Master's thesis

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

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Introduction of a Parallel Electronic Currency in a Eurocrisis Country

Modelling and Simulation of Transient Economic Dynamics

Master's thesis in Master of Science in Cybernetics and Robotics
Supervisor: Trond Andresen

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Summary

This thesis develop a model of probable dynamics of the introduction process of a parallel electronic currency in a euro crisis country. The model dynamics are based on a proposal for Electronic Parallel Money (EPM).

The dynamics of the introduction process are first presented in a causal diagram. The diagram is used to study how social behaviour will affect the development process. Unemployment and a need for circulation in the economy will contribute to a pressure for utilization of the new currency. At the same time, counteracting mechanisms are making it hard to trust the money.

The causal diagram is then used to develop a block model. The model presents two currencies running in parallel, with behavioural variables affecting the money velocities. Two different taxation alternatives are presented. One where the amount of taxes claimed in euros stays the same as before the introduction. The other is the recommended alternative, and fits with Modern Monetary Theory (MMT) principles. Some of the euro tax flow should in this case be exchanged for taxes in the new currency, which will help make the new currency attractive.

The model is used to simulate introduction of an electronic parallel currency to the euro in Italy. The results shows that a parallel currency will work for the situation in Italy. The simulations also demonstrates that the government should inject the new money into the economy for several weeks before taxation. The counteracting behavioural mechanisms have stronger effects at outset and it takes time for both trust the money stocks to grow. When deciding on the delay between government injection and taxation start, the behavioural dynamics should be studied closely. The reaction time of the firm sector matters greatly, and so does the general trust in the new currency.

The model is finally argued to be an important tool in an implementation process. It presents opportunities for continuous discussions on the development, which then can be studied in simulations.

Sammendrag

Denne avhandlingen utvikler en modell for sannsynlig dynamikk ved en introduksjonsprosess av en parallell elektronisk valuta i et eurokriseland. Modelldynamikken baserer seg på et forslag kalt Electronic Parallel Money (EPM).

Introduksjonsprosessens dynamikk er først presentert i et kausaldiagram. Diagrammet brukes til å studere hvordan sosial oppførsel vil påvirke utviklingsprosessen. Arbeidsløshet og et behov for sirkulasjon i økonomien bidrar til et trykk for bruk av den nye valutaen. Samtidig gjør motstridende effekter det vanskelig å stole på pengene.

Kausaldiagrammet brukes videre til å utvikle et blokkdiagram. Modellen presenterer to valutaer i parallell, der pengehastigheten påvirkes av sosiale oppførselsvariable. Oppgaven presenterer to alternativer for skatteinnkreving. I det ene alternativet forblir skattestrømmen i euro den samme som før introduksjonen. Det andre alternative er det anbefalte i denne avhandlingen, og det som best passer med moderne pengeteoris prinsipper. Noe av euroskatten bli i dette tilfellet erstattet med skatt i den nye valutaen. Dette vil bidra til å gjøre valutaen attraktiv.

Modellen brukes til å simulere en introduksjonsprosess av en elektronisk valuta i parallell med euroen i Italia. Resultatene viser at an parallell valuta vil kunne vokse i Italia. Simuleringene viser også at den nye valutaen må få sirkulere en tid før de kan brukes til skatt. De motvirkende effektene har større kraft i begynnelsen. Det tar også tid å bygge opp både tillit og en mengde penger for sirkulasjon. Når tidsperioden mellom oppstart og start av skattebetaling skal bestemmes, bør den sosiale dynamikken studeres nøye. Bedrifters respons og nivået av tillit til den nye valutaen er avgjørende i dette spørsmålet.

Modellen argumenteres til sist for å være et viktig verktøy i en implementeringsprosess. Den gir muligheter for kontinuerlig diskusjon, som kan studeres ved simuleringer.

Preface

The work presented in this thesis has been carried out at the Department of Engineering Cybernetics at the Norwegian University of Science and Technology (NTNU).

The project has given me the opportunity of combining my interest for the social world with my technical education. It has also brought about a new interest for economics. The eurozone crisis is affecting many lives, and the necessary actions to change the situation are not taken seriously by the EU institutions.

I would like to thank my supervisor Trond Andresen for great support and valuable conversations. Andresen's work on parallel currencies and continuous time economic models are the main inspirations of this project. The love and support from friends and family have also been very helpful in the process. I am forever grateful to all of them.

Sandefjord, 26 March 2021
Thea Allum Granbakken

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Chapter 1

Introduction

More than ten years have past since the European debt crisis began. The economies of the crisis-hit countries are still suffering and unemployment rates are high. The EU institutions have not been able to find an ending to the crisis. It should be clear by now that it is necessary to look for alternative ways of dealing with the situation.

Parallel currency proposals represent one category of approaches to ending the crisis. The proposals all share the same main goal of changing course and economic structure. Other than that, they vary in end goals and implementation strategies. Some proposals aim for a soft transition out of the euro. Another common suggestion is an economy with two currencies running in parallel. This could enable the advantages of both currencies. Parallel currencies are also considered a plan B by many. Having a credible plan B can be helpful in negotiations with the EU institutions, in order to push for a plan A.

This thesis will focus on the introduction process of an electronic parallel currency. An electronic solution will make it easy to study the development along the way, and make decisions based on how the situation evolve. Digital money also play a role in facilitating a legal proposal, and encourages an easy transition.

The prolonged situation has affected Europeans' confidence in institutions. Primarily, they are blaming their own governments for not handling the situation. As the EU institutions hold on to a failing structure, many are also changing their attitudes towards the EU. Confidence plays an important role in economic growth, and the lack of confidence should be considered when studying potential ways out of the crisis.

