Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Engineering Cybernetics

Erlend Evenstad Dahlen

A crisis-robust modern macroeconomic system - a Control Systems Approach

Master's thesis in Cybernetics and Robotics
Supervisor: Trond Andresen
May 2021

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Kunnskap for en bedre verden

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Preface

This thesis marks the culmination of 5 years of studies at the Norwegian University of Science and Technology (NTNU) in the field of cybernetics and robotics. In this regard, I would like to thank my family and friends for their continued support.

As someone with a deep interest in finance, it is truly inspiring to work in the intersection of macroeconomics and control systems theory and try to contribute to a better financial system. The groundwork for this has been laid by Trond Andresen, and I want to thank him for valuable discussions and insights from his role as my supervisor.

Abstract

The financial system is essential to the coordination of people, projects and resources, and it therefore has a devastating impact when it stops functioning properly in a financial crisis. As a macroeconomic challenge, it is recognized that the United States(and the world) are currently undergoing a long-term debt crisis where interest rates are at zero percent so that monetary policy needs to be reevaluated. To demonstrate how such a long-term debt crisis can be avoided, this thesis investigates two approaches based on control of money stock and money velocity, respectively. This work expands the model of a modern financial system by bridging the gap between debt crisis simulations and reform proposals.

A macroeconomic model consisting of a central bank, banks, a financial market and a real economy is implemented based on an established stock-flow modelling framework from the existing literature. The model is first used to simulate a debt crisis, and then to compare the two proposed approaches for avoiding the crisis. The first approach is based on Modern Monetary Theory(MMT), where the central bank controls money stock, while the second approach is based on central bank digital currencies(CBDC) and a negative fee on money, where money velocity is the control variable. In this thesis, the two approaches are evaluated by comparing financial stability, the role of the financial market and their validity. In the simulation for the MMT approach, the government debt service(repayment and interest) becomes unsustainable, and the financial market increasingly "soaks" up money. In the simulation with a negative fee, the financial market deploys money faster, but there is a shift towards higher consumption. The central bank is able to keep the interest rate at a higher level with a negative fee. Since the rate is a proxy for stimulation of the economy, the negative fee is able to continuously stimulate the economy, whereas the MMT approach becomes gradually less efficient. The results from this thesis show that control of money velocity leads to the most crisis-robust system, and demonstrate the importance of this control variable for central banks.

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Chapter 1

Introduction

The financial system is essential to the coordination of people, projects and resources, and it therefore has a devastating impact when it stops functioning properly in a financial crisis. Most recent examples are the Great Recession and the COVID-19 recession, where central banks have been important in the recoveries. As a macroeconomic challenge, this thesis recognizes that the United States(and the world) is currently undergoing a long-term debt crisis where rates are at zero percent so that monetary policy needs to be re-evaluated.

To demonstrate how such a long-term debt crisis can be avoided, this thesis investigates two approaches based on control of money stock and money velocity, respectively. The first approach is based on Modern Monetary Theory(MMT) and control of money stock. Following the theory, a government issuing its own currency has no budgetary constraints because deficits can be monetized by the central bank. The second approach is based on central bank digital currencies(CBDC) and a negative fee on money to control money velocity. In a fully digital economy, the central bank can implement a negative fee on money to accelerate economic spending. The approaches are then evaluated on financial stability, the role of the financial market and their validity.

The model is implemented with the stock-flow modelling framework established by Trond Andresen, where a system of nodes is interconnected through differential equations and represented by block diagrams. The model consists of four main parts: the central bank, the banks, the financial market and the real economy. Briefly, the central bank controls the interest rate, the banks issue loans to the households, the financial market channels investments into the real economy and the real economy is a circular flow of consumption, taxes and wages between the government, firms and households.

The contribution from this thesis is twofold. First, it expands the model of a modern financial system. Most notable is the inclusion of a central bank that controls the interest rate, can operate in an MMT regime and implement a negative fee on money. Secondly, it fills the gap between a simulated debt crisis and reform proposals, where two approaches are implemented and simulated to show how they avoid the crisis.

In the simulations, both approaches avoid a debt crisis. In the MMT approach the government debt service(repayment and interest) becomes unsustainable and the government becomes dependent on issuing new debt to repay its existing debt. New investments remain an important driver in the economy, but the financial market increasingly "soaks" up money. In the negative fee approach the financial market deploys money faster, but there is a shift towards higher consumption so that investments become less important in the economy. The central bank is able to keep the interest rate at a higher level with a negative fee. Since the rate is a proxy for stimulation of the economy, the negative fee is able to continuously stimulate the economy, whereas the MMT approach becomes gradually less efficient. In addition, it is recognized that both approaches are premised on their unique assumption. In the MMT approach it is assumed that money retains its attractiveness as a store of value, and in the negative fee approach it is assumed that people react strongly to the fee.

The thesis is structured in the following way. Chapter 2 provides the theoretical foundation. The chapter starts with long-term debt cycles and how aggregate demand can be increased with money stock and money velocity. Two approaches are explored with Modern Monetary Theory(MMT) and central bank digital currencies(CBDC). This is followed by a classification of financial stability before the chapter ends with an explanation of the control systems approach to economics. Chapter 3 presents the model of the economy. It starts with a simple overview of the model and continues with the banks, the financial market, the real economy and the central bank. Chapter 4 provides the results from the simulations of the debt crisis, MMT approach and negative fee approach. In chapter 5, the results are discussed and evaluated on financial stability, the role of the financial market and the validity of the approaches. To end, chapter 6 contains conclusions, potential limitations and suggestions for future work.

Chapter 2

Background

This chapter will provide the necessary theoretical background. It starts with long-term debt cycles and how aggregate demand can be increased with money stock and money velocity. Two approaches are explored with Modern Monetary Theory(MMT) and central bank digital currencies(CBDC) and a classification for financial stability is introduced. The chapter ends with a control systems approach to economics.

2.0.1 Long-term debt cycle

A systematic review of economic cycles can be found in "Big Debt Crises" where Ray Dalio examines 48 big debt cycles. These cycles are defined as all the cases that led to real GDP falling by more than 3 percent in large countries, and forms an archetypal long-term debt cycle. [1]

There is a distinction between a short-term debt cycle and a long-term debt cycle. A long-term debt cycle begins with no or low levels of debt, but the debt gradually expands with short-term cycles. In the short-term debt cycles debt and debt service costs rise faster than the incomes that are needed to service them, leading to a crisis. To alleviate this, the central bank reduces the interest rate which produces a positive wealth effect, stimulates economic activity and eases debt-service burdens. These short-term cycles continue until the interest rate reaches zero percent so that the central bank cannot alleviate the crisis with normal monetary policy. This marks the end of the long-term debt cycle. [1]

Over the last century, the United States has gone through a long-term debt crisis twice—once during the boom of the 1920s and the Great Depression of the 1930s, and again during the boom of the early 2000s and the financial crisis starting in 2008. Based on this, the United States(and the world) is currently undergoing the unfolding of a long-term debt crisis.[1]

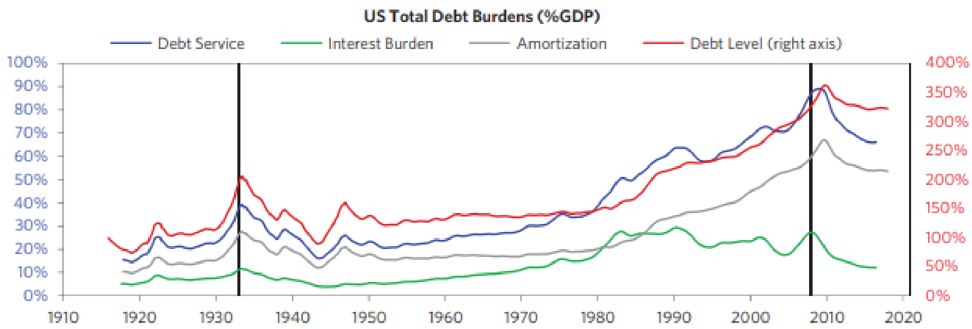

Figure 2.1: Debt and debt service burden in the United States since 1910. Because the central bank reduces the interest rate, the interest payments remain flat or go down even when the debt goes up. When the interest rate reaches zero percent, the deleveraging begins. [1]

2.0.2 Aggregate demand

In "The General Theory of Employment, Interest and Money" Keynes challenged the neoclassical view that free markets would lead to full employment during the Great Depression. He argued that in a depression the aggregate demand, total spending in the economy, would be below its potential and therefore lead to unemployment. To counter this he advocated for fiscal and monetary policies to increase the aggregate demand. [2]

In the equation of exchange from the Quantity Theory of Money the total output in the economy is the product of the money stock and money velocity. This is given in equation 2.1 where P is the price level, Y is real output, M is the quantity of money in circulation and v is the income velocity of circulation. [3] [4]

$$Mv = PY \tag{2.1}$$

To increase the nominal value of the total output in the economy PY, the quantity of money M or the income velocity v has to increase. Based on this, the thesis explores two approaches to increase aggregate demand.

2.0.3 Modern Monetary Theory

Modern Monetary Theory(MMT) places the government, as the currency issuer, at the center of the monetary system. Because the government issues the currency, it can never default or become insolvent so that it can sustain deficits indefinitely without solvency risk. [4]

It further argues that a deficit in one sector must be offset by a surplus in another sector. Here, it is useful to differentiate between stocks and flows, where a flow is a magnitude per time, while stock is measured at a point in time. While a sector deficit accumulates to a financial liability, a sector surplus accumulates to a financial asset. In theory, a persistent government deficit will therefore equate to the non-government sector accumulating financial assets. [4]

For the theory to work, the government deficits need to be financed by someone. Traditionally, government deficits have been dependent on borrowing already existing money from the domestic or international markets. But instead of being restricted from borrowing already existing money, it is argued that the central bank can monetize government debt with newly created reserves. This is possible if the treasury and central work together in a consolidated government sector. Because of legal constraints, this process has to go through primary dealer banks today [4]

It is also important to recognize that central banks are already indirectly monetizing government debt with new reserves through Quantitative Easing. The Bank of England provides a good explanation of the mechanics of Quantitative Easing:

> Quantitative easing is a tool that central banks, like us, can use to inject money directly into the economy.
>
> Money is either physical, like banknotes, or digital, like the money in your bank account. Quantitative easing involves us creating digital money. We then use it to buy things like government debt in the form of bonds. You may also hear it called 'QE' or 'asset purchase' – these are the same thing.
>
> The aim of QE is simple: by creating this 'new' money, we aim to boost spending and investment in the economy. [5]

Quantifying this, today the Federal Reserve balance sheet holds almost $5 trillion in U.S. treasuries, and the ECB's balance sheet holds over € 3,5 trillion in securities of euro area residents.[6][7]

The real limitation for this theory is the potential inflation, a continuous rise in the price level. As the framework wants to ensure that there is no under-utilized labor or resources, it brings the risk that too much money is being put into the economy compared to the productive resources. The argument is that the government can dynamically adjust its spending and taxes so that the economy does not become overheated. However theoretically sound, this equilibrium is difficult to determine because the inflation can show up in unintended places and with unknown time-lags. [4] [8]

2.0.4 Central bank digital currency

> A central bank digital currency (CBDC) is a digital form of central bank money denominated in the official unit of account for general purpose users. It is a claim on the central bank, in the same way that banknotes and coins are today. By comparison, bank deposits are claims on private banks. [9]

The main idea, that digital money can be held directly at the central bank, is rather intuitive. The technical implementation, however, requires several steps and The Bank of England has divided it into four key parts. 1) The central bank provides a fast, secure and resilient core ledger for simple payments. 2) There is API access to the core ledger open for authorised access. 3) Payment Interface Providers interact with the ledger on one side and provide user-friendly interfaces for the customer. 4) Users access CBDCs through the Payment Interface Providers. [10]

In his doctoral thesis, Andresen envisions an electronic money system with 100% reserves where all accounts are at the central bank. This would dispense with bank credit money and make all money in circulation base money(High-Powered Money). The central bank would still control the interest rate, but it would also become the savings hub for society: [11]

> On the savings side, the CB can — due to the information technology revolution discussed above — offer individual accounts not only for banks, but for all agents: citizens and firms; both a checking account and a spectrum of time deposits yielding different rates, payment profiles and durations. Since individual depositors' money at the CB — whether from persons or businesses — would be completely risk-free, a checking account there should yield zero interest. Such accounts could be cost-free for the user, considered part of a modern welfare state's shared free infrastructure, like healthcare and schools. [11]

Most importantly, in this system it becomes possible to control money velocity with 1) A fee on money held and 2) A fee on transferring money between accounts.

