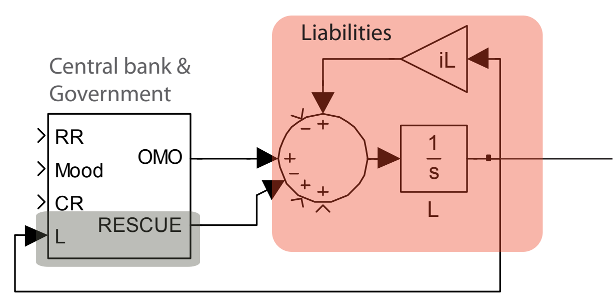
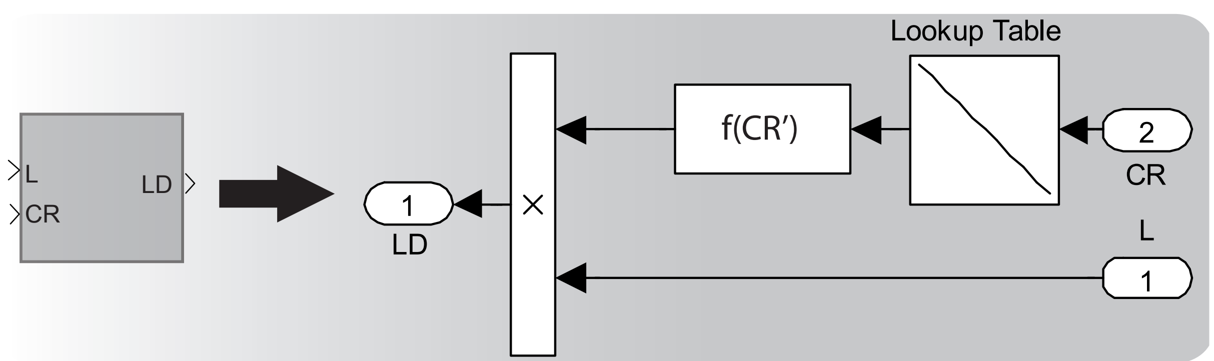


Figure 48. Sub system for calculating bank insolvency



is derived in the same manner to that of real economy insolvency (see 5.5). These figures show how this is implemented.

Capital ratio is used determine the amount of liabilities deleted. The capital ratio is transformed to values 0 to 1, in order to use the same equation used to calculate real economy debt deletion. 8% capital ratio roughly translates to 1% insolvency, as some insolvency is to be expected even though the aggregate bank sector is healthy. In the opposite scale 0% capital ratio means that all banks are insolvent, and all accumulated liabilities are deleted. Even though liabilities are erased depositors still have their claim, only the government/central bank has to cover the losses.

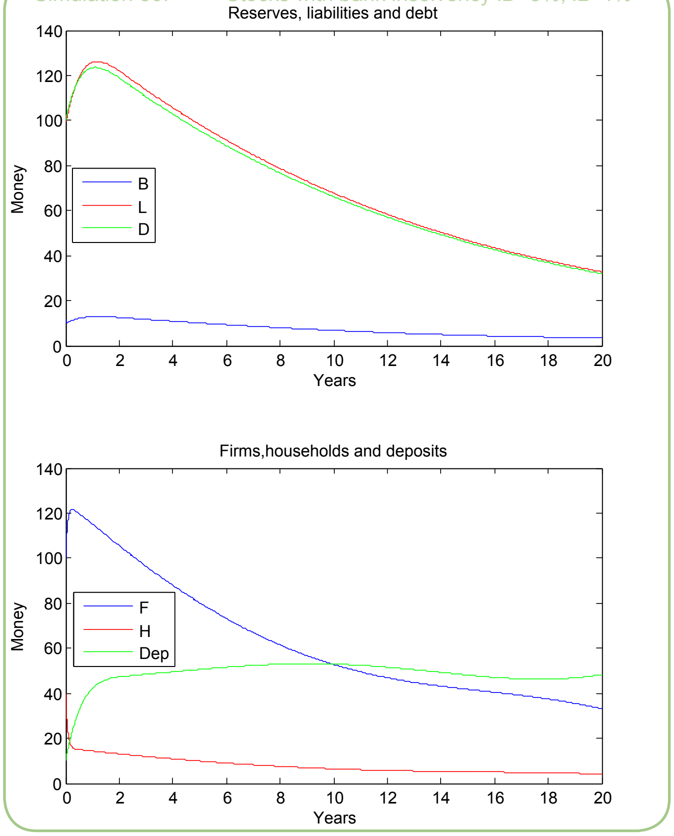
Further simulations

We will now repeat the last simulation in order to see the what effect this new rescue/insolvency loop will have.

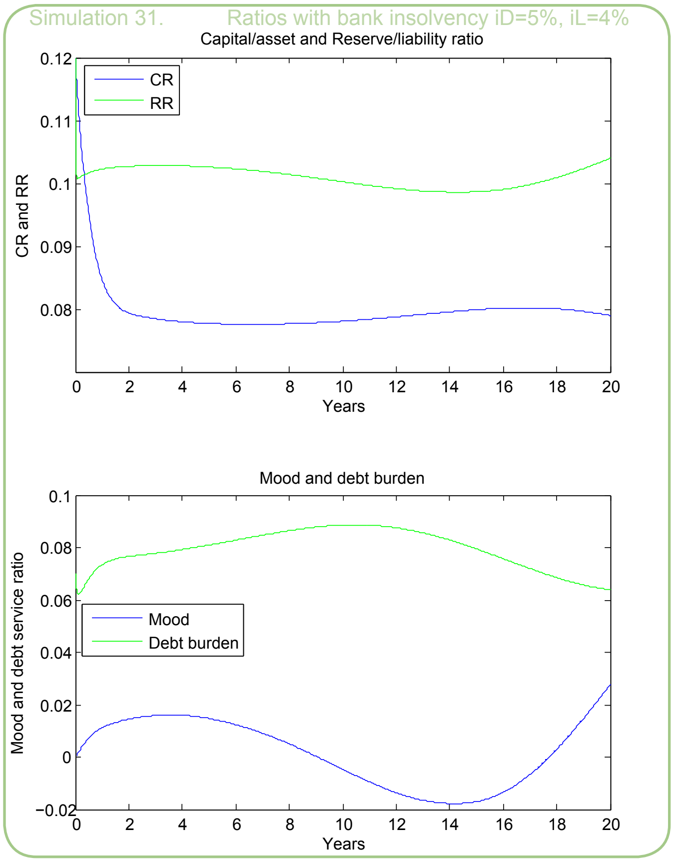
At once we see the effect. Even though liabilities still surpass debt, the difference between them is minimized by this new loop. Granted, the real economy has less money compared to the last simulation, but it is also mush more stable. Less money is saved/invested because of the a much more cautious mood just fluctuating around zero. And the debt burden keeps around the sustainable level of 8%, instead of having large fluctuations under and over.