The first part of the thesis consists of a literature study. Chapter 2 focus on the euro crisis, parallel currency proposals, confidence in the economy and electronic money. Chapter 3 presents a brief introduction to Modern Monetary Theory (MMT) and continuous time modelling of the economy.

The second part presents model development and simulations. Chapter 4 develop a model of probable dynamics of the introduction process of a parallel electronic currency in a euro crisis country. The model is then used for simulations in Chapter 5. Results from the model development and simulations are discussed in Chapter 6. Finally, Chapter 7 presents a project conclusion.

Chapter 2

Literature

This literature chapter consists of four parts. Section 2.1 gives a brief introduction to the Eurozone Crisis. Section 2.2 focus on parallel currencies, and presents the EPM proposal. How confidence plays a role in the economy is studied in Section 2.3. Lastly, Section 2.4 consider the concept of electronic money.

2.1 The Euro Crisis

The aftermath of the 2008 global financial crisis brought the eurozone into a crisis that is not yet over, often referred to as the European debt crisis. Especially Portugal, Ireland, Italy, Greece and Spain experienced serious debt problems. Originally the countries did not have unmanageable debt ratios, but the exchange rates were fixed among the euro countries. That led to chronic trade deficits in countries with higher inflation. Indebted countries were led into debt traps. They could either borrow from markets, which would increase interest rates. Or they could borrow from The Economic and Monetary Union (EMU). EMU would in return demand austerity, leading to growth fall (Randall Wray, 2015).

The crisis is also a social crisis with high unemployment rates in the crisis-hit countries, especially among the young. The coronavirus pandemic has brought additional social and economic challenges to countries already in crisis.

Joseph E. Stiglitz argues that there are one underlying mistake above all the contributing factors to the situation. The creation of a single common currency without a structure enabling diversity among the economies (Stiglitz, 2016). Yanis Varoufakis served as Minister of Finance in Greece in 2015. He led negotiations with the European Troika which ended in a third bailout loan in five years. Varoufakis (DiEM25, 2019) accuse the EU institutions for delivering austerity for the many and socialism for the few. The effects are not only of economic character, but also political. The situation is turning Europeans against each other, because of a project that was originally aiming at peace and corporation. Varoufakis still thinks the European Union can be transformed to an democratic institution of genuine solidarity.

Italy is one of the crisis-hit countries, even though it has the third biggest economy of the eurozone. Growth is still low and frustration is increasing (Legorano, 2021). A parallel currency proposal, called the mini-BOT, has previously been proposed by the League and Claudio Borghi Aquilini (Papadia and Roth, 2018). Mario Draghi, Italy's new president, has expressed clear disbelief in the mini-BOTs (Paolo, 2019). Between 2011 and 2019 Draghi served as President of the European Central Bank. He is, however, open to explore Modern Monetary Theory (MMT) (O'Brien, 2019).

2.2 Parallel Currency Proposals

In the development process of a common currency for the European Community (EC) many economists suggested introducing the euro parallel to the national currencies. The framework for the political institutions was not complete, and parallel currencies would therefor give a soft transition and possibilities for national maneuvering. The option for a parallel currency to the euro was however switched off from the beginning, but debates on alternative solutions have been going on ever since.

This section presents the EPM proposal in detail, and gives overviews of the mini_BOTs and Fiscal Money.

2.2.1 Electronic Parallel Money - The EPM Proposal

Trond Andresen has since 2010 argued for argued for the introduction of a parallel electronic currency, complementary to the euro, for Greece and other countries affected be the eurocrisis. He has published several articles on the topic, and in collaboration with colleagues developed a proposal for electronic parallel money (EPM). The proposal is based on MMT, the topic of Chapter 3. The following summary of the EPM proposal is based the article (Andresen, 2019) and the lasted update (Andresen, 2020).

The EPM will be a domestic means of exchange, parallel to the euro. All transactions will exclusively happen electronically. As an alternative to the central bank, a new facility under the treasury called the Treasury Bank (TB), manage the servers, EPM supply and EPM accounts. The government, local governments, citizens and domestic firms have EPM accounts at the TB. The central bank manage the euro by the EU/ECB regulatory as usual. This way the TB can manage the EPM as independently as possible.

Employees, pensioners and suppliers now payed by the government in euros, will be payed in a mix of euro and EPM. That is government payments by all levels of government, including local governments. In the introduction process an amount of EPM is added to the government payments in euros. The EPM-euro ratio can later be adjusted. EPM can be used to pay taxes in the same mix of euro and EPM, counting the value of one euro equal to one EPM. This will assure some confidence in the EPM. The initial confidence will however be low, due to lack of trust in politicians and authorities who have not been able to overcome or improve on the effects of the economical crisis. The lack of trust in a new currency can also be strengthened by the financial press, EU, ECB and other authorities influencing the economic mood. Andresen suggests defining the two entities "trust" and "need" to describe the dynamics of the initial phase of EPM. While the initial trust in the

currency is low, the mass unemployment, low income and low pensions will lead to high need.

The EPM accounts will grow until taxes are due. The combination of high need and growing EPM accounts will give incentives to pressure vendors to accept payments in a mix of euro and EPM. The ratio on the private marked does not have to be the same as the one from the TB, but can be chosen freely. Vendors in a depressed economy might have to choose between accepting a mixed payment or no sale at all. In many cases this forces vendors to accept. With a continuing use of EPM, a feedback process can be expected to start. Observations of increased EPM spending give increased trust, then more acceptance, more spending and again increase in trust. The next expected stage is for the private sector to pay wages in a mix of the currencies. The employees may have to choose between accepting this or loosing their job, forcing them to accept. It is then easier for firms to continue accepting mixed payments. The same goes for suppliers of the government. If the government engage the suppliers who are most willing to accept mixed payments, these suppliers can also pressure their employees to accept wages in a similar mix.