1. A fee (negative interest, demurrage) on money held: M decreases slowly, v increases strongly and immediately, therefore Y increases immediately. And a government can exploit shrinking M by creating a corresponding extra HPM flow and thus spend more. This is a bonus in a recession/depression.
2. A fee on transferring money between accounts: M falls slowly, v falls stronger and immediately, therefore Y decreases immediately. [11]

The proposed negative fee on money is inspired by the successful implementation of a parallel currency during the Great Depression in the Austrian town Wörgl. By having a negative fee on this parallel currency, people were incentivized to spend it quickly, increasing the demand in the crises-ridden economy. [12] While the fee on transferring money between accounts is an interesting approach to inflation control, it will not be pursued further in this thesis.

2.0.5 Financial stability

A critical criterion for evaluating the approaches is how they compare on financial stability and the conceptual framework for this is found in Minsky's Financial Instability Hypothesis.

At a high level the theory explains how fluctuations in investment drive the economic cycle. The theory is based on a modern capitalist economy where economic actors acquire assets that will generate future income flows in exchange for liabilities that require future debt service flows. Because the income flows are uncertain while the debt service flows are more or less certain, each economic actor needs to operate with a 'margin of safety' in case something unexpected happens. This margin is difficult to quantify and because economic actors base the margin on their experiences and more recent years, this leads to an inherent contradiction where a stable economy is destabilizing. [13] [4] [14]

Minsky classified the reduction in 'margin of safety' and shift towards instability into three categories: "Hegde", "Speculative" and "Ponzi". In "Hedge" the expected income flows are sufficient to pay interest and repay the debt. In "Speculative" the near-term expected income flows are only sufficient to pay interest on the debt. And finally, in "Ponzi" the expected income flows are not sufficient to pay the interest on the debt so that additional debt has to be issued. [13] [4]

This leads to the Financial Instability Hypothesis. The economy starts in a stable state where most actors are classified in "Hedge". But as the economy booms over a long time, the 'margin of safety' seems unjustified and shifts more and more actors towards "Speculative" and "Ponzi". At some point, the debt service costs rise or incomes come in below expectations, overshooting the small 'margins of safety' so that bankruptcies start to snowball through the economy. [13] [4]

2.0.6 A control systems approach to economics

In "On the Dynamics of Money Circulation, Creation and Debt – a Control Systems Approach" Trond Andresen establishes a stock-flow modelling framework for economics. The framework is built from a signals- and systems-based toolbox where a system of nodes is interconnected through differential equations and represented by block diagrams. It is argued how this can be aggregated at the macro level, and the framework is then used to to build a modern financial system. [11]

The building block

The main building block is an economic agent with an incoming money flow F_i, an outgoing money flow F_o, and the accumulated money stock M. The change in the money stock $\dot{M}$ is given by F_i minus F_o, as expressed in equation 2.2.

$$\dot{M} = F_i - F_o \tag{2.2}$$

It is argued that the outgoing money flow F_o is given by the money stock M divided by the first order time-lag T. This follows the analogy of a buffer vessel where a sudden increase in the incoming flow F_i will initially increase the money stock M, leading to a time-dispersed and gradually increasing outgoing flow F_o. This is given in equation 2.3. [11]

$$F_o = \frac{M}{T} \tag{2.3}$$

Equation 2.2 and equation 2.3 can then be combined in the Laplace-domain, resulting in the first-order transfer function given in equation 2.4.

$$\frac{1}{1+Ts} \tag{2.4}$$

This can be used as a compact representation of one economic agent. Economic agents can then be aggregated into a sector, where the time-lag now is given by both the time lag for each agent, and the flows of money between the agents inside the sector. This is given in an Aggregation theorem, where ρ is an outside spending coefficient, and $0 < \rho \leq 1$.

> **Theorem 2.1** Given a network of an infinite number of identical units which are all first order transfer functions (2.4), and which have identical outflow coefficients, and where the outflow share for each transfer function that goes to all other agents, sum to 1-ρ . Then the transfer function for the network, regardless of how the input to the network is partitioned between agents in the network, is [11]

$$h_a(s) = \frac{F_o}{F_i}(s) = \frac{1}{(1+T_a s)}, \ where\ T_a = \frac{\tau}{\rho} \tag{2.5}$$

A modern generic bank model

The framework is then used to build a modern financial system and a modern generic bank model. The bank model is based on a capital-asset ratio requirement from the Bank for International Settlements(BIS), which requires that a bank's claims on others must exceed the others' claims on the bank by some pre-defined margin. This capital-asset ratio κ is given in equation 2.6 where D is loans, R is reserves at the central bank and M is deposit money. [11]

$$\kappa = \frac{D+R-M}{D}, \tag{2.6}$$

The bank maximizes profits by issuing new loans until κ reaches the minimum capital-asset ratio κ_0. This dynamic is obtained with a PI-controller which reduces the difference with a flow of new loans F_{nl}. When the bank makes loans, it needs to keep track of the corresponding money M and debt D. The modern generic bank model is depicted in figure 2.2. [11]

The change in money $\dot{M}$ is the sum of new loans F_{nl} minus repayment of debt rD and the net interest income $\sigma_B(i_D D - i_M M)$. This is given in equation 2.7.

$$\dot{M} = F_{nl} - rD - \sigma_B(i_D D - i_M M) \tag{2.7}$$

The change in debt $\dot{D}$ is the sum of new loans F_{nl} minus debt losses λD and repayment of debt rD. This is given in equation 2.8.

$$\dot{D} = F_{nl} - \lambda D - rD \tag{2.8}$$

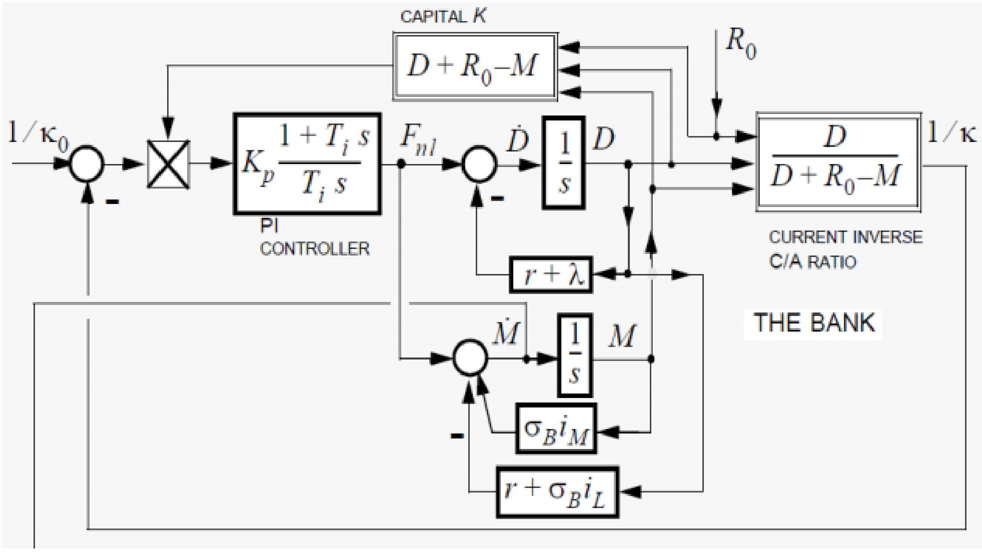

Figure 2.2: The bank uses a PI-regulator to issue new loans to reach the minimum required capital-asset ratio and keeps track of money and debt in the economy. [11]

Chapter 3

Method

This chapter will present the model of the economy. It starts with a simple overview of the model and continues with the banks, the financial market, the real economy and the central bank. To end, it explains how the model was simulated.

3.0.1 Overview

The model consists of four main parts: the central bank, the banks, the financial market and the real economy. Figure 3.1 shows how these are connected. In the figure, the central bank, banks and financial market are represented in yellow boxes, while the real economy is represented in green. The arrows between the boxes represent flows of money, while the dotted arrows represent flows of information.

The central bank controls the interest rate in the economy, it can implement a negative fee on money, and it can create new reserves. In the illustration, the interest rate is an information flow to the banks and the financial market, the negative fee is an information flow to the financial market, and the reserves are a flow of money to the banks.

The banks create new money and debt by issuing loans to the households in the real economy. To operate, the banks also have costs in the form of wages, taxes and profits. There is therefore a flow of money from new debt and costs into the real economy. Reversely, there is a flow of money from debt service from the households.

The financial market channels investments into the real economy. There is a flow of money to the real economy as money is invested into new equity and debt. Reversely, there is a flow of money from the real economy in the form of profits and debt service.

The real economy is a circular flow of consumption, taxes and wages between the government, firms and households. The government pays wages to the households, and the households pay taxes to the government. The households pay for the consumption of goods and services from firms, and the firms pay wages to the households. And finally, the firms pay taxes to the government while the government pays for the consumption of goods and services from firms.