The capital/asset and reserve/liability ratios are calmly swinging about the required values of eight, and roughly ten percent (varies with mood). It is safe to say that the addition of this loop stabilizes the system, and keeps it at a sustainable state.

Simulation 30. Stocks with bank insolvency iD=5%, iL=4%



Simulation 31. Ratios with bank insolvency iD=5%, iL=4%



5.8 Stock market

Stock market's effect on the economy

In the following we will include the effect of a stock market on the macro economy's mood. This model is borrowed from Trond Andresens paper "Overvaluation—not volatility—is the main danger in stock markets ". The model has been simplified as we do not need the complex behaviour of his model. The chief characteristic of interest to us is its constant movement. The system can never be in equilibrium, it will always self-oscillate. We will use this trait to induce mood swings in the macro economy.

This way of coupling the stock market with the economy is obvious a gross simplification. The representation of the stock market as a separate and somewhat artificial system, isolated from the actual economy does not hold in the real world.

A stock market refers to a market that enables the trading of company stocks, securities, and derivatives. It is a place of trading ownership, with shares of companies being bought and sold. This is in no way less real than the operations of the economy

Personal impacts of the stock market

More and more people have some of their personal savings invested in the stock market. These people will see a fall in their wealth. If the fall is significant it will affect their financial outlook. If they are losing money on shares they will be more hesitant to spend money; this can contribute to a fall in consumer spending. This change of behaviour has been accounted for in this models Mood system, through which the stock market makes its impact on the economy.

Anybody with a private pension or investment trust will also be affected by the stock market, at least indirectly. Pension funds invest a significant part of their funds on the stock market. Therefore, if there is a serious fall in share prices, it reduces the value of pension funds. This means that future pension payouts will be lower. If share prices fall too much, pension funds can struggle to meet their promises. Long term movements in the share prices is central. If share prices fall for a long time then it will definitely affect pension funds and future payouts.

Business impacts of the stock market

The initial issuing of stocks gives the economy its most important capital; the shareholders equity. For banks this make up most of the tier 1 capital, discussed earlier, which BASEL 1 in turn use to limit banks lending. As we know, more lending usually gives more profit.

Falling share prices can of course hamper firms ability to raise finance on the stock market. Firms who are expanding and wish to borrow often do so by issuing more shares - it provides a low cost way of borrowing more money. However, with falling share prices it becomes much more difficult and growth is inhibited. This important factor is one not included, as the buying and selling of shares is not implemented. However, negative mood will decelerate spending and will to a degree imitate this problem.

Often share price movements are reflections of what is happening in the economy. However, the stock market itself can affect consumer confidence. Bad headlines of falling share prices are another factor which discourage people from spending. On its own it may not have much effect, but combined with falling house prices for instance, share prices can be a discouraging factor. This being said, share prices can also fall without causing a downturn in the economy. For example the stock market crashes of October 1987; there wasn't an obvious economic factor causing this share price fall. The major economies remained relatively unaffected by this stock market crash. In fact, the UK had record growth in the late 1980s (Becker, 1997)

It is evident that the stock market contributes with more than confidence in the economy or the lack of it. However implementing it as if it only affects the economy's mood is satisfactory for this model.

The model

From the complete stock market model (See Overvaluation—not volatility—is the main danger in stock markets, for details of his model), built by Trond Andresen, we have chosen to remove dynamics that make up the notorious panics and crashes in a stock market. These dynamic were deemed unnecessary since his model is self-oscillating at its foundation, already going through ups and downs.

We have also opted to remove the noise factor, which consists of “the aggregate effect of agents making erroneous and different assumptions about the stock value “ and “differences in individual speculative behaviour into this noise process” (Andresen, in progress c). These effects are all short term dynamics not needed in our model with a time horizon of several decades.

For this same reason we have removed the “bandwagon“ effect, which consists of speculators and hobby brokers who, quote: “will jump on the bandwagon and buy now in the hope that prices will continue to rise” (Andresen, in progress c).