Time delay between injection and taxation can be chosen such that the EPM flow has some time to grow. Having a longer initial time delay might be beneficial for spending incentives. With time, the dynamics explained will lead to increase in trust and use of EPM. As this happens the government can do careful adjustments of the euro/EPM mix used when paying employees, pensioners and suppliers. A slight increase in the EPM share and a smaller cut in the euro share can free up euros and, for instance, be spent on initiatives decreasing unemployment.

Businesses trading imported goods and services can more easily accept mixed payments, than buninesses working with import. Trades with a domestic dominant factor will be the first to accept a low initial share of EPM of the payment. With time there is room for increasing the share of EPM. Traders of foreign products and services, on the other hand, can be expected to depend on higher trust in the currency, and it will therefor take more time before they accept mixed payments. The EPM share of the payment might never become high. EPM will still to some degree be valuable for firms trading imported products as well, if mixed wages become more common.

According to the dynamics explained, the value of the EMP will initially be low and with time end up floating just below the euro. This is because in tax payment they are valued equally, but as long as the euro remains the stronger currency the EPM will not approach or exceed the euro. In order to avoid a black market, the exchange rate should be allowed to float rather than to be maintained artificially advantageous.

A common critique of parallell currency proposals in the eurozone is the question of legality. By EU regulations printing money parallel to the euro is illegal and only the euro can be declared legal tender in countries using the euro. These issues are avoided by having a strictly electronic solution and by not declaring the EPM as legal tender. Anyone can therefor refuse to accept payments in EPM. Yet the need for circulation in the economy will lead to the dynamics explained in the proposal. Another common critique on legality is that EPM should be considered debt under the Maastricht rules. This would be true if the government were obliged to pay back the circulating the EPM in euro, which is not the case for the EPM. EPMs are never redeemed in euros, only accepted as a part of tax payments.

Andresen points out three more questions often raised regarding the EPM proposal. The first one is whether the introduction of EPM will solve the euro debt problem. As an answer to this he emphasises the weak position euro countries have when negotiating interest rates and repayment times on debt with euro as a single currency. With a parallel medium of exchange the power can be balanced out. The second question regards the issue of agents moving money out of the country. Could the introduction of EPM lead to more fear of losses and capital flight? To this Andresen agrees that introducing the EPM will not solve this issue. At the same time the problem of capital flight is already there, and the EPM might contribute to increase in confidence and thereby willingness to invest.

The last major critique commented in this paper is on the topic of leaving the euro. ”But is this not only a trick to (catastrophically) leave the euro?” The question is often raised to all parallel currency proposals, and Andresen therefor gives an answer on behalf of parallel currencies in general. As previously stated, having an additional currency will lead to a change in power. It will give the indebted country a better position in negotiations. This means that having a parallel currency could be the final motive, and does not necessarily imply a future plan of a single national currency. In countries like Italy and Greece the majority does not want to leave the euro, and to suppress the opinion of the public can contribute to alarmist reactions in the population. A parallel currency does however enable a controlled transition away from the euro, if wanted. By making the transition gradual, the TB is able to make decisions based on developments and gained experience. The gradual transition therefor also facilitates a permanent parallel currency, or a gradual transition back to the euro as a single currency, if that is preferred. Another advantage of a gradual shift could be a healthy public, continuous discussion. If the public knows when it starts and have the possibility to choose not to use the parallel currency, much speculation, skepticism and fear can be avoided. As confidence in the currency increases, the public opinion may also change. Decisions for further adjustments can then be made continuously.

By activating the underused potential in unemployment and underemployed people, the EPM proposal will improve the living standards for most people in crisis hit countries and recover social stability, Andresen concludes.

2.2.2 The Mini_BOT

The proposal called mini-bills of Treasury (mini_BOTs) has been discussed in Italy. Claudio Borghi of the League is one of the driving forces of the proposal, and presents the mini-BOT as IOUs (”I owe you”) with no maturity. The mini-BOT will be issued in paper form in order to make it convenient to use, and therefor lead to local spending (Papadia and Roth, 2018).

Initially the mini_BOTs will be used by the government to pay public arrears, and guarantee to accept it for future tax payments. The mini-BOT will also be accepted as payment for public goods and services such as energy bills and train tickets. Use of mini_BOTs in the private sector will not be obliged, but availability and the practicality of the paper form will encourage mini_BOT as means of payment between private agents.

In the case of Greece in 2015, Varoufakis wanted to use the parallel payment system to gain bargain power for debt restructuring, which again would lead to long-term economic growth. In the article ”Fiscal Money Can Make or Break the Euro” he criticizes the mini-

BOT proposal for having the incentive to break up the eurozone. He thinks the main difference between his own solution for Greece in 2015 and the mini_BOT is political. A parallel currency can be used to improve a country's position in the eurozone, as well as it can be used to transition away from the euro. In this sense, the proposal of a parallel currency in itself is neutral, according to Varoufakis (2019).

A technical criticism is the physical form of the mini_BOT. Printing money parallel to the euro is illegal by the rules of the Euro scheme. Even though the mini_BOT is not called money, the banknote form can provoke the European Central Bank (ECB) (Redwood, 2019). Another critique of the physical form is the danger of a grey market. In his own proposal for Greece Varoufakis wanted to avoid this by a exclusively digital solution, to ensure full transparency and prevent overproduction of credit.

2.2.3 Fiscal Money

Fiscal Money is another proposal for a parallel currency to the euro in Italy. The government will issue bonds which can be used for taxes after two years. The possibility of using it for taxes gives the Fiscal Money immediate value (Cattaneo et al., 2018). The dynamics of the proposal are very similar to the dynamics of the EPM and the mini_BOTs.