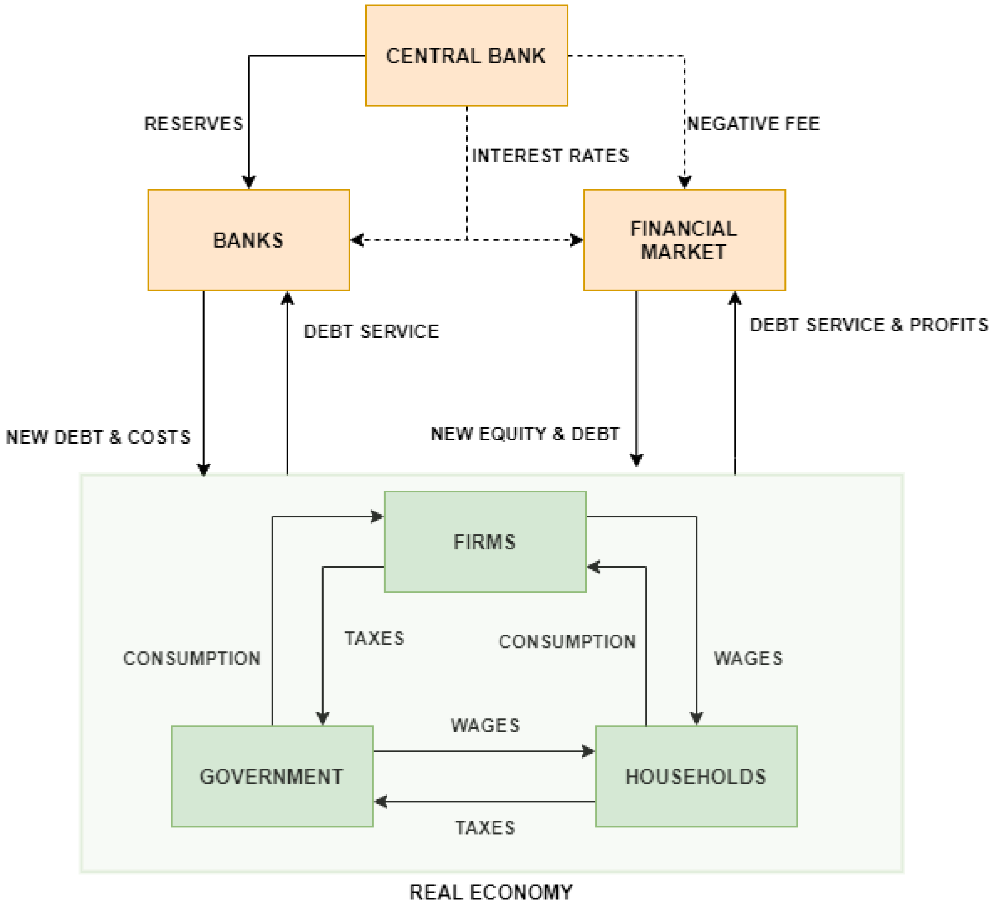

Figure 3.1: An overview of the modelled economy. The model consists of four main parts: the banks, the financial market, the real economy and the central bank. The corresponding implementation of this in Simulink can be found in figure A.1 in Appendix A.

3.0.2 Banks

As in the implementation in figure 2.2, the banks use a PI-regulator to issue new loans to reach the minimum required capital-asset ratio and keep track of money and debt in the economy. In addition, the model has dynamic interest rates(explained in subsection 3.0.5), a dynamic loss rate and a cost flow to the real economy. The implementation of the banks is shown in figure 3.2.

Parameters

$D(t)$ bank debt [$]

$M(t)$	deposit money [$]
$R(t)$	the bank's reserves at the Central Bank [$]
$K(t)$	the bank's capital, K=D+R-M [$]
$B_f(t)$	flow of new loans minus debt service, equation 3.3 [$/y]
$B_c(t)$	flow of costs(wages, taxes and profits), equation 3.4 [$/y]
$F_{nl}(t)$	flow of new loans [$/y]
$L_b(t)$	loss rate on bank debt, equation 3.5 [1/y]
$i_{cb}(t)$	central bank interest rate [1/y]
$i_b(t)$	interest rate on bank debt [1/y]
r_b	repayment rate on bank loans (0.1) [1/y]
$K_a(t)$	current capital-asset ratio []
K_0	minimum required capital-asset ratio (0.08) []
b_s	share of net interest income that is left for the bank (0.28) []

The model

The change in bank debt $\dot{D}$ is given by the flow of new loans F_{nl}, the loss rate on bank debt L_b, the repayment rate on bank loans r_b and bank debt D. This gives equation 3.1.

$$\dot{D} = F_{nl} - (r + L_b)D \tag{3.1}$$

The change in deposit money $\dot{M}$ is given by the flow of new loans F_{nl}, the central bank interest rate i_{cb}, the interest rate on bank debt i_b, the repayment rate on bank loans r_b, the share of net interest income that is left for the bank b_s, bank debt D and deposit money M. This gives equation 3.2.

$$\dot{M} = F_{nl} - rD - b_s(i_b D - i_{cb} M) \tag{3.2}$$

Equation 3.2 can be divided into the flow of new loans minus debt service B_f and the flow of costs(wages, taxes and profits) B_c. These flows are given in equation 3.3 and equation 3.4. This distinction is made so that the flows can be inserted into different places in the real economy. B_f will be inserted in front of households, and B_c will be inserted in front of firms.

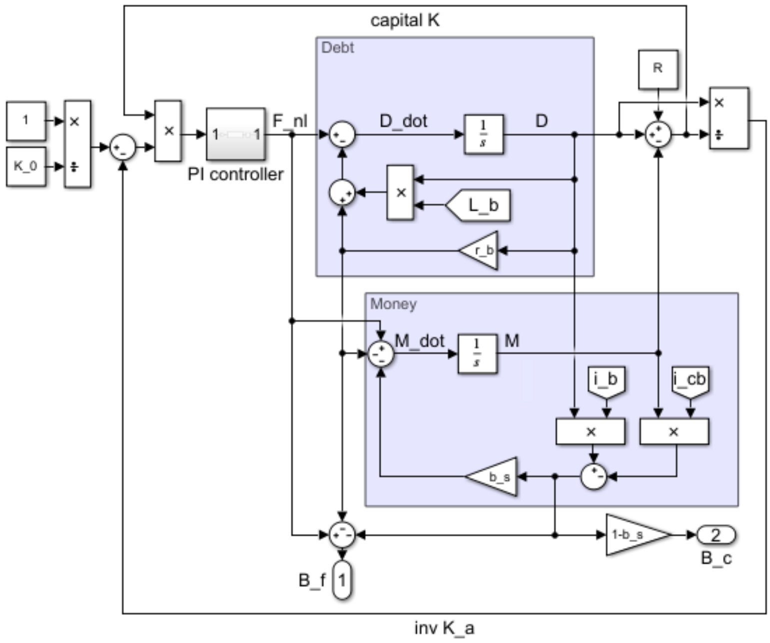

Figure 3.2: Implementation of the banks in Simulink. The banks use a PI-regulator to issue new loans to reach the minimum required capital-asset ratio and keep track of money and debt in the economy.

$$B_f = F_{nl} - rD - (i_b D - i_{cb} M) \tag{3.3}$$

$$B_c = (1 - b_s)(i_b D - i_{cb} M) \tag{3.4}$$

The loss rate on bank debt L_b and firm debt L_f were set as a function of the debt-to-GDP ratio, the debt service level and a constant for a normal loss rate. A high debt-to-GDP ratio and debt service level are considered signals of a more fragile economy and will lead to exponentially higher loss rates. To determine the most suitable functions, the loss rates were simulated and compared to data for global corporate default rates and loan losses for the United States. [15] [16] The resulting loss functions L_b and L_f are given in equation 3.5. The simulated loss rates and the implementation in Simulink can be found in figures A.2 and A.3 in Appendix A.

$$L_b = \frac{1}{400}(\frac{D/Y_d}{1.6})^6 + \frac{1}{20}(\frac{D(i_b + r_b)}{I})^6 + 0.002 \tag{3.5a}$$

$$L_f = (\frac{D_f/Y_d}{1.6})^4 + (\frac{3}{2}\frac{D_f(i_f + r_f)}{Y_d})^4 + 0.005 \tag{3.5b}$$

3.0.3 Financial market

The financial market consists of exchanges, the equity market, firm debt and government debt. There is a flow of profits and debt service from the real economy into the exchanges, and from the exchanges there are flows into new equity and debt. The implementation of the financial market is shown in figure 3.3.

Parameters

$D_f(t)$	firm debt [$]
$D_g(t)$	government debt [$]
$E(t)$	equity investments [$]
$F(t)$	money on exchanges [$]
$S_{df}(t)$	debt service on firm debt, $D_f(i_f+r_f)$ [$/y]
$S_{dg}(t)$	debt service on government debt, $D_g(i_g+r_g)$ [$/y]
$F_i(t)$	profit and debt service from the real economy [$/y]
$F_o(t)$	flow into new equity and debt [$/y]
$F_e(t)$	flow into new equity [$/y]
$F_{df}(t)$	flow into new firm debt [$/y]
$F_{dg}(t)$	flow into new government debt [$/y]
$L_f(t)$	loss rate on firm debt, equation 3.5 [1/y]
$L_e(t)$	loss rate on equity investments, $L_e = 2L_f$ [1/y]
$i_g(t)$	interest rate on government debt [1/y]
$i_f(t)$	interest rate on firm debt [1/y]
r_g	repayment rate on government debt (0.1) [1/y]
r_f	repayment rate on firm debt (0.1) [1/y]
$T_k(t)$	time lag for investments into new equity and debt [y]

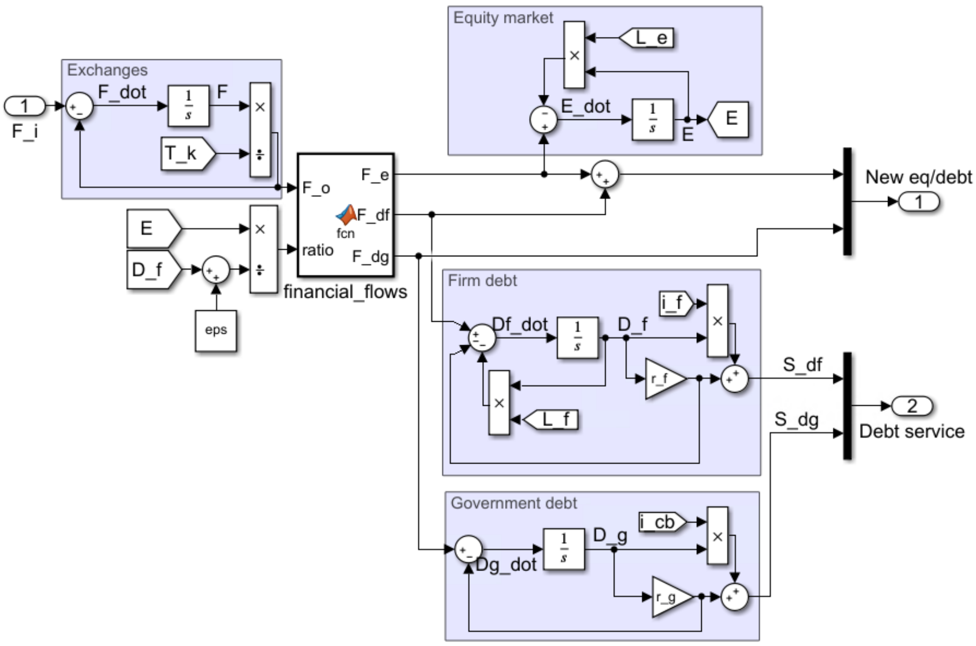

Figure 3.3: Implementation of the financial market in Simulink. The financial market consists of exchanges, the equity market, firm debt and government debt.