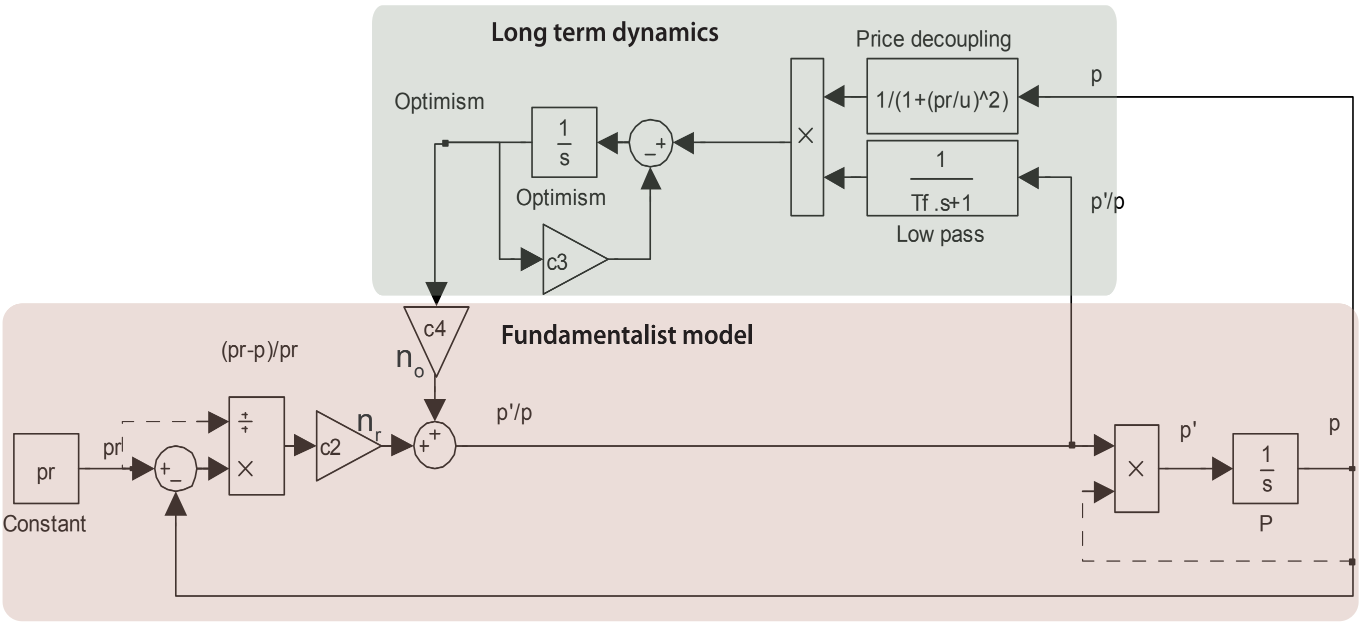
We only need a simple representation of a stock market that influences the economy, and in turn is influenced by the economy. This provides a satisfying degree of complexity for this model.

We will not go into detail elaborating Andresen’s model, a short description will suffice. How we use the model and why (discussed already), is the point of interest.

The stock market model in figure 49 is divided into two main components. The first is the fundamentalist model. This is based on agents’ belief about the sustainable value of the stock. They act rationally and increase the demand for stocks that have sustainable values lower than its present price, indeed this is how a stock market is supposed to work.

The second component is the long term dynamics loop. This uses the price change rate P’/P through a low pass filter. This means that increased rate of ‘optimism’ is assumed proportional to the long-term trend in index increase. The same principle holds for a decrease in P’/P. Short term fluctuations are

Figure 49. Stock Market model (Andresen, In progress c)



N_r = Demand component due to fundamentalist' agents' belief about the sustainable value of the stock

N_o = Demand component due to long term optimism

P_r = 'Real' or sustainable value of the stock

P = Current market price

P'/P = Price change rate

C_2 = Constant factor transforming price deviation into corresponding net demand

C_3 = "Forgetting factor": the market will gradually forget its initial mood and tend towards neutral

C_4 = Gain determined by requiring long-range periodic cycles disregarded entirely.

With some degree of lag, to signify the need for sustained trends in price change rate, the model outputs a level of optimism or pessimism. This value is fed back to the demand in the fundamentalist model through a gain as N_o.

Coupling the stock market to the economy

We have already discussed in what way the stock market trends will affect the economy. We will now look into how this is done in practice.

Figure 50 and figure 51 shows how we couple the two together. Optimism is given a numerical value, with range that is both positive and negative, similar to mood. Mood however is restricted to [-1,1] and generally resides far from these two extremes. Simulations with the stock model however, shows that the values naturally oscillates with much higher amplitude than mood. In order not to exaggerate the effect of the stock market optimism on the economy, we choose the gain K_0 smaller than K_m.

The two systems influence each other as inputs to states, thus we will see delayed mood-effects from and to the two systems.

Figure 50. Mood influenced by Stock market

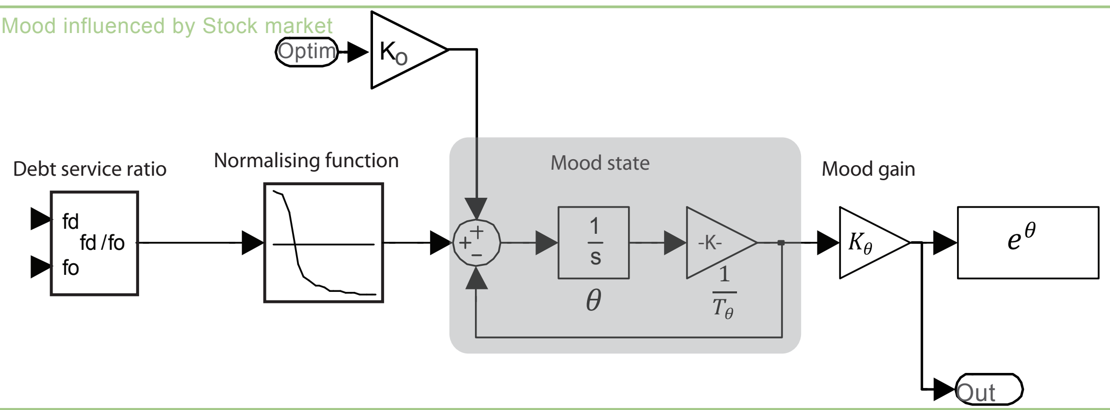
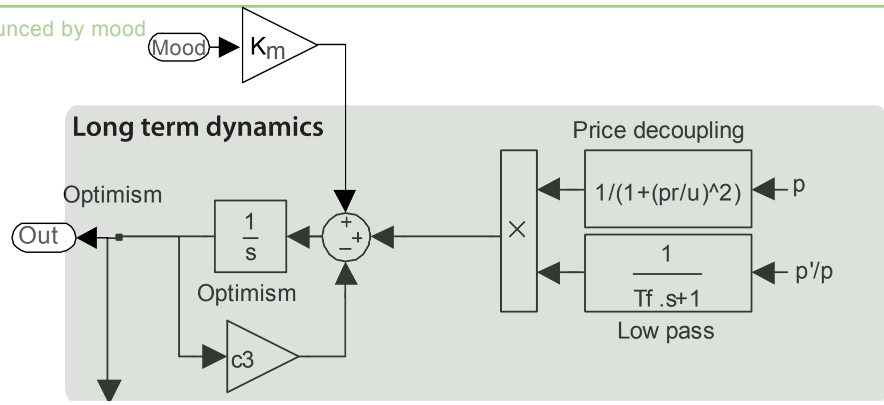