2.3 Trust and Confidence in the Economy

Consumer confidence represents the consumer optimism about the state of the economy and personal finance. Optimistic consumers feel less of a need to save money, thus more spending and economic stimulation. The same is true for business confidence, and both are important factors in economic fluctuations. Confidence is even more important in a recession, as it can contribute in changing the negative trend. The recession will, however, have a negative impact on confidence, and a feedback loop between the economic state and confidence makes it hard to restore confidence. Guo and He (2020) backs this knowledge in a study on how consumer confidence and business confidence affects economic growth.

In their study Guo and He (2020) found that the effects of consumer confidence and business confidence are amplified during recessions. The asymmetric effect is explained by fiscal and monetary policies. Higher levels of confidence will amplify the effects of fiscal and monetary policies during an economic downturn. A result of which is support of forward guidance policies as important for maintaining confidence. Confidence should in general be regarded crucial for policymakers, and especially in recessions.

The research done on trust and confidence in relation to the economy is in development. Confidence, being a soft factor, has many possible definitions, interpretations and ways of being measured. The 2008 financial crisis sparked a new emphasis on the matter, and the discussion on contributing factors as well as degree of human rationality is still going on (Tonkiss, 2009). The relevance of consumer confidence and confidence at a micro economic level are backed by an increasing number of studies. Guo and He (2020) also found that business confidence is an equally pivotal factor.

Confidence does not only affect the economy by being directed at the economic state, but general confidence is also found to play a role. This is where the term trust comes is. The two, trust and confidence, are often used interchangeably. Tonkiss (2009) defer the

terms by defining confidence as, to some degree, being backed by objective information, whereas trust can be defined as more dependent on subjective perceptions. The differentiation is done in an attempt to show how both affects the real economy. Confidence is determined by information, contracts and regulations. These are important factors in decision making, and if one of them fail, it is hard to have confidence in the institution presenting the information, contracts or regulations. In the case where mechanisms of confidence fail, Tonkiss (2009) argues that trust will substitute for confidence when making decisions where risk is involved. Going back to the role of confidence in the economy, trust will now also affect economic fluctuations, and especially during recession. That is, during crisis, recession or failure in financial systems, social trust has a significant impact on economic growth.

Further more, research has shown a positive relationship between level of trust and national wealth. The levels of interpersonal trust and trust in economic and political institutions are higher in wealthier economies (Tonkiss, 2009). Distribution of wealth is also linked to higher levels of trust. Financial markets are directly dependent on trust, as investment decisions always include some risk. Higher level of trust increase the share of personal and corporate wealth spent on investments.

As Tonkiss (2009) points out, the shaded are between trust and confidence is large. The variety of studies done have not resulted in unambiguous definitions or clear driving mechanisms. Consumer confident, and consumer sentiment, is among the more popular topics, especially in media. Boef and Kellstedt (2004) found that, in the case of the United States, political governance influence consumer confidence. Their research looked at independent, direct effects of political evaluations, political events, monetary policy and indirect effects of media. In the long run economic conditions make up the base for consumer confidence. When the current economic situation looks good, it is easier to feel optimistic about the present and future economy. Confidence in the president's ability to manage the economy positively affects consumer confidence in the long run. Federal fund rates negatively affect the long-run consumer confidence. Economic shocks has temporary effects on the sentiment, but will adjust back to equilibrium quickly.

Boef and Kellstedt (2004) found that politics also affect consumer confidence in the short run. Economic approval, how citizens view the president's ability to manage the economy, has higher short term effects. Boef and Kellstedt (2004) argue that economic approval is dependent on media coverage of the economy, in addition to the economic state itself. This way, news coverage has indirect effects in the long run, as well as the short run. Media coverage from nonpolitical sources in total makes up the long term economic approval. The same sources also have short term effects, together with media coverage of political sources. Politicians messaging in the news does give short term effects, but it does not affect the long term public view of economic approval. In short, media coverage has indirect effects on consumer confidence through economic approval.

2.3.1 Europeans' Confidence in Government

Europeans' confident in government and political institutions have been declining rapidly since 2009, varying between countries and socio-economic groups. Foster and Frieden (2017) compared baseline factors for confidence in national government and EU institutions. They found the main contributors to the rapid change to be economic factors. More

specifically, the countries hardest hit by the crisis showed a more significant decline, and unemployment and structural adjustment programs came out as the clear explanations for the immediate change.

Foster and Frieden (2017) presents a baseline of economic, cultural and political factors contributing to trust in government. In their statistical analysis they predict the likelihood of expressing confidence in the national government and EU institutions based on baseline factors, on both a national and individual level. Data was gathered from the Eurobarometer surveys from 2004 to 2015. Higher educated groups have more confidence in the government than groups with less education. In countries with more political rights the government support is high. Individuals on the political far left and those exclusionary identifying with nationality are less supportive of European governments. Income is another telling factor, where the confidence in national governments and the European Union is lower in countries with higher income per capita.

These baseline factors determines the underlying long-term elements in confidence. As stated by Foster and Frieden (2017), a common view is for political and cultural factors to be seen as the main drivers for the drop in confidence in Europe after 2008. What Foster and Frieden (2017) found, however, was that the rapid change could mostly be explained by economic factors. Among debtor countries it is the rise in unemployment which is the biggest contributor to a dramatic decline in confidence in both the national government and the EU. The gap in confidence between the employed and unemployed has increased since the crisis.

With a one percentage point increase from 10% in unemployment in a country, followed a two percentage points decrease in probability of indicated confidence in the national government, and one percentage point for the EU institutions. Median income level is not a significant contributor to the rapid decline compared to unemployment, and should only be counted as a baseline factor.