The model

The time lag for investments into new equity and debt T_k is a function of the loss rate on bank debt L_b and firm debt L_f and a constant. The time lag increases when loss rates increase because investors become more pessimistic and risk averse. This is given in equation 3.6.

$$T_k = 60L_b + 15L_f + 0.1 \tag{3.6}$$

The change in money on exchanges $\dot{F}$ is given by the profit and debt service from the real economy F_i, money on exchanges F and the time lag for investments into new equity and debt T_k. This is given in equation 3.7.

$$\dot{F} = F_i - \frac{F}{T_k} \tag{3.7}$$

The change in equity investments $\dot{E}$ is given by the the flow into new equity F_e, the loss rate on equity investments L_e and equity investments E. This is given in equation 3.8.

$$\dot{E} = F_e - L_e E \tag{3.8}$$

The change in firm debt $\dot{D}_f$ is given by the flow into new firm debt F_{df}, the repayment rate on firm debt r_f, the loss rate on firm debt L_f and firm debt D_f. This is given in equation 3.9.

$$\dot{D}_f = F_{df} - (r_f + L_f)D_f \tag{3.9}$$

The change in government debt $\dot{D}_g$ is given by the flow into new government debt F_{dg}, the repayment rate on government debt r_g and government debt D_g. It is assumed that the government cannot default on its own debt so there is no loss rate on government debt. This is given in equation 3.10.

$$\dot{D}_g = F_{dg} - r_g D_g \tag{3.10}$$

The profit-share for firms p_s is given by a constant and the ratio between equity investments E and demand from firms Y_d. The profit-share is higher when equity investments are a big part of the economy. This is given in equation 3.11.

$$p_s = \frac{1}{20}\frac{E}{Y_d} + 0.4 \tag{3.11}$$

The function financial_flows divides the flow into new equity and debt F_o between a flow into new equity F_e, new firm debt F_{df} and new government debt F_{dg}. It is assumed that the flow into government debt is constant at 20%, while the flow into new equity and firm debt is balanced by their ratio so that the markets remain fairly equal in size. The code is listed in 3.1.

Code listing 3.1: Function for financial flows

```
function [F_e,F_df,F_dg]= fcn(F_o, ratio)

F_dg = F_o*0.2;

if ratio > 1
    F_e = F_o*(0.5 - 0.1*ratio);
    F_df = F_o*(0.3 + 0.1*ratio);
else
    F_e = F_o*(0.5 + 0.1*ratio);
    F_df = F_o*(0.3 - 0.1*ratio);
end
```

From the function financial_flows, the flow into new equity F_e, firm debt F_{df} and government debt F_{dg} branch into "New eq/debt" and the Equity market, Firm debt and Government debt. The flow into "New eq/debt" is a money flow, while the flows into the Equity market, Firm debt and Government debt are informational.

3.0.4 Real economy

The real economy consists of the government, firms and households. There is a flow from new equity and debt into the real economy, and there is a flow of profits and debt service out of the real economy. The implementation of the real economy is shown in figure 3.4.

Parameters

$Y_d(t)$	demand from firms (GDP) [$/y]
$Y_o(t)$	output from firms [$/y]
$G_i(t)$	government inflow [$/y]
$G_o(t)$	government spending [$/y]
$H_i(t)$	household inflow [$/y]
$H_c(t)$	household consumption [$/y]
$I(t)$	household income from government and firms [$/y]
$T(t)$	government taxes [$/y]
$F_c(t)$	consumption from exchanges [$/y]
$C(t)$	consumption from households and financial market, C $= H_c + F_c$ [$/y]
$w(t)$	household wages from firms [$/y]
$p(t)$	flow of profits [$/y]
T_g	time lag for government (1.0) [y]
T_f	time lag for firms (0.5) [y]
T_h	time lag for households (0.1) [y]
$p_s(t)$	profit-share for firms, equation 3.11 []
t_x	tax rate (0.3) []
g_s	share of government spending going to firms vs. households (0.5) []
f_s	consumption-share for exchanges (0.2) []

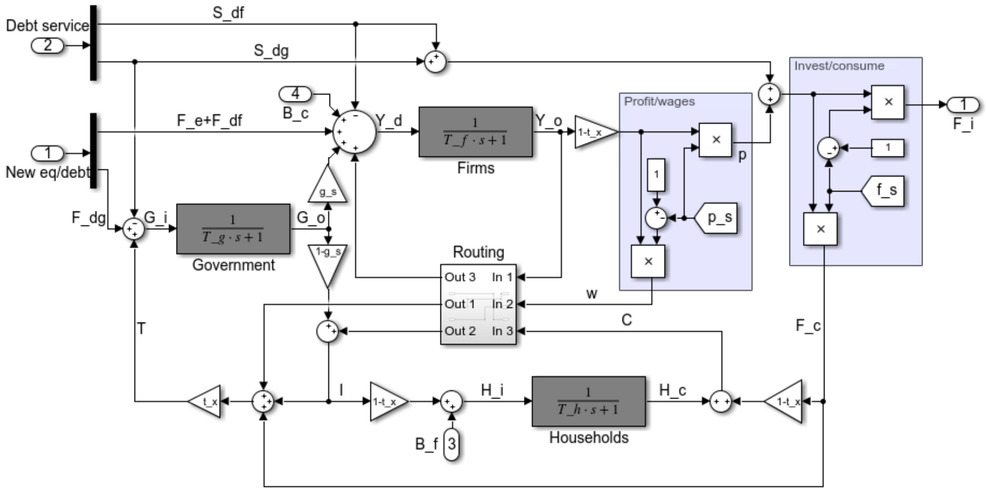

Figure 3.4: Implementation of the real economy in Simulink. The real economy consists of the government, firms and households.

The model

The government inflow G_i is given by government taxes T, the flow into new government debt F_{dg} and the debt service on government debt S_{dg}. This is given in equation 3.12.

$$G_i = T + F_{dg} - S_{dg} \tag{3.12}$$

The demand from firms Y_d is given by the flow into new equity and firm debt F_e+F_{df}, the debt service on firm debt S_{df}, the flow of costs B_c, the government spending to firms $g_s G_o$ and the consumption from households and financial market C. This is given in equation 3.13.

$$Y_d = (F_{eq} + F_{df}) - S_{df} + B_c + g_s G_o + C \tag{3.13}$$

The household inflow H_i is given by the government spending to households $(1-g_s)G_o$, the household wages from firms w, the tax rate t_x and the flow of new loans minus debt service B_f. This is given in equation 3.14.

$$H_i = ((1-g_s)G_o + w)(1-t_x) + B_f \tag{3.14}$$

The block "Profit/wages" divides the after-tax output from firms Y_o into the flow of profits p and the household wages from firms w based on the profit-share for firms p_s given in equation 3.11. This gives equations 3.15 and 3.16.

$$p = Y_o(1-t_x)p_s \tag{3.15}$$

$$w = Y_o(1-t_x)(1-p_s) \tag{3.16}$$

The block "Invest/consume" divides the flow of profits and debt service from firms and government $p + S_{df} + S_{dg}$ into the profit and debt service from the real economy F_i and the consumption from exchanges F_c based on the consumption-share for exchanges f_s. This gives equations 3.17 and 3.18.

$$F_i = (p + S_{dg} + S_{df})(1 - f_s) \tag{3.17}$$

$$F_c = (p + S_{dg} + S_{df}) f_s \tag{3.18}$$

3.0.5 Central bank

The central bank controls the interest rate in the economy, it can create new reserves to monetize government debt, and it can implement a negative fee on money. The implementation of the central bank is shown in figure 3.5.

Parameters

$D_{gr}(t)$	government debt held by central bank [$]
$F_{dgr}(t)$	government deficit monetized by central bank [$/y]
$y_g(t)$	growth rate in demand from firms (GDP growth) [1/y]
$n_f(t)$	negative fee [1/y]
i_{bm}	risk premium on bank interest rate [1/y]
i_{fm}	risk premium on firm interest rate [1/y]

Interest rates

The central bank controls the central bank interest rate i_{cb} and this is the basis for the interest rates on government debt i_g, bank debt i_b and firm debt i_f. These interest rates are given by i_{cb} plus a risk premium to account for the expected loss rates. Bank debt has a risk premium of 2,5%, firm debt has a risk-premium of 5%, and government debt has no risk premium because it is assumed that the government cannot default on its own debt. The interest rates are given in equation 3.19.

$$i_g = i_{cb} \tag{3.19a}$$
$$i_b = i_{cb} + 0.025 \tag{3.19b}$$
$$i_f = i_{cb} + 0.05 \tag{3.19c}$$

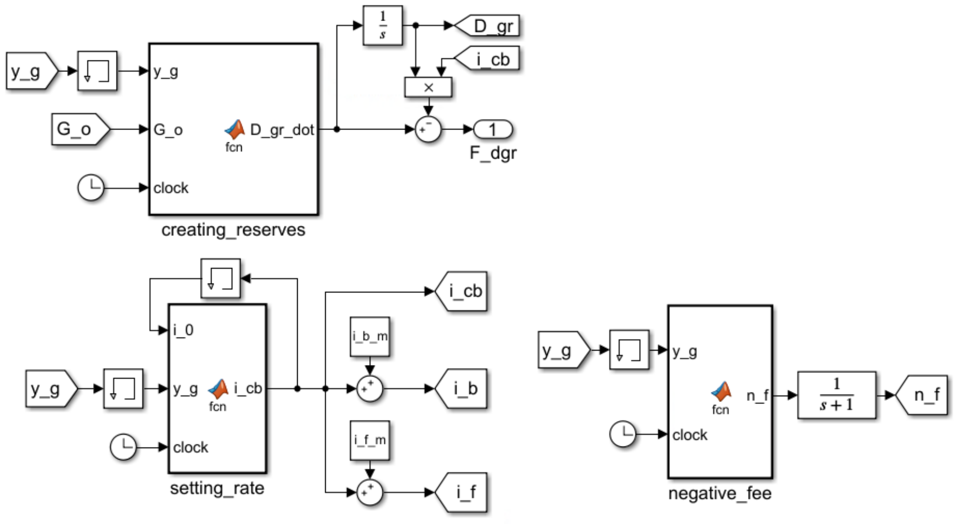

Figure 3.5: Implementation of the central bank in Simulink. The central bank controls the interest rate in the economy, it can create new reserves to monetize government debt, and it can implement a negative fee on money.

The function setting_rate sets the central bank interest rate i_{cb} based on the GDP growth y_g. If y_g is below 1% the central bank will lower i_{cb} with 50 basis points. Reversely, if y_g is above 6% the central bank will increase i_{cb} with 25 basis points. It is assumed that i_{cb} cannot be negative and the function activates after 5 years to let the simulation "start up". The code is listed in 3.2.

Code listing 3.2: Function for interest rates

```
function i_cb = fcn(i_0, y_g, clock)

i_cb = i_0;

if y_g < 0.01 && clock > 5
    i_cb = i_0 - 0.005;
elseif y_g > 0.06 && clock > 5
   i_cb = i_0 + 0.0025;
end

if i_cb <= 0
    i_cb = 0;
end
```

MMT regime

The central bank can operate in an MMT regime where it creates new central bank reserves to monetize government debt. Subsection 2.0.3 explained that this process has to go through primary dealer banks today because of legal constraints, but because there are no legal constraints in this implementation there is a direct flow from the central bank to the government.