Figure 51. Stock market influnced by mood

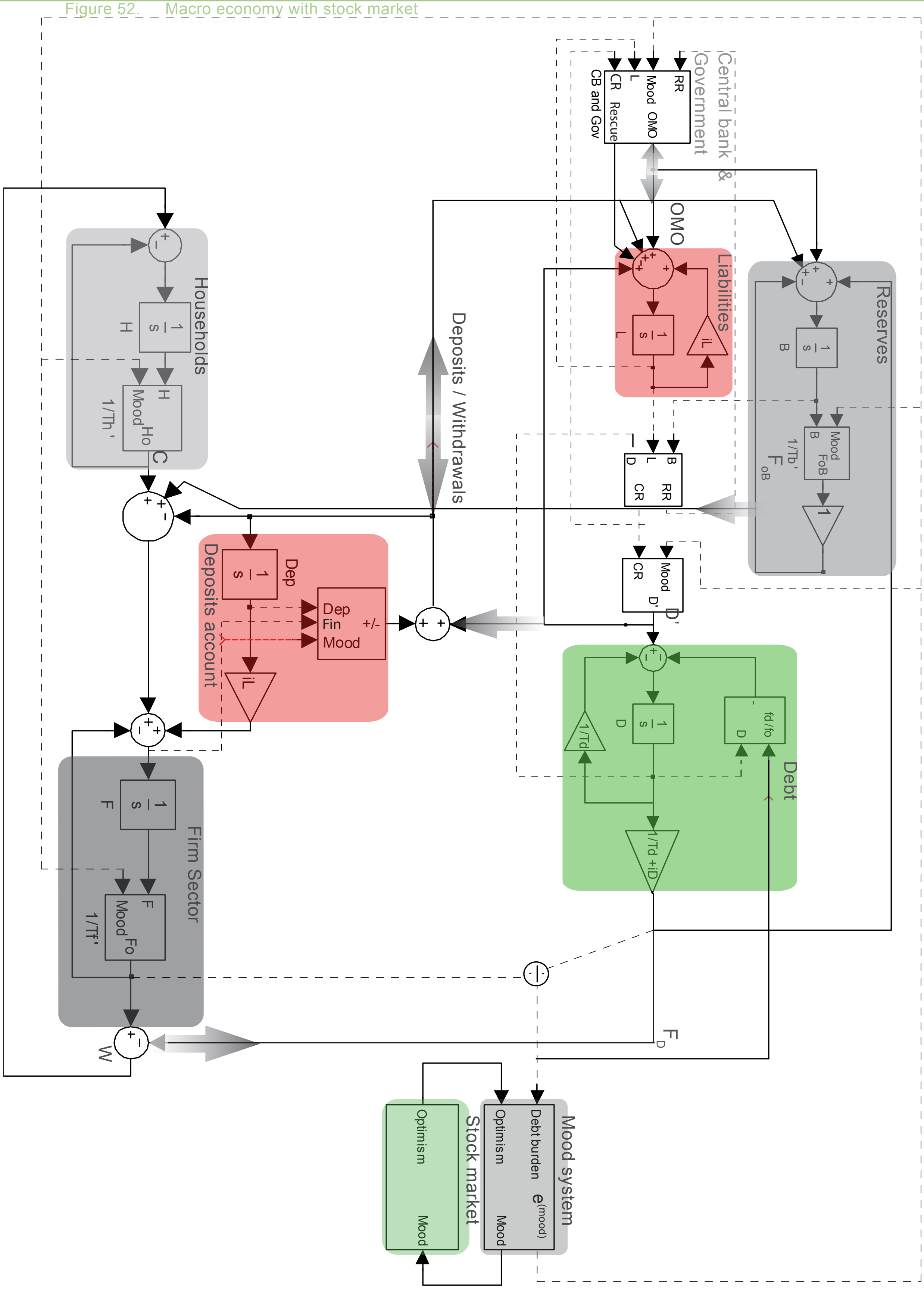


Macro economy with stock market

In the following we will examine the impact of the added stock market interfering with the economy's mood.

Examining the model in figure 52, on the next page, we see that a stock market has been added, connected to the input of the mood system, and in turn the mood system is connected to the stock market, as just described. We have also added the loop that signifies bank insolvency, or the act of rescuing banks from insolvency. This is now the complete model for this master thesis.

Figure 52. Macro economy with stock market



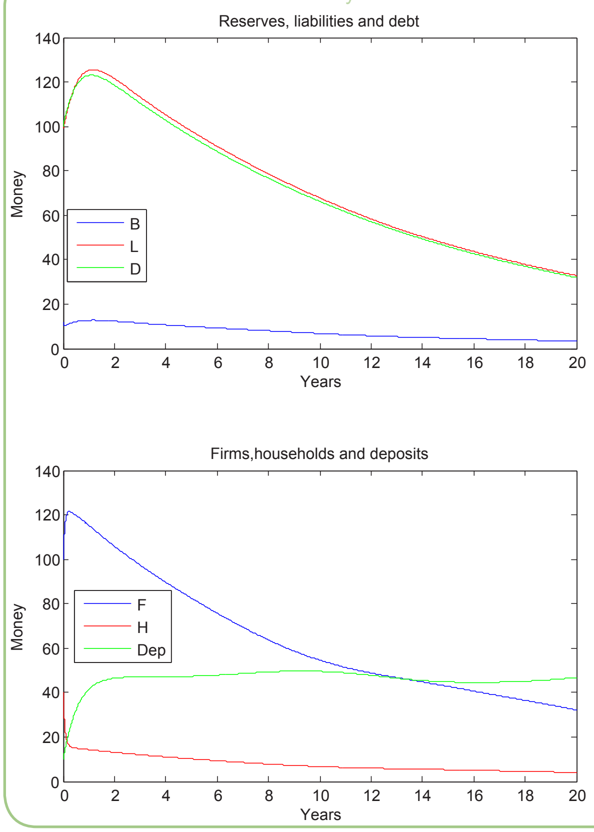
Simulations

We continue with the exact same simulation that we ended the last sub chapter, so as to compare the to results. We set the gains connecting the stock market and economy K_m to 1/3 and K_o to 1/12.