Along with the decrease in confidence due to unemployment, a country enrolled in a structural adjustment program run by the European Financial Stability Mechanism (EFSM) or European Stability Mechanism (ESM) showed an additional collapse of seven percentage points in confidence in the national government. The confidence in European institutions decreased at the same rate, and had a negative effect twice the size of countries not enrolled in similar programs. Reduction in confidence as a consequence of a structural adjustment program is shown to be caused by the economic effects, and the national governments are blamed to a higher degree than the EU for the outcome.

2.4 Electronic Money

Electronic money is slowly replacing money in physical forms. It is easier and cheaper for both consumers and businesses (Al-Laham et al., 2009). For electronic currencies, also called digital currencies, there are no physical money involved. The trendy cryptocurrencies and virtual currencies are often unregulated and not traceable. This is not the case for electronic currencies issued by the state, often referred to as Central Bank Digital Currencies (CBDC).

CBDC can provide financial inclusion and a stable payment system. It facilitates systematic and transparent regulations of monetary policy (Bordo and Levin, 2017). The

principles of CBDC can also be used to implemented an electronic currency not defined as legal tender. Tagpay is an example of a banking system that can be used for quick implementation of a parallel currency (Sharma, 2021).

Chapter 3

Modern Monetary Theory

Modern Monetary Theory (MMT) is an approach to macroeconomics, opposing what today is seen as conventional economic theory. In "Modern Monetary Theory - A Primer on Macroeconomics for Sovereign Monetary Systems" by Randall Wray (2015) MMT is described as a challenger of orthodox views about government finance, monetary policy, the Phillips curve trade-off, fixed exchange rates and current account surpluses. This chapter aims to give the reader a brief introduction to some of the basic principles of MMT and to how control systems engineering can be used in modeling.

3.1 Basic principles

According to MMT a government issuing its own currencies is spending money into existence. That means the government can spend what is needed, as long as the need for workers and equipment is met (Coy et al., 2019). Like Keynes, MMT emphasises the circulation of money and how a government cannot, unlike a household, cut down on spending when income falls. Less spending also means reduction of money in circulation, and will affect income - which again will reduce spending and so forth. It is the responsibility of the government to avoid downward spirals like these, simply by spending money. In more general terms, the economy should be guided by fiscal policy more so than by adjusting interest rates.

The concepts presented in this subchapter are based on the MMT primer by Randall Wray (2015), which can be recommended for a more thorough presentation of the basics of MMT.

3.1.1 Stocks and Flows of Money

MMT often uses stocks and flows when describing budget balances. Flows of money accumulate to stocks. Accumulation of wealth is possible when spending is less than income over a period of time. Each sector in the economy has its own stock of wealth, and flows of spending runs between them. When one sector accumulates wealth, it will affect

the other sectors. One sector's deficit is another sector's surplus. It is often hard to know the monetary value of non-financial assets, and it is therefor common to look at flow and accumulation of money and financial assets in stock-flow models.

The bathtub analogy is useful for understanding the stock-flow models. A stock can be seen as a bathtub with water, a faucet fills the tub and the water runs of out the drain. The water running in and out represent the inflow and outflow. The outflow does not have to be equal to the inflow. An example can be seen in figure 3.1. The inflow is government spending on goods and services (G), filling the private sector-stock. The tax outflow (T) is draining the private sector. If the private sector is saving, that means the tub is filling up and the outflow (taxes) is less than the income (government spending), resulting in government deficit.

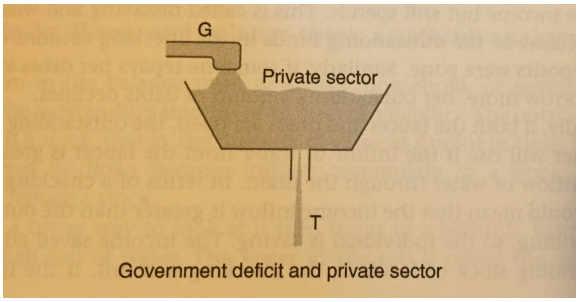


Figure 3.1: The bathtub analogy for government spending, the private sector and taxes (Randall Wray, 2015).

The simplified model in figure 3.1 is easily expanded. Net exports (NX) can be included by adding an inflow of exports and an outflow of imports. By then adding another inflow of private domestic investment (I), the national income and product identity (S) is fulfilled as in equation 3.1.

$$S = (G - T) + I + NX \tag{3.1}$$

The economy can be divided into three main sectors: a domestic private sector, a domestic government sector and a foreign sector. Each sector can be represented by stocks with inflows and outflows, where the inflow of one sector is the outflow of another. A budget surplus in one sector within a time period is the deficit of another, or a combination of the others, in the same period. MMT states that there is no reason for a single sector to balance its inflows and outflows each year. The sum of surpluses and deficits across all sectors, however, will always be zero.

3.1.2 Sovereign Currency

MMT strongly supports the view that a nation should issue its own currency, often called a domestic or a sovereign currency. The sovereign currency is to be used on government spending and tax collection. By having a fiat currency, a currency not backed by reserves or other currencies, the government can produce sales of labour, resources and output with more flexibility. Tax obligations drives the money by making sure all taxpayers need to

obtain the national currency. That is, taxes are not for the government to produce revenue, but to produce output. It is also important to state that MMT does not oppose the use of foreign currencies within a country. The main point is rather for a nation to issue its own currency in order not to run a budget deficit in a foreign currency.