The government deficit monetized by the central bank F_{dgr} is given by the change in government debt held by the central bank $\dot{D}_{gr}$ minus the interest expense on the existing debt $i_{cb}D_{gr}$. It is assumed that the government will pay interest, but not repay this debt. This is given in equation 3.20.

$$F_{dgr} = \dot{D}_{dgr} - i_{cb}D_{gr} \tag{3.20}$$

The flow of money F_{dgr} will go to the government so that the government inflow G_i changes to equation 3.21.

$$G_i = T + F_{dg} - S_{dg} + F_{dgr} \tag{3.21}$$

The function creating_reserves creates new central bank reserves to monetize government debt $\dot{D}_{gr}$ based on the GDP growth y_g. If y_g is below 6% $\dot{D}_{gr}$ equals 4% of the current government spending G_o. The function activates after 50 years as the central bank starts operating an MMT regime. The code is listed in 3.3.

Code listing 3.3: Function for creating reserves

```
function D_gr_dot = fcn(y_g, G_o, clock)

D_gr_dot = 0;

if y_g < 0.06 && clock > 50
    D_gr_dot = G_o*0.04;
end
```

Negative fee

The central bank can implement a negative fee on money. The fee can be turned on and off, and in the model it is implemented on money held at exchanges. This is based on an observation from the simulations where money soaked up on the exchanges, while the money in the households, firms and government remained reasonable "buffers". As a result, the negative affects the time lag for investments into new equity and debt T_k and the consumption-share for exchanges f_s.

In the model, the negative fee n_f is implemented on money at the exchanges F. This changes the equation for change in money on exchanges $\dot{F}$ to equation 3.22.

$$\dot{F} = F_i - (\frac{1}{T_k} + n_f)F \tag{3.22}$$

The flow of money $n_f F$ will go to the government so that the government inflow G_i changes to equation 3.23.

$$G_i = T + F_{dg} - S_{dg} + n_f F \tag{3.23}$$

It is assumed that investors want to avoid a negative fee, so that the time lag for investments into new equity and debt T_k decreases when the negative fee is implemented. This changes T_k to equation 3.24.

$$T_k = 60L_b + 20L_f + 0.1 - 3n_f \tag{3.24}$$

It is assumed that the consumption-share for exchanges f_s increases when the negative fee is implemented because it becomes less attractive to have money on exchanges. This changes f_s from a static parameter into the time-varying parameter in equation 3.25.

$$f_s = 0.2 + 15n_f \tag{3.25}$$

The function negative_fee activates the negative fee n_f based on the GDP growth y_g. If y_g is below 6% the negative fee n_f is set to 1%. The function activates after 50 years as the central bank starts implementing the negative fee. The code is listed in 3.4.

Code listing 3.4: Function for negative fee

```
function n_f = fcn(y_g, clock)

n_f = 0;

if  y_g < 0.06 && clock > 50
    n_f = 0.01;
end
```

3.0.6 Simulation

The model is simulated in three parts. The first simulation shows a long-term debt cycle and crisis. Debt gradually increases while the interest rate decreases, ending in a crisis after 55 years.

The second and third simulations extend on the first simulation but implement a change in how the central bank can operate at year 50 to avoid the crisis. In the second simulation the central bank starts operating an MMT regime and in the third simulation the central bank implements a negative fee on money. These simulations last until year 100.

Chapter 4

Results

In this chapter the results from the simulations will be presented.

For each simulation, the results are plotted in the same format of 5 subplots: 1) "Money, debt and reserves in bank sector", 2) "Debt in financial market", 3) "Demand from firms (GDP)", 4) "Sector debt to GDP", 5) "Total debt to GDP" and 6) "Central bank interest rate vs. GDP growth".

In subplot 4) "Sector debt to GDP" household debt is the equivalent to debt in the bank sector. In subplot 5) "Total debt to GDP" there is a distinction between "Total", "Financial" and "Bank" debt. "Total" describes all the debt in the economy, "Financial" describes all the debt from re-lending existing money, and "Bank" describes all the debt with corresponding money creation.

4.0.1 Long-term debt cycle and crisis

The first simulation shows a long-term debt cycle. There is no debt to begin with, but the amount gradually increases. In parallel, the central bank reduces the interest rate i_{cb} to alleviate short-term contractions in the economy. At year 47 the interest rate i_{cb} reaches 0%, and as the central bank cannot reduce the interest rate further, this leads to a crisis around year 55. The results from the simulation are shown in figure 4.1 and seem to be fairly consistent with the simulated debt crisis done by Andresen. [11]

Money and debt in the bank sector, debt in the financial market and GDP grow exponentially until the crisis. In the beginning, there is an initial spike in money and debt in the bank sector as new loans F_{nl} are issued to get the current capital-asset ratio K_a close to the minimum required K_0. This money flows directly into the real economy, and the same spike can be found in the GDP. In contrast, debt in the financial market has a slow start. This initial difference between bank debt and financial debt is caused by the banks being able to create money and debt "out of thin air", while the financial market is dependent on re-lending already existing money. Because there is no money to re-lend at the beginning, money first has to be created and propagate through the real economy.

In "Sector debt to GDP" the ratio for households has the initial spike, gradually

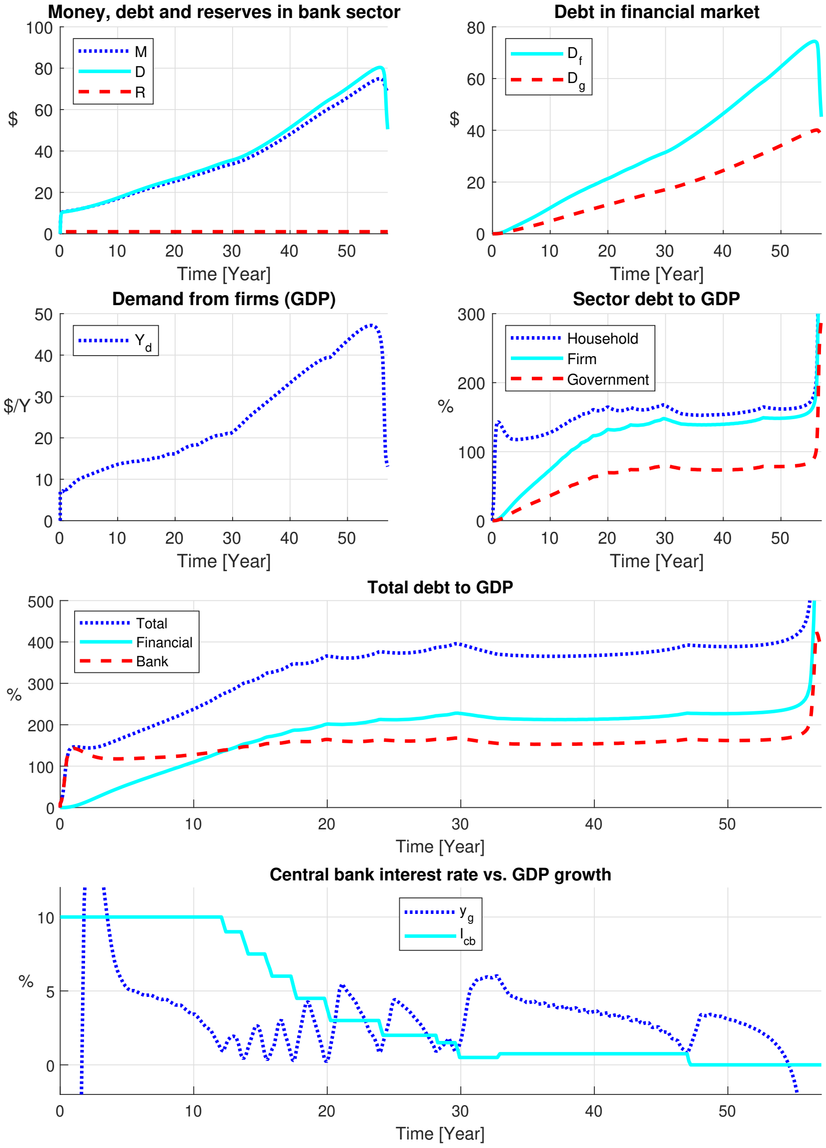

Figure 4.1: The simulation shows a long-term debt cycle and crisis. In the beginning, money and debt in the bank sector, debt in the financial market and GDP grow exponentially. But at year 47 the interest rate i_{cb} is reduced to 0%, leading to a crisis around year 55.

increases and stabilizes at around 160% from year 30. The ratio for firms and government both increase to year 30, where they stabilize at around 140% and 75%, respectively. In "Total debt to GDP" all ratios increase to year 30, where the ratio for bank debt stabilizes at around 160%, the ratio for financial debt stabilizes at around 220%, and the ratio for total debt stabilizes at around 380%. As a reference for these debt-to-GDP ratios, data from the last 50 years in the United States can be used. Government debt to GDP has varied between 30% and 135%, firm debt to GDP has varied between 30% to 57% and household debt to GDP has varied between 42% and 98%. [17][18][19][20]

In "Central bank interest rate vs. GDP growth" the central bank interest rate i_{cb} follows a downward trend during the simulation. i_{cb} starts at 10% and remains flat for the first 11 years. From year 11 to year 30 i_{cb} drops sharply from 10% to 0.5%, but remains fairly stable from year 30 to year 50. GDP growth y_g has an initial spike but cools down to around year 11. From year 11 to 30 it fluctuates between 0.4% and 5.2%. At year 30 y_g spikes to 6%. and gradually declines until year 47. This spike seems to be caused by a too aggressive rate-cut from 1.5% to 0.5%, where i_{cb} has to be increased to 0.75% 3 years later. At year 47 i_{cb} is reduced to 0% to stimulate y_g. When y_g then falls below 1% at year 54, and the central bank cannot cut the rate further, this leads to a crisis.

In the simulation the economy is dependent on a falling interest rate for GDP to continuously grow. When rates reach 0% so that the interest rate can no longer stimulate GDP, GDP eventually starts shrinking. This, in turn, starts a negative spiral between an increasing time lag for investments into new equity and debt T_k and increasing loss rates L_b and L_f.

4.0.2 Operating an MMT regime

In the second simulation the central bank starts operating an MMT regime at year 50. In this regime, the central bank creates new reserves to monetize government deficits to stimulate the economy. This avoids a debt crisis, and the results from the simulation are shown in figure 4.2.

Money and debt in the bank sector, debt in the financial market and GDP grow exponentially from year 50 to year 100. A big difference in the bank sector is the growth in reserves from year 50. This is caused by the central bank creating new reserves to monetize government debt. This means that government debt is both held by the central bank and the financial market, and the total government debt is therefore the sum of reserves and government debt in the financial market.