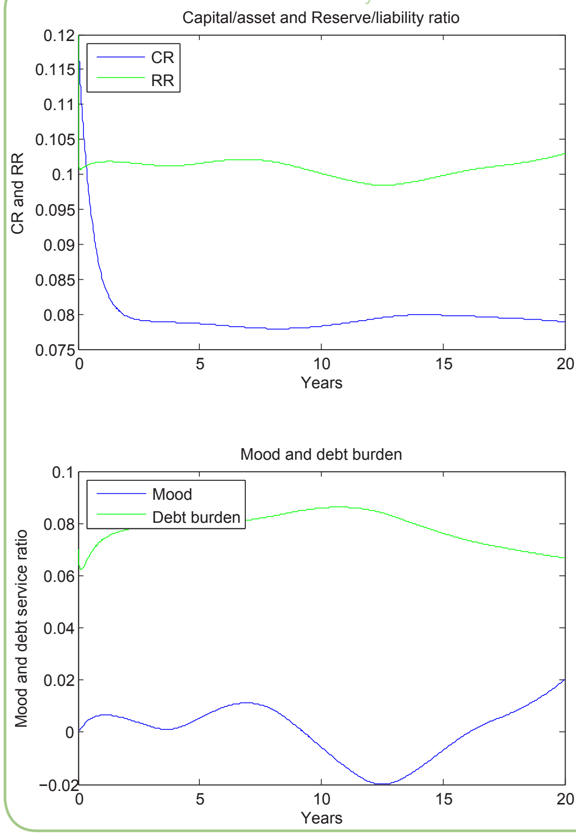
By examining the graphs, we se that the results look quite similar. The only noticeable difference is seen on mood, which should be suspected. Mood has a more erratic fluctuation around zero than in the simulation in 5.7. This is likely a result of the interference from the stock market. The reason that the actual economy has not been significantly affected by the stock market is simply that mood has not, to any extent, been affected itself, and mood is the only channel through which the economy is

B_init	=12	[currency]
D_init	=100;	[currency]
F_init	= 100	[currency]
H_init	= 40	[currency]
L_init	=100	[currency]
Dep_init= 10		[currency]
Theta_init= 0		[mood]
iL	= 4	[%]
iD	= 5	[%]
T_F	= 1,2	[year]
T_H	= 0,08	[year]
Td	= 15	[year]
Tb	= 1,2	[year]
Ttheta	= 12;	[year]
CR0	= 8	[%]
RR0	= 10	[%]

Simulation 32. Macro economy with stock market: Stocks



Simulation 33. Macro economy with stock market: Ratios

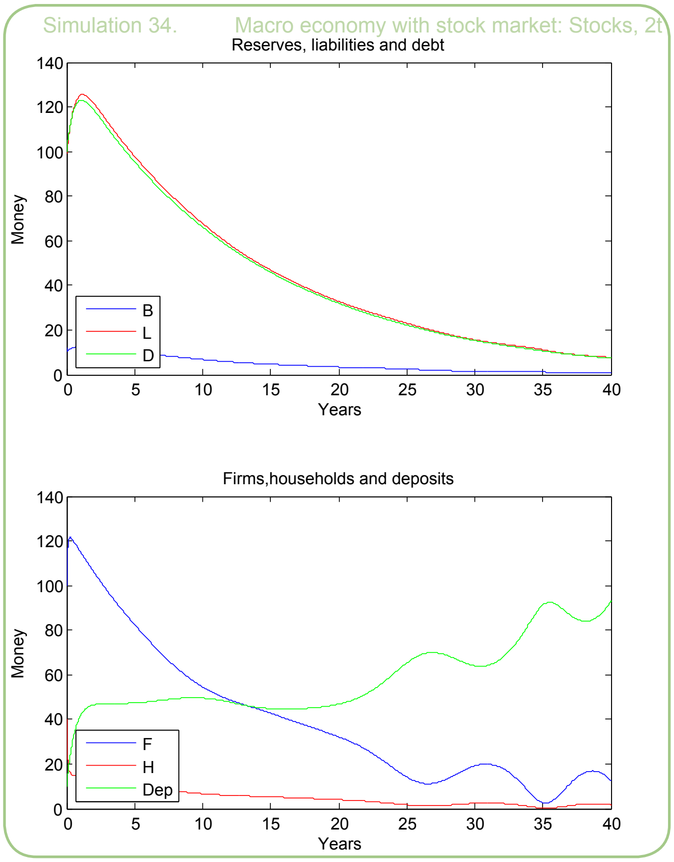


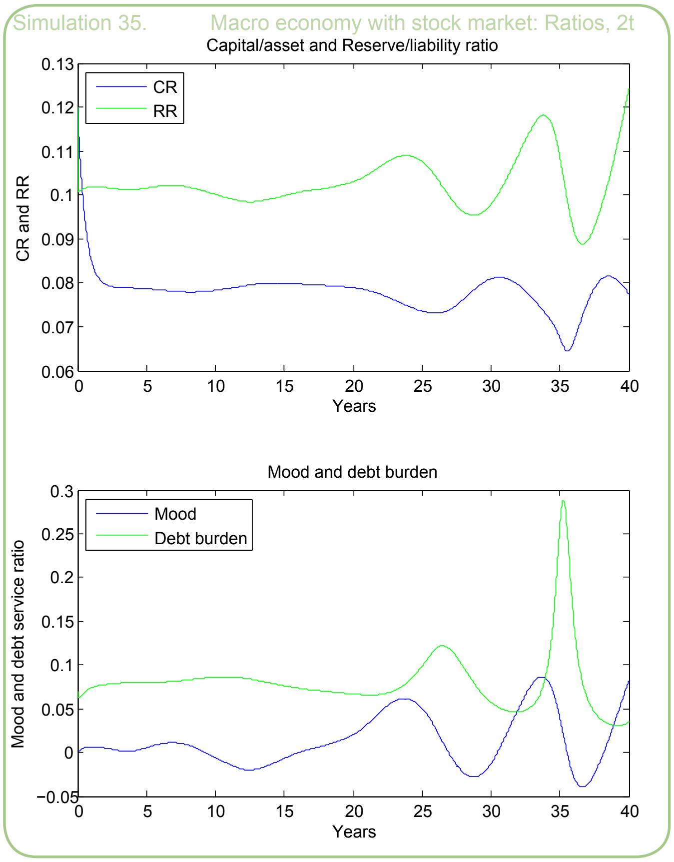
"feels" the optimism or pessimism of the stock market. It seems clear that we must extend the time horizon in order to draw any conclusions.