3.2 A Control System Approach to MMT

In the thesis "On the Dynamics of Money Circulation, Creation and Debt – a Control Systems Approach" Andresen (2018) explores the stock flow approach to macroeconomics in terms of the field of control systems. He develops tools for use in analysis of financial dynamics, and later uses them to study financial accumulation, debt and crisis caused by financial accumulation and indebtedness. Continuous time models, in comparison with discrete time models, are also strongly supported.

Among his contributions is an understanding of the velocity of money in monetary circuits, as well as an understanding of time lags. This section will include brief overviews of these topics. Throughout the thesis Andresen presents different stock-flow macro models, and uses them for analysis. The models considered most relevant for this thesis will be presented in the last subsection of this chapter. That is, a simple textbook economy with households and firms, and some expansions to include savings, government spending and taxation. The aim is for the reader to better understand how to mathematically represent macroeconomic stock-flow models.

Other relevant contributions of the thesis, which will not be discussed any further in this chapter, are arguments for the advantages of a purely electronic monetary system, and for electronic national currencies in crisis-hit dollarised and eurozone countries. The more complex models for financialisation and debt crisis will not be discussed in this chapter.

3.2.1 The Velocity of Money

The stock-flow approach provide a clear separation between money within a sector and money in transit between sectors. This is important because stocks and flows have different effects on the economy. Demand in the economy is decided by the aggregate money flow Y, and not the aggregate money stock M. Andresen argues that the average velocity of money v is often ignored in the following relationship between the money stock and the flow of money.

$$Y(t) = M(t)v(t) \tag{3.2}$$

What is important to understand from this equation is the possibility to affect the flow of money not only by controlling M but also v, the transaction frequency. In a system using electronic money it is possible to change v more rapidly than M, as it is a behavioural variable and not a stock.

Coming back to the introduction of Section 3.1 and the scenario of income fall and government reaction. If the government also reduces spending the result will be a downward spiral of income fall and less spending. The result is not only a reduction of money in the circuit, but probably also decrease in money velocity. When income falls, or the

economy seems insecure or less stable, confidence in the economy may also decrease and this is why the velocity of money v can be called a behavioural variable.

In a system with a constant amount of money the velocity can still variate. Money can move infinitely fast from one account to another, but stay with an agent (a household or a firm) for some amount of time. This depends on uncertainty and the practical fact that spending does not always happen at the same time as income is received. The dispersed response in outlow due to change in inflow is called a time lag.

3.2.2 Time Lags

In the simple example of a single household, an inflow of money will be distributed over a period of time, normally a month. Bills might be payed immediately, but food and other necessities often have to be purchased regularly. In a stock-flow view the result is an outflow dispersed in time. Looking at the household sector, the same will be true for the combination of all households. An average time lag can then be approximated. This applies equally to the firm sector and other sectors, with different average time lags. Especially in the firm sector, transactions between agents within the sector will also influence the time lag. In continuous time modeling the simplest representation of a time lag is the first order transfer function.

Macroeconomic models are often time-discrete, while the economy in reality runs in real time. It becomes easy to confuse stocks and flows in time-discrete models, as the denomination of the flows in discrete time becomes equal to the stocks. The first order time lag has the purpose of describing stocks and flows in a correct manner, in addition to including the natural behaviour of distributed spending. Another advantage continuous time has over time-discrete models, is that variations in time lags between the sectors are easily included. The household sector is in general more fast-moving than firms, banks and the government. It is easier to introduce, remove and change time lags in continuous time models. Modern simulations software can handle these changes, and is useful in examining how different time lags affect the system.

3.2.3 A Simple Textbook Economy with Households and Firms

The stock-flow approach is used by Andresen (2018) to present a simple textbook model of an economy with households and firms in figure 3.2. Neither the government nor the financial sector are included here. The M_F stock represents the money stock for the firm sector, with aggregate demand as inflow. The outflows are profit and wages. In this diagram aggregate demand consists of consumption and investment only, all profits are invested and no external investments are included. Similarly the M_H stock represents the household money stock with wages flowing in and spending flowing out. The model parameters are defined in table 3.1.

The equivalent block diagram representation of the flow diagram is presented in figure 3.3 (Andresen, 2018). The money stocks are represented by integrators $\frac{1}{s}$, and time lags are also included in the block diagram. T_H is the time lag for the aggregate of households

M_F = firm money stock [$]
M_H = household money stock [$]
Y_d = aggregate demand [$/year]
Y_o = aggregate output [$/year]
w = workers share of output []
π = $1 - w$ = profit share of output []
Π = profit [$/year]
W = wages [$/year]
C = consumption [$/year]
I = investment [$/year]
T_F = time lag for the financial sector [year]
T_H = time lag for the aggregate of households [year]

Table 3.1: Model entities for Figure 3.2 and Figure 3.3 (Andresen, 2018).

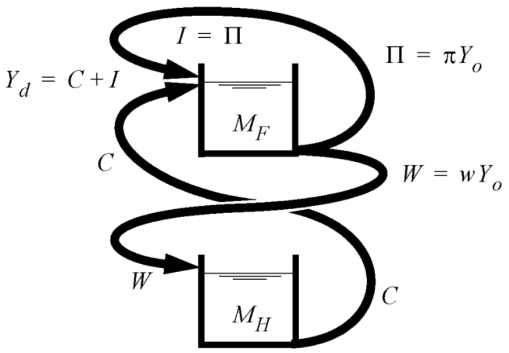


Figure 3.2: Monetary flow diagram of system with firms and households (Andresen, 2018).

and T_F for the firm sector. The system is dependent on continuous time t, such that the aggregate demand is denoted $Y_d(t)$ and so forth.