In "Sector debt to GDP" the ratio for the government increases from 80% to 120%, the ratio for households stays at 160% and the ratio for firms stays at 150%. In "Total debt to GDP" the ratio for bank debt now also includes the reserves from the central bank. From year 50 the ratio for financial debt decrease from 225% to 220%, while the ratio for bank debt increases from 160% to 205%. As a result, the ratio for total debt increases from 385% to 425%. There is a large increase in the ratio for the government, and because the ratios for households and firms

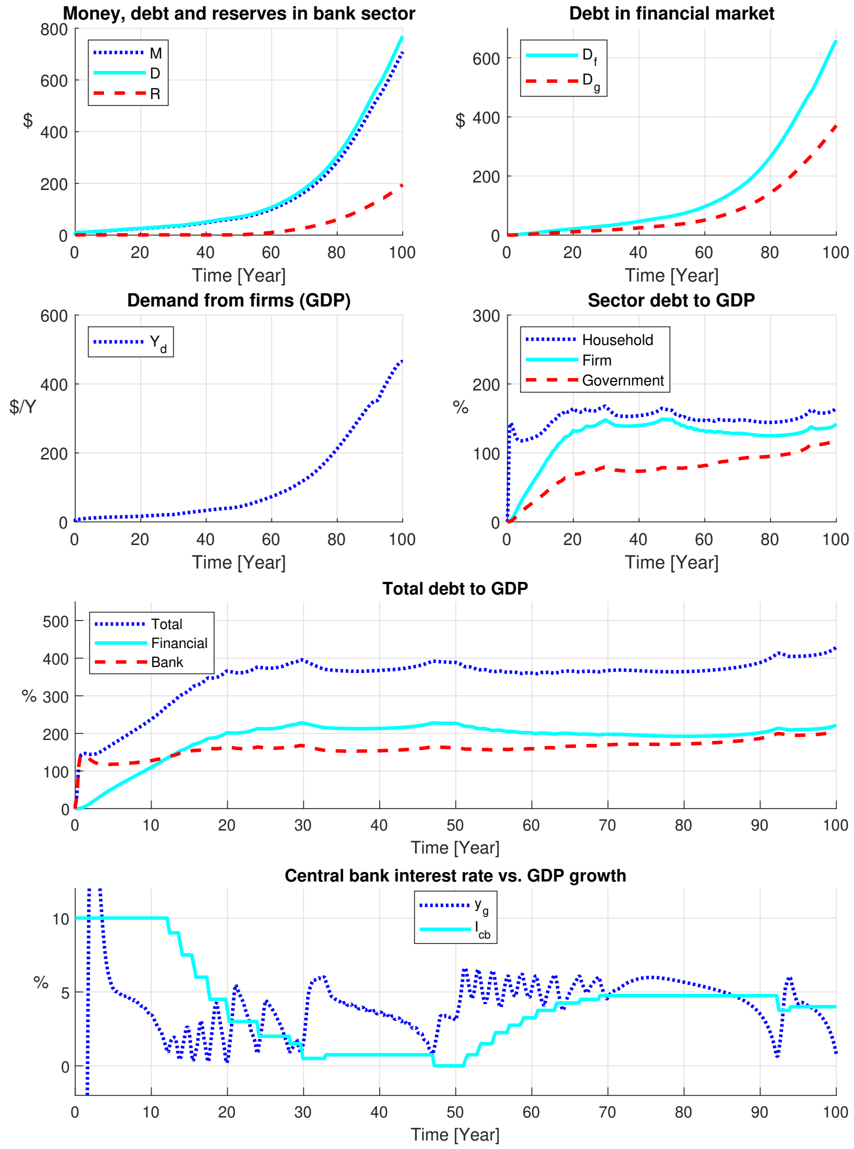

Figure 4.2: In the simulation, the central bank starts operating an MMT regime from year 50. It creates new reserves and monetizes government deficits, and this stimulates the economy and avoids a debt crisis.

remain stable, this increase is reflected in the ratio for total debt as well.

In "Central bank interest rate vs. GDP growth" the GDP growth rate y_g spikes to 6.6% at year 50 as the government starts to deficit spend to stimulate the economy. From year 50 to year 70 y_g fluctuate between 3.75% and 6.6% and this triggers rate increases by the where i_{cb} increases from 0% to 4.75%. From there, the rate remains flat until year 92. At year 92 y_g falls to 0.6% and the central bank decreases i_{cb} to 4% to stimulate the economy. This interest rate cut indicates that the government deficit spending alone is not enough to stimulate the economy at year 92.

4.0.3 Implementing a negative fee

In the third simulation the central bank implements a negative fee on money at year 50. The central bank can dynamically turn the fee on and off to accelerate consumption and investments in the economy. This avoids a debt crisis and the results from the simulation are shown in figure 4.3.

Money and debt in the bank sector, debt in the financial market and GDP grow exponentially from year 50 to year 100.

In "Sector debt to GDP" the ratio for households decreases from 160% to 150%, the ratio for firms decreases from 150% to 105% and the ratio for the government decreases from 80% to 55%. This decrease can also be seen in "Total debt to GDP", where the ratio for financial debt decreases from 225% at year 50 to 155% at year 100. The ratio for bank debt starts at 160% and decreases to 155% at year 100. As a result, the ratio for total debt goes from 385% at year 50 to 310% at year 100. There is a large decrease in the ratio for government and firms, and because the ratio for households remains stable, this decrease is reflected in the ratio for financial debt and total debt.

In "Central bank interest rate vs. GDP growth" the GDP growth rate y_g spikes to 7.8% at year 50 as the central bank implements the negative fee. From year 50 to year 75 y_g fluctuates between 3% and 7.8% and this triggers interest rate increases by the central bank where i_{cb} increases from 0% to 7.5%. From there, the rate increases more gradually and i_{cb} reaches 8.25% at year 100. From year 75 to year 100 y_g fluctuates more slowly and within a tighter band of 4.5% and 6%. During the simulation, the central bank is able to increase and keep the interest rate at a high level, indicating that the negative fee is able to continuously stimulate the economy.

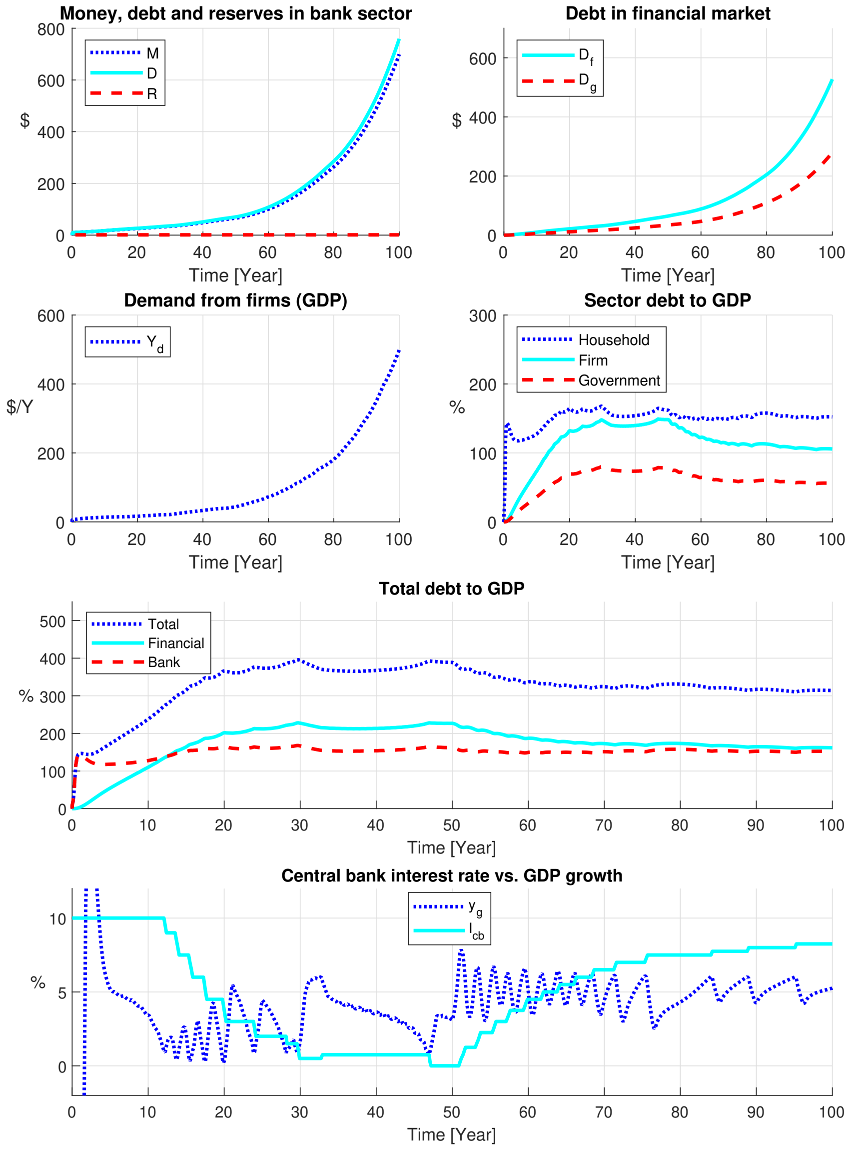

Figure 4.3: In the simulation, the central bank implements a negative fee on money at year 50. This accelerates the consumption and investments in the economy and avoids a debt crisis.

Chapter 5

Discussion

This chapter will include the discussion. It will compare the two approaches on financial stability, role of the financial market and validity of the approaches.

5.0.1 Financial stability

The main criterion for evaluating the approaches is the crisis-robustness of the economies. To do this, the approaches will be classified in the system provided by Minsky in subsection 2.0.5, where the focus is a 'margin of safety' between the future income flow and debt service flow:

> In "Hedge" the expected income flows are sufficient to pay interest and repay the debt. In "Speculative" the near-term expected income flows are only sufficient to pay interest on the debt. And finally, in "Ponzi" the expected income flows are not sufficient to pay the interest on the debt so that additional debt has to be issued.

To make the analysis more realistic, the repayment rates in the analysis were updated based on data from BIS and CBO. While the repayment rate in the simulation was set to 10 years for all the debt, the repayment rates used in this analysis are 18 years for household debt, 13 years for firm debt and 5 years for government debt. [21] [22]

It is important to emphasize the different interest rates in the two approaches. The interest rate gradually increase to 8.25% in the negative fee approach, but in the MMT approach the rate first increases to 4.75% and then has to be reduced to 4%. Since the rate is a proxy for stimulation of the economy, the negative fee is able to continuously stimulate the economy, whereas the MMT approach becomes gradually less efficient. Because the interest rate is higher in the negative fee approach, the interest component of debt service will be higher. In addition, with a high interest rate, the central bank is more flexible to reduce the interest rate to stimulate the economy, contributing to a more robust system.

Figure 5.1 shows a comparison of the income flow and debt service flow for households, firms and the government for the MMT approach and negative fee approach. For households the income is wages, for firms the income is consumption in the economy and for the government the income is taxes. The plots on the left show the ratio for the interest expense, while the plots on the right show the ratio for the interest expense and repayment.