We double the time horizon and see what happens the next 20 years of simulation. It is difficult to see the effect of the stock market on financial sectors stock, as they are rapidly shrinking, as are the real economy sectors. Deposit/withdrawal however, is strongly connected to mood, and starts rising while oscillating with a period of about 9 years. Saving is rising because mean mood, now strongly oscillating, is increasing.

From the graphs of the ratios the influence from the stock market is now quite evident. Capital and reserve ratio's small fluctuations in the first 20 years are now amplified and increase in amplitude with each period. The natural oscillation of the stock market seems to make the economy instable.

In the last graphs it is obvious that there is a problem at hand. Mood is, as the ratios, oscillating with higher and higher amplitude. It is of course this oscillation in mood that make capital and reserve ratio oscillate, and it also makes the debt burden oscillate. This is not only an effect of mood changing the agents willingness to spend, but also the irrational saving/investment of these same agents. Since mood is oscillating with a positive mean, firm and household agents keep believing that investing money is a good idea. They therefore leave next to nothing to cover debt payments as debt burden rises with a delay to mood. This





situation only worsens until the entire economy breaks down.

We will now compare stock market optimism with the mood of the economy, to examine what really causes this.

The stock market optimism is scaled down 1:10 to fit into this simulation. We see the stock market optimism oscillating with lower tops when the economy's mood is at a low point, and higher tops when in phase with mood. With time the two fall into phase and correlation increases.

However these simulations show that the decision rule to deposit/withdraw is obvious broken. Although it does reflect some of the irrational behaviour of human beings, it breaks basic vessel dynamics by allowing to deposit money that does not exist. We fix this by separating the withdrawing and depositing. Withdrawing is dependent on current deposit "Dep", while depositing/investing is dependent on money in the firm sector F. The subsystem is depicted figure 53. Saturations make sure the two separate actions of depositing and withdrawing do not interfere with each other.

Simulation 36. Correlation between mood and optimism

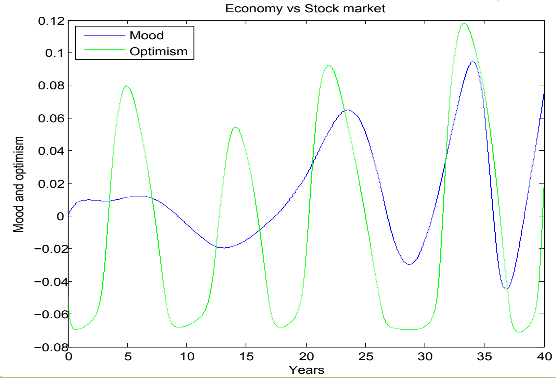
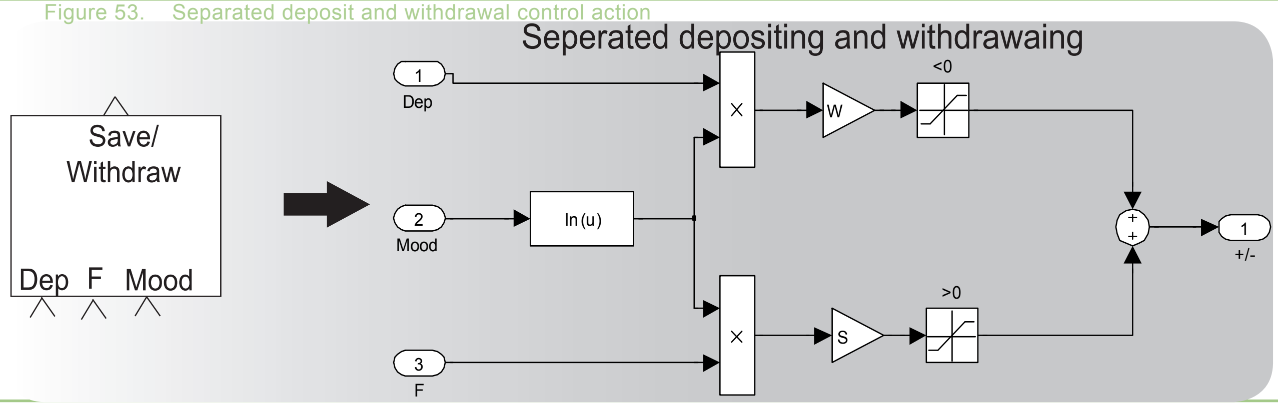


Figure 53. Separated deposit and withdrawal control action



Further simulations

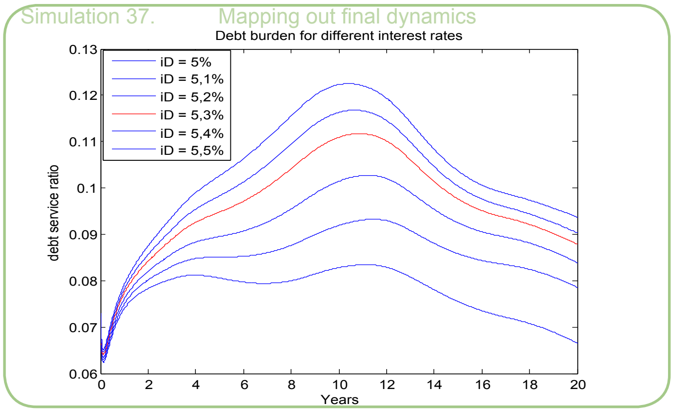
Now that we have a depositing/withdrawing control actions that does not break basic vessel dynamic, we set out to examine and review the model. Simulations give reason to believe that there exists a marginal interest rate, where the system is at a somewhat stable state. We now attempt to find this.