In figure 3.4 Andresen introduces a taxation flow and a government spending flow. A share θ of the gross income Y results in the tax outflow T. The disposable income YD then becomes the remaining share $1 - \theta$ of Y. Government spending is here divided, by the use of the coefficient β, into two different inflows. One directly in to the firm sector representing government spending. The other added to the income flow, representing government wages and pensions. The model in figure 3.4 also includes a distinction between household consumption out of income and out of wealth, by the introduction of a spending share α_1. On flow, $(1 - \alpha_1)YD$, flows into the household money stock, whereas the other flow, $\alpha_1 YD$, is consumed immediately. Infinite-speed money circulation, which never occurs in reality, is avoided by a very small time lag ϵT. In simulations the ϵT time constant can be chosen very small, and the simulation time step even smaller.

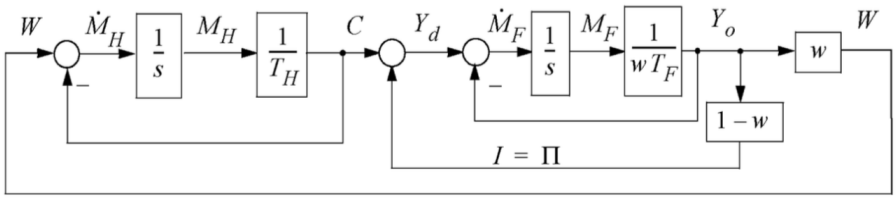


Figure 3.3: Elementary block diagram of system with households and firms (Andresen, 2018).

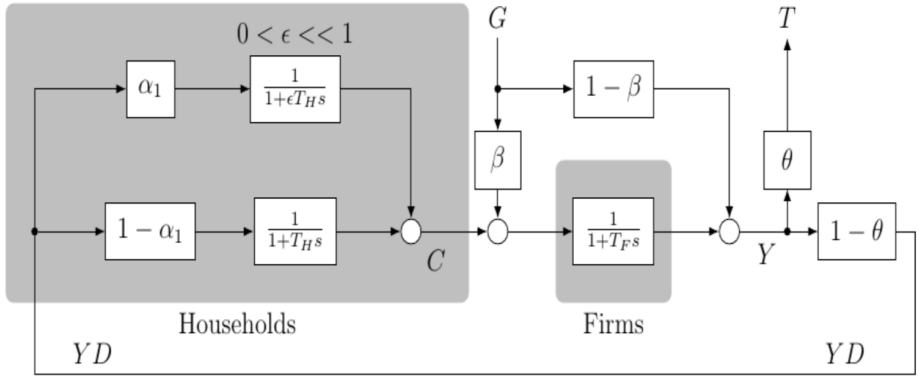


Figure 3.4: The households and firms-model with a government spending inflow and a tax outflow (Andresen, 2018).

Chapter 4

Model development

A variety of parallel currency proposals contribute to discussions on how to improve the economic situation in today's euro area. They all present similar, but different, strategies of implementation. The EPM proposal, portrayed in Section 2.2.1, describes one way of introducing a parallel currency to the euro and the dynamics at play. A closer look at the EPM proposal might contribute to a deeper understanding of the general parallel currency dynamics, as well as to understanding strategy differences.

This chapter is a three-part presentation of a model representing the EPM introduction process. The first part presents a causal diagram of the dynamics. Section 4.2.1 develops a block diagram of an economy with EPM running in parallel with the euro. The model is based on the simple textbook economy model by Andresen (2018) from Section 3.2.3. The result is a continuous time model in line with MMT principles. In Section 4.3 the model is expanded to include the behavioural dynamics described in the EPM proposal. Section 4.4 gives an overview of all model entities.

4.1 Introducing a Currency in Parallel to the Euro

This section presents a simple causal model of the introduction process of a parallel currency, the EPM, to the euro. The EPM proposal describes the start-up phase, how to the get the EPM in circulation, adjustment possibilities when in circulation, subsequent reallocations of euros, and how it can work both in parallel to the euro and as a single currency. The focus of this thesis, and the following model, is on the dynamics of getting the EPM in circulation. Thisis referred to as the introduction process of the EPM.

Social factors are crucial to the dynamics of the introduction process. There will both be resistance and support among the population, affecting the development in different directions. Social mechanisms are hard to predict, and maybe even harder to simulate. In the EPM proposal Andresen (2020) describes the influence of trust in the initiating process and how lack of trust will lead to resistance. The topic of trust and confidence is therefore also at center in this thesis.

The causal diagram has two main purposes. Firstly, the discussions on the dynamics of parallel currency proposals are complex. There are many opposing mechanism at work, and the debaters emphasizes distinct areas of focus. Among the main driving mechanisms are several behavioural variables, like confidence, politics and media coverage. These are still areas under research and continuous discussions. A causal diagram can contribute to an overview over relevant connections, reinforcing loops and present a base for further expansions.

The second main purpose is preparation for developing a continuous time model of the EPM introduction process. This will be done in Section 4.2.1 and Section 4.3. The block diagram can contribute to understanding the dynamics, and can be used for simulations.

Some clarifications before getting into the model development:

- The term "government" will refer to the combination of national and local governments throughout this thesis.
- @ is used as the currency sign for the EPM.
- The model focuses on the introduction process and the short-term dynamics only.

4.1.1 The Dynamics of the EPM Proposal

The full causal diagram can be seen in Figure 4.2. All model entities are described in Table 4.1. Figure 4.1 is meant as a way of easing into the model, and includes the dynamics described in the first part of the following text. There are endless amounts of ways to represent the EPM dynamics. This causal diagram aims to portray the combination of economic and social factors counteracting and contributing to EPM circulation.