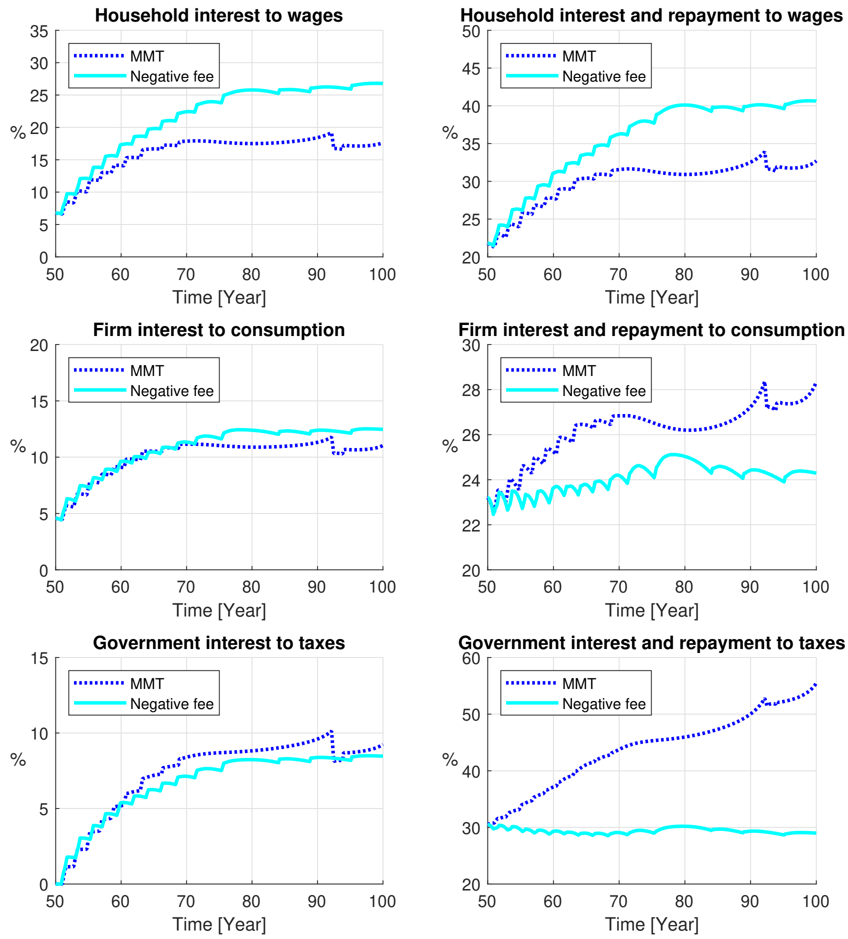

Figure 5.1: A comparison of the income flow and debt service flow for households, firms and the government for the MMT approach and negative fee approach. The plots on the left show the interest expense, while the plots on the right show the interest expense and repayment.

Household interest to wages starts at 6.7% for both approaches and increases to 26.8% for the negative fee approach and 17.6% for the MMT approach. Household interest and repayment to wages starts at 21.8% for both approaches, and increases to 40.6% for the negative fee approach and 32.7% for the MMT approach. As a reference, debt service(interest and repayment) ratios for households in the United States and Norway were at 7.9% and 15.8% in 2019. [21] Based on this, one can argue that households should be able to service the interest in both approaches, but it is not certain that they will be able to repay the debt. This places households in the "speculative" category in both approaches. An interesting observation is that household wages do not keep up with rising interest rates, as expressed in the rising debt service ratios.

Firm interest to consumption starts at 4.4% for both approaches and increases to 12.4% for the negative fee approach and 10.9% for the MMT approach. Firm interest and repayment to consumption starts at 23.2% for both approaches and increases to 24.3% for the negative fee approach and 28.4% for the MMT approach. As a reference, debt service(interest and repayment) ratios for non-financial corporations in the United States and Norway were at 42.6% and 47.9% in 2019. [21] It, therefore, seems reasonable to categorize firms in "hedge", where the expected income flows are sufficient to pay interest and repay the debt.

Government interest to taxes starts at 0% for both approaches and increases to 8.5% for the negative fee approach and 9.2% for the MMT approach. Government interest and repayment to taxes starts at 30.5% for both approaches but decreases to 29.0% for the negative fee approach and increases to 55.5% for the MMT approach. As a reference, the debt service(interest) ratio for the federal government in the United States was at 8.4% in 2019. [23] Based on this, the government is at least able to service the interest in both approaches. It is considered that in the negative fee approach the government is able to also repay the debt, placing it in "hedge". But in the MMT the government is considered to become completely dependent on using new debt to repay the existing debt, placing it in "speculative". This illustrates the necessity of the MMT argument that the government does not have to repay its debt.

To sum up, the MMT approach ends up with households in "speculative", firms in "hedge" and government in "speculative", while the negative fee approach ends up with households in "speculative", firms in "hedge" and government in "hedge". The negative fee ends up with the most robust system, without accounting for the different interest rates.

5.0.2 Role of financial market

Well-functioning financial markets are crucial for allocating resources productively in the economy. As such, financial markets should deploy money into new quality investments quickly so that investments are a driving force in the economy.

In the analysis of the financial market it is assumed that there is an abundance of productive investments in the real economy. Further, it is assumed that the quality of investments remains constant regardless of how long time the financial market uses to deploy the money. These assumptions are considered reasonable approximations at the aggregate level.

Money in the financial market grows exponentially in both approaches, but fastest for the MMT approach. This is rather expected as money in the economy

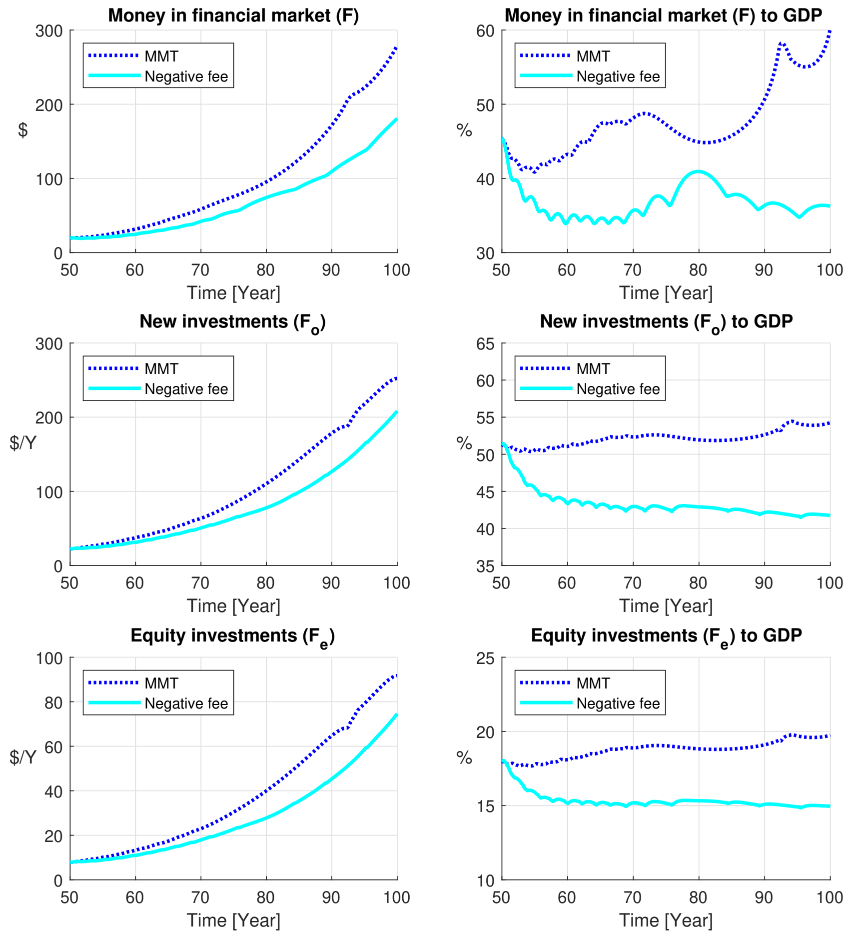

Figure 5.2: A comparison of the money in the financial market and investments in the economy for the MMT approach and the negative fee approach. The plots on the left show the absolute numbers, while the plots on the right are divided by GDP.

also grows exponentially. When divided by GDP there is a clear divergence between the approaches. While both approaches start at a ratio of 45%, the MMT ratio increases to 60%, but the negative fee ratio decreases to 35%. In other words, in the MMT approach the financial market increasingly "soaks" up money, while the financial market becomes more efficient at deploying money back into the real economy with a negative fee.

"New investments" shows the flow into new equity and debt, and "Equity investments" shows the flow into new equity. The absolute numbers grow exponentially for both approaches in both plots. But there is a divergence when dividing by GDP. In "New investments" the ratios start at 51% and increases to 54% in the MMT approach, but decreases to 42% with a negative fee. In "Equity investments" the ratios start at 18% and increases to 20% in the MMT approach, but decreases to 15% with a negative fee. This shows that the economy is increasingly being driven by new investments in the MMT approach, while investments become less important with a negative fee. In the negative fee approach, this can be explained by a shift towards higher consumption.

To sum up, in the MMT approach the economy is being driven by new investments, but the financial market increasingly "soaks" up money. Reversely, with a negative fee the financial market becomes better at deploying money, but there is a shift towards higher consumption so that investments become less important in the economy. As a result, the approaches complement each other in their impact on the financial market.

5.0.3 Validity of the approaches

Both approaches are premised on their unique assumption. In the MMT approach it is assumed that money retains its attractiveness as a store of value, and in the negative fee approach it is assumed that people react strongly to the fee.

In the MMT approach the central bank creates new reserves "out of thin air" and increases the money stock. Following the Quantity Theory of Money this debases the value of money and an increase in the money stock will lead to an increase in the price level. Proponents of MMT dispute this and argue that there is no simple proportionate relationship between rises in the money supply and rises in the general price level. [3] [4]

But, the real threat to MMT is not a monetary debasement against the general price level, but against other money-like competitors. If there exist alternatives that function as money but with less monetary debasement, these alternatives should increase in price as they are more attractive as a store of value. This threat is concretized by the emergence and growth of cryptocurrencies such as Bitcoin. If cryptocurrencies overcome their current technical and legal challenges, traditional money would have to lower its monetary debasement to compete, rendering the entire premise of MMT worthless. At the same time, a sovereign nation can always outlaw competing money if it wants to.

In the negative fee approach the central bank implements a negative fee on money to increase money velocity. To assess the validity of this approach, it is necessary to better understand its practical implementation.

In the electronic money system envisioned by Trond Andresen the central bank will offer a spectrum of time deposits yielding different rates, and checking accounts with a zero percent yield. A time deposit is an interest-bearing bank account that has a date of maturity, and the money in a time deposit must be held for the fixed term to receive the interest in full. [24] It can therefore be argued that a negative fee would not affect money in these accounts as they are locked for a fixed time. In addition, it can also be argued that a negative fee would have the same effect on yields as lowering the interest rate. For those reasons, it seems reasonable that the negative fee will be applied to the checking accounts. And since the checking accounts have a zero percent yield, this can be a valuable control tool for the central bank.

But, the effectiveness of the negative fee is then determined by the amount of money held at the checking accounts and the elasticity of this money. Because there is a zero percent yield on these accounts, it can be argued that people will only keep a minimum necessary buffer. As a consequence, this money could be more or less inelastic to a negative fee. If it is uncertain whether a negative fee will accelerate economic spending, the approach loses its appeal. This does not invalidate the approach, but rather exposes that the implementation needs to be more thorough.

Chapter 6

Conclusion

This final chapter includes the conclusions, limitations and suggestions for future work.

6.0.1 Conclusions

The thesis investigates how a long-term debt crisis can be avoided with two approaches based on control of money stock and money velocity. The first approach is based on MMT and control of money stock, while the second approach is based on CBDC and a negative fee on money to control money velocity. A macroeconomic model consisting of a central bank, banks, a financial market and a real economy is implemented with a stock-flow modelling framework. The model is first used to simulate a debt crisis, and then to compare the two proposed approaches for avoiding the crisis.