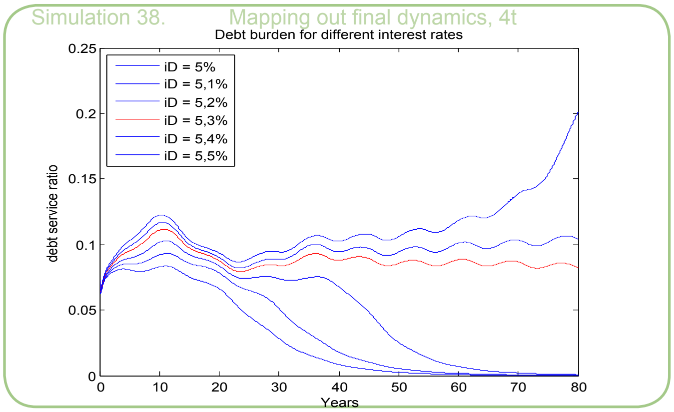
We make use of the debt burden, i.e. debt service ratio and simulate its evolvement for different interest rates on loans, but keep liability interest rate constant at 4%.

The lower debt burdens naturally represent the lower interest rates From the first simulation it is difficult to see wether or not such an interest rate exists, as none the simulations seem to come to any kind of equilibrium. However, we highlight the graph the most likely to have a marginal interest rate, and run the simulation again, with 4 times the time horizon.

We now se what we suspected to be true. The highlighted graph oscillates around a sustainable debt burden, it seems to be at a fragile, but stable state. As in 5.5, this economic model seems to be governed by path dependencies.

Although the notion of Path dependency was originally developed by economists to explain technology adoption evolution of industry, it applies to a broad group of processes. More and more technologists, and also to a degree economists are becoming open to the idea that this is a common characteristic of several





processes in modern economies. There are many economic processes do not progress steadily toward some predetermined and unique equilibrium, and where the nature of any equilibrium achieved, partly depends on the process of getting there. The outcome of a path dependent process will often not converge towards a unique equilibrium but instead reach one of several equilibria (Sterman, 2000).

This view very different from that of the neoclassical economics tradition, and seem to intimidate many who have based their education and careers on this classical belief. Leaving behind the assumption that, in economic processes, only single outcomes could possibly be reached, regardless of initial conditions or transitory events, may be difficult. However, for a “soon to be“ civil engineer in cybernetics it made perfect sense.

In our model, the smallest changes in parameters at one time in the simulation, seem to be lock the economy into a specific state, which is difficult to depart from.

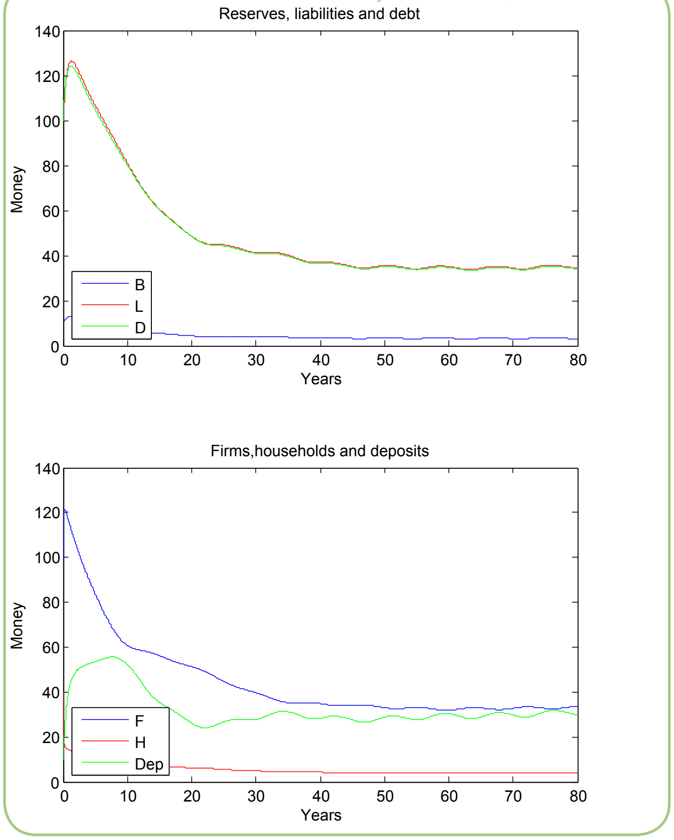
We will now do a full analysis of the model with the marginal interest rates to see how this evolves.

The stocks in the financial sector decline to a certain level, and then marginally stabilize, while oscillating. Debt and liabilities, alternate being higher, but since the sector has a solid reserve stock, there is no danger of reaching insolvency.

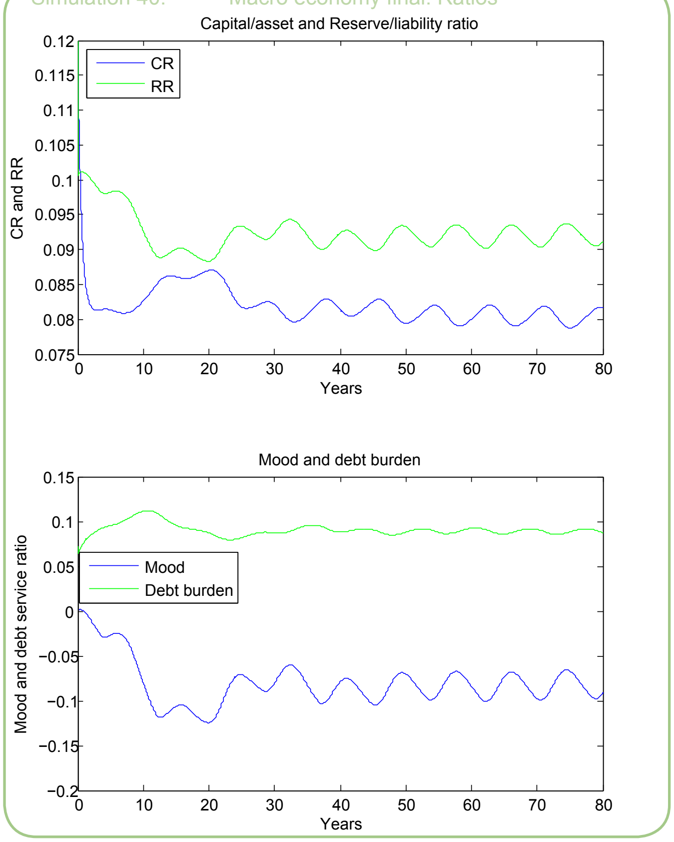
In the real economy the situation is similar. At first the money supply drop, but it also stabilizes. Deposit/withdrawal oscillates with mood, but no longer take unrealistic shapes, although its mean value is unrealistically high.

Common for all the stocks is that they decline considerably the first 40 years, before reaching an “equilibrium”. As discussed before, this can be explained as deflation, so long as the relationship between the sectors remain, money will only increase in value. Internationally, this would of course have consequences, but we will not be concerned with that here. We could easily had tweaked up the financial sector’s expenses as well as loan interest rate, and thereby had an initial growth, with a consequent inflation instead.

Simulation 39. Macro economy final: Stocks,

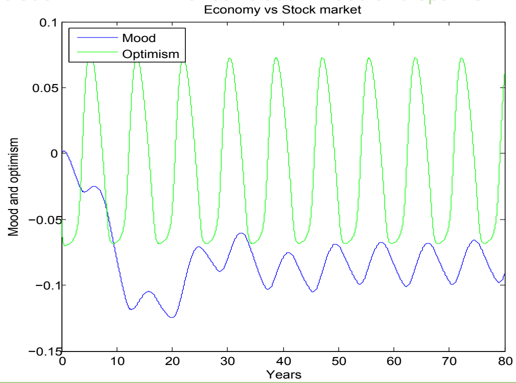


Simulation 40. Macro economy final: Ratios

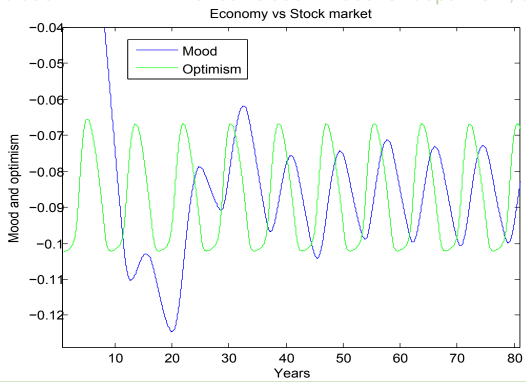


The next show the two financial ratios oscillating around their target values. A better control action in both central bank and financial sector could be able to smooth out these oscillations. However, we want to represent reality, and neither central bank or financial sector would possess all the necessary information to do this.

Simulation 41. Final correlation mood and optimism



Simulation 42. Final correlation mood andoptimism, scaled



Debt burden is stabilizing at a slightly higher value than the neutral 8%, creating sustained negative mood through the simulation. This must be a result of some kind of imbalance in the model making the financial sector somewhat larger than is should, and thereby also the debt burden. Further examination show that there is a slight disalignment in the size of the two insolvency functions at neutral input values. This might well be the reason why mood stabilizes at a slightly negative value.

We look at the correlation between mood and stock market optimism. In the first simulation optimism is scaled down 1:10, and even here we clearly se the two increasing in correlation.

In order to get make this even clearer, we scale down optimism further to 1:40, and we also put a negative bias on the readout, so that they align. Now we also se that mood lags slightly behind the optimism of the stock market, but the correlation is obvious.

The Stock market's innate oscillating behaviour induces oscillations in the and the economy and makes it less robust. Slight shifts in parameters now have large consequences, as the tops of the stock market optimism and economic mood align, the trend of the economy is amplified and can therefore easily disturb an already fragile equilibrium.

6. FUTURE WORK

IMPROVEMENTS

An inclusion of price and thereby accounting for inflation and deflation, and a difference in present value of money and future value. This would bring a new dimension to the model, and would be very relevant to the issue of debt burden.

Developing a better control action for deposit / withdrawal from the real economy's "deposit account", should be made priority. Although it catches some of the irrational behaviour that people exhibit, it does not have give realistic behaviour especially the accumulated level of savings is far to high.

The central bank / government should be able to help increase the aggregate bank capital to asset ratio, so that banks may issue new loans. At this moment the capital to asset ratio is such a simplified fraction that the only way of increasing it is by reducing the balance sheet.

6. CONCLUSION

FINAL WORDS

Most discussion and conclusions are made throughout the report, as results are shown and discoveries are made. This chapter will only sum up of final words regarding the model the entire economy. The economy was fragile early in the model building and testing. When simulating for various Reinvestment coefficients, and interest rates in 5.5, only a few marginal interest rates were able to keep the economy in balance. If the model resided outside these limit values, either the financial economy broke down, or the real economy did.

The largest surprise was that including a regulating agent, with non-intrusive control actions that are at least based those in use in modern economies today, the model remained just as, if not more fragile than in 5.5. We have of course changed the entire premiss of the model, from 5.5 to the final model. The vessel dynamics that governed the issuing of loans have been replaced by real banks that “create“ money when lending, and their lending is only limited by a capital ratio. It might therefore by difficult, if not wrong to compare the two. But it is interesting to se that two such different approaches to modelling a macro economy debt burden, give as resembling results. In both cases the model shows signs of path dependencies. Slight variations in parameters makes the economy lock into different states from which it does not recover. Although the central bank showed that it balances the financial sector in an isolated simulation, we could never show its balancing effect on the entire economy.

The implementation of a stock market further lowered the level of robustness did not cause any qualitative change in behaviour that was not already present. Granted it induced oscillations that were part of making the economy path dependent, since when the tops or bottoms of economic mood align with stock market optimism, we get a sort of resonance that amplifies the effect of mood, and in turn might cause the economy to go of track. The economy already displayed this behaviour, but it seems to be more obvious after the inclusion of the stock market.

The bottom line is however, that the economy act qualitatively equivalent or at least very similar in 5.5 and the final model. Despite the drastically different approach to model the economy.

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