In the simulations, both approaches avoid a debt crisis. In the MMT approach the government debt service(interest and repayment) becomes unsustainable and the government becomes dependent on issuing new debt to repay its existing debt. New investments remain an important driver in the economy, but the financial market increasingly "soaks" up money. In the negative fee approach the financial market deploys money faster, but there is a shift towards higher consumption so that investments become less important in the economy. The central bank is able to keep the interest rate at a higher level with a negative fee. Since the rate is a proxy for stimulation of the economy, the negative fee is able to continuously stimulate the economy, whereas the MMT approach becomes gradually less efficient. In addition, it is recognized that both approaches are premised on their unique assumption. In the MMT approach it is assumed that money retains its attractiveness as a store of value, and in the negative fee approach it is assumed that people react strongly to the fee.

It is believed that these results are of relevance to the macroeconomic discourse today. It shows that both control of money stock with MMT and control of money velocity with CBDC and a negative fee stimulate aggregate demand and avoid a debt crisis. When comparing the approaches, the negative fee approach is most promising based on financial stability, the approaches complement each other in their impact on the financial market, but the MMT approach seems to be most valid. The results from this thesis show that control of money velocity leads to the most crisis-robust system, and demonstrate the importance of this control variable for central banks.

6.0.2 Limitations and future work

The model is necessarily a simplification of the economy and simplifications have both been made at a high level and a more granular level. At a high level, the main simplifications are the lack of a foreign sector, inflation and wealth ownership. At a granular level, there is a long list, where one example is the central bank setting the interest rate solely based on GDP growth, while in reality it has to at least consider inflation and potential asset bubbles as well.

Potential future work can be directed in two ways. The first direction addresses the simplifications in the model to build a more realistic modern financial system. There is a big potential in expanding the financial market with price dynamics and an investment flow that is both pushed by the financial market(as in this model) and pulled from the real economy. Another way to expand the model is to incorporate a new concept, such as inflation or wealth ownership. The second direction specifically addresses how to control money velocity. A proposal is to explore the MMT argument that the government can dynamically adjust spending and taxes to control money velocity.

From an engineering perspective, there is a third, and perhaps most interesting, direction. As these two approaches remain untested in the real world, working towards actual implementation is the main challenge. This requires a combination of specifically designed models and pilot projects to get real feedback. If the results are promising, the models and projects can be scaled up in size, until hopefully reaching country-level implementation.

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Appendix A

Simulink models and plots

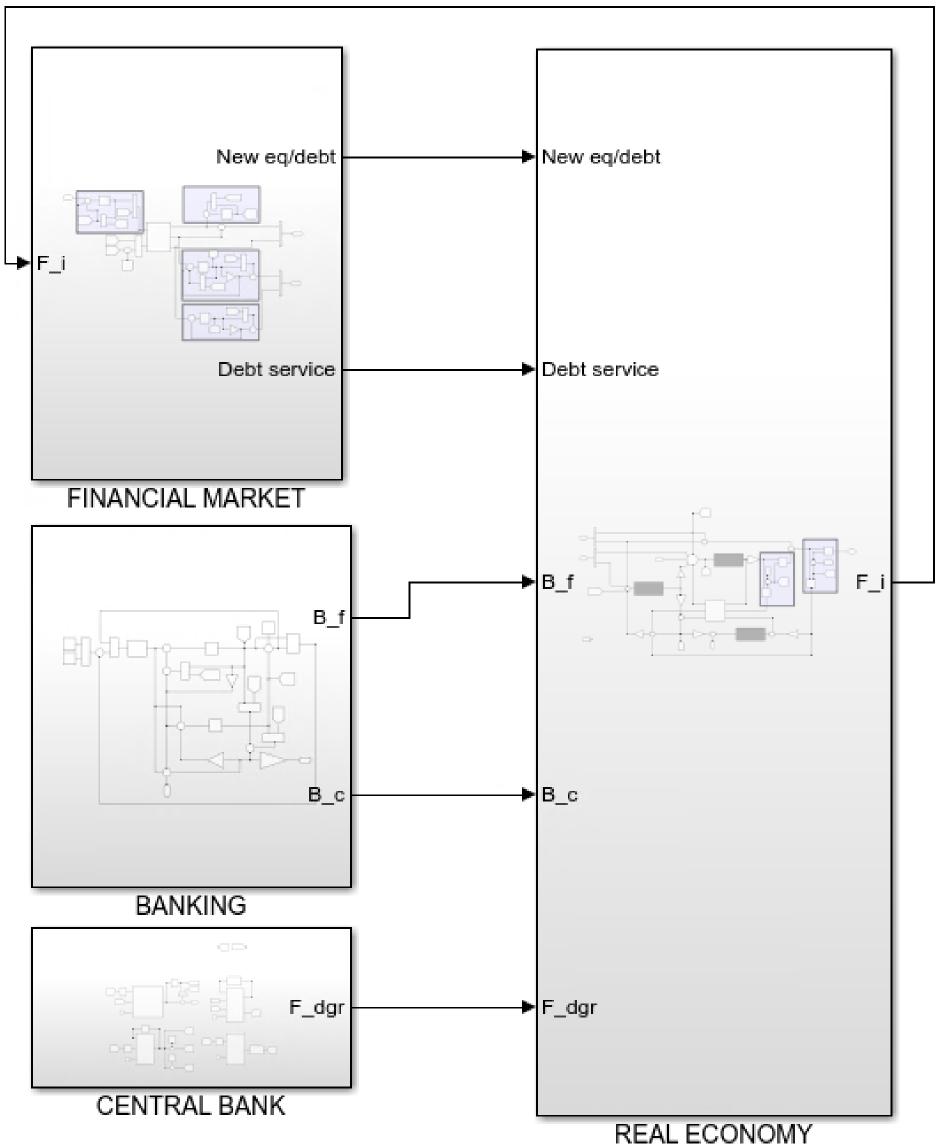

Figure A.1: Implementation of the modelled economy in Simulink. There is a small deviation from figure 3.1 where the flow of reserves from the central bank to the banks is replaced by a direct flow from the central bank to the real economy. This is explained in subsection 3.0.5.

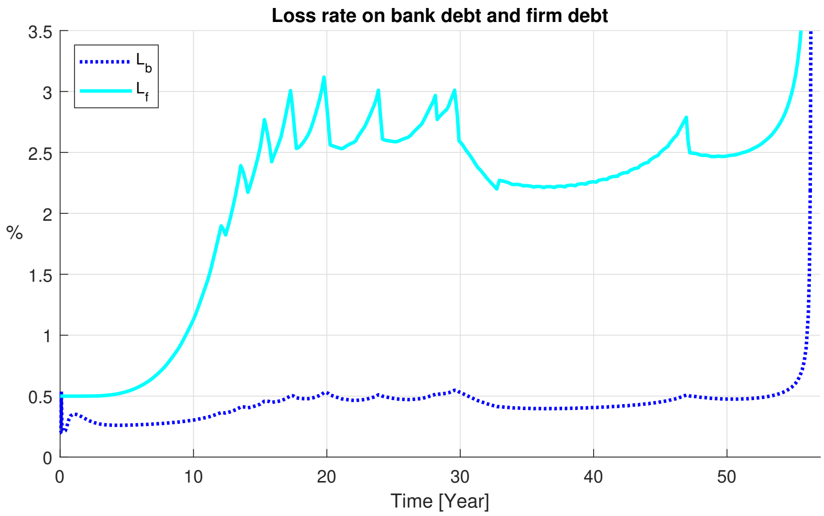

Figure A.2: Simulated loss rates. As a reference, global corporate default rates varied around 1-3% for the period 1981 to 2018, and bank loan losses varied around 0.5-1.5% from 1986 to 2020.[15] [16].

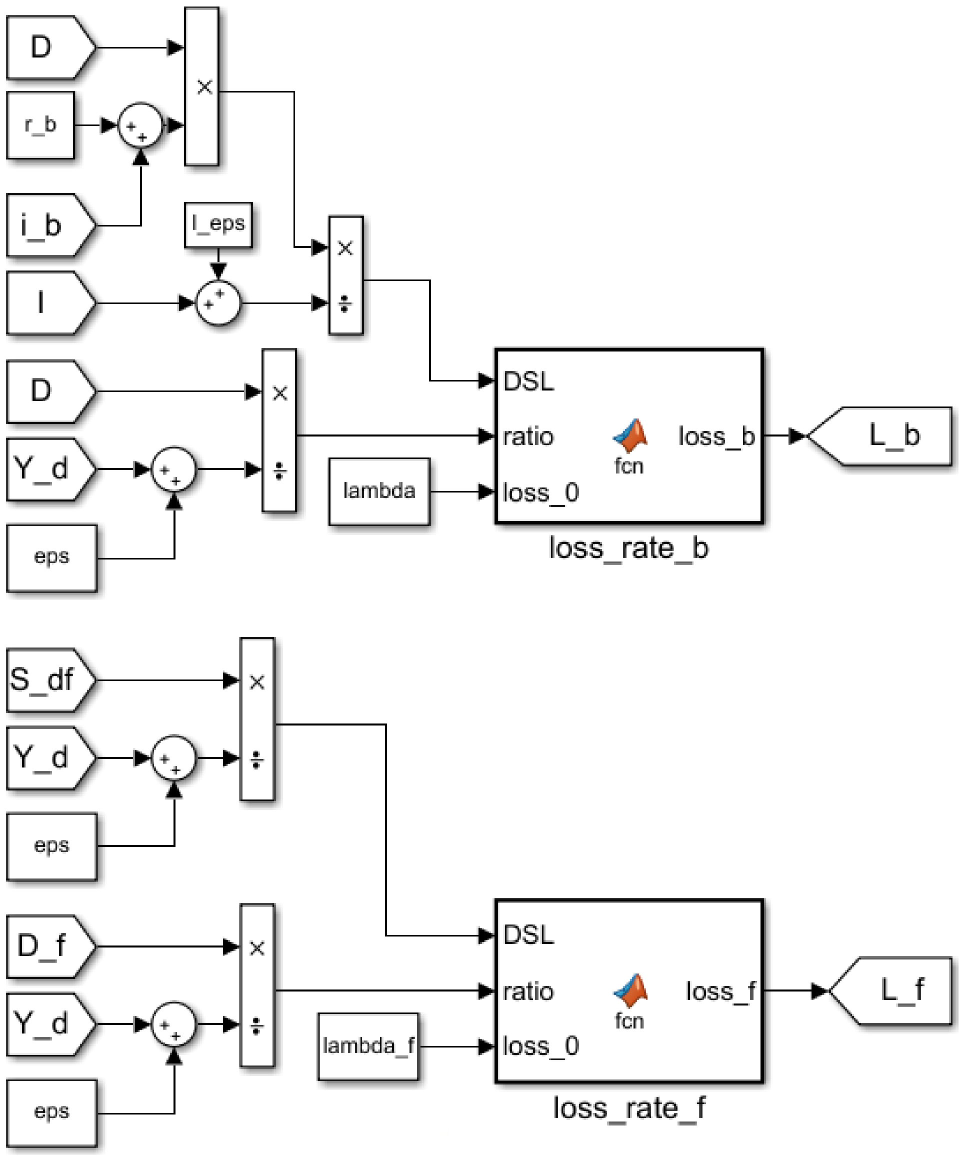

Figure A.3: Implementation of the loss rates in Simulink.

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