EPM Government Flows

The EPM will be injected into the economy in two ways. The first flow is to be called $G_{H,@}$. Employees of the government and pensioners receive payments in a mix of euro and EPM, resulting in a EPM flow from the government to the household sector, $G_{H,@}$. Similarly, suppliers of the government will have to accept mixed payments, or the government will find alternative suppliers. In most cases, the trade is assumed to be accepted, and the resulting flow is named $G_{F,@}$.

The $G_{H,@}$ flow will give people a choice between letting the EPM accumulate in their accounts or try spending it. In the initial phase the EPM cannot be used to pay taxes, and the EPM accounts will grow. When the economic activity is in a downturn, the proposal assumes that pressure will emerge from EPM holders on vendors. That is, a pressure from the household sector on the firm sector to accept payments in EPM, called PHF. The relationships are presented in Figure 4.1. The $G_{H,@}$ flow leads to a growing household money stock, $M_{H,@}$, which in turn will lead to the pressure PHF increasing EPM spending, $C_@$.

Private Sector Wage Share

With a share of the household spending in EPM, businesses will also want to pay their employees in a mix of EPM and euro. This results in the household consumption in EPM,

$C_{@}$, increasing the EPM private wage share, $w_{@}$. Businesses now have a way of spending EPM, other than purchases from other businesses accepting mixed payments. One consequence of higher wage share is increased EPM flow to the households, included in the model by a positive link between the wage share, $w_{@}$ and the EPM money stock, $M_{H,@}$. The $G_{F,@}$ flow will encourage the initial wage share $w_{@}$ to be higher than zero, as the government can force government suppliers to accept mixed payments. This can be seen in Figure 4.1 by the positive link between $G_{F,@}$ and $w_{@}$. The relationships described to this point results in a reinforcing loop between M_H, PHF, $C_{@}$ and $w_{@}$.

Another consequence of higher wage share is higher acceptance of mixed payments, and thereby also increase in EPM consumption. There will, however, be a difference between trades of domestic and imported goods. Businesses trading domestic goods have the possibility of negotiating mixed payments with their own suppliers, in addition to paying their employees in a mix of the two currencies. With time, if EPM spending and the wage share increases, the firms trading significant shares of imported goods will be able to accept mixed payments by pushing for higher a higher EPM wage share, $w_{@}$. In 4.1 there is a loop between $C_{@}$ and $w_{@}$ covering how EPM spending and the wage share reinforce each other. The complications of trading imported goods are included by a negative relationship between a demand of imported goods, DIG, and the household consumption in EPM, $C_{@}$.

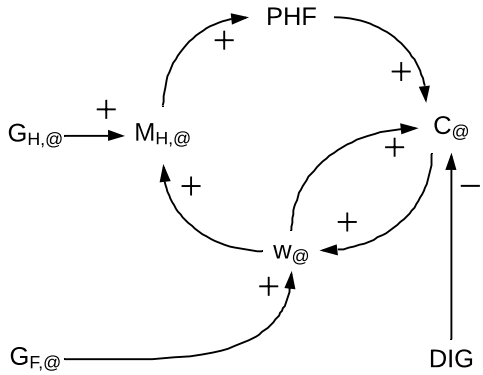


Figure 4.1: The first part of the causal diagram.

Unemployment and Need

The initial EPM circulation is depending on a need for more circulation in the economy. As suggested by Andresen a $need$ entity is introduced. Unemployment is a critical factor for the economic state, and a high unemployment rate, u, will give a significant $need$. The $need$ will further lead to people holding EPM attempting to use the new currency. This is what causes the pressure on businesses to accept mixed payment, PHF. The unemployment rate u is an exogenous parameter in this short-term model.

Trust and Confidence

Another suggested entity is $trust$, which will be defined as general trust in the EPM as a medium of exchange. The public has no previous experience with similar solutions, and the interpretation of trust as dependant on subjective perception (Tonkiss, 2009) is relevant here. The $trust$ entity will in this model be used as a general term to help explore some aspects of trust and confidence in the introduction process. The dynamics of trust and confidence in the economy is already a part of the economy with euros. The concepts from Section 2.3 are not directly translatable to the introduction process, but some key ideas are assumed to work in a similar way.

When it is increasingly considered possible to use the EPM, it will become easier to trust the currency. Higher $trust$ will then again facilitate more spending, as accepting mixed payments is less risky. The result is a reinforcing loop between household spending, $C_{@}$, and $trust$. Something similar to consumer confidence is at play here, as higher trust leads to increased household spending.

From Guo and He (2020) we know that business confidence is just as important as consumer confidence. A business relation to trust is also included in the loop between $C_{@}$ and $trust$. The reason being the dynamics of the $C_{@}$ entity. Consumers can not spend EPM without firms accepting mixed payments, as there exists an alternative of simply paying in euros. By MMT theory (see Chapter 3) the outflow of one sector is the inflow of another. Money out of the household sector will therefor either go to the government or business related sectors. The government sector complicates the argument, but it should still be clear that $C_{@}$, and the connection to $trust$, is also relevant for businesses. In this model the combination of $C_{@}$ and PHF represent businesses accepting trades.

The exact driving mechanisms of the $trust$ entity are hard to predict. Still, some similarities to consumer confidence will be assumed. The short term influence of confidence in politicians and media coverage has on consumer confidence (Boef and Kellstedt, 2004), can be expected to also be true for $trust$.

Andresen (2020) emphasises trust in politicians and authorities, financial press and attitudes among economic influencers, EU and the ECB as important contributions to trust in the EPM. "Economic influencers" here refers to economists and commentators with influence on the economic mood. Boef and Kellstedt (2004) separates media coverage of political sources from nonpolitical source. In the model the two categories are included in the distinct entities $conf_G$, $conf_{EUi}$ and CP. CP cover counterpressure from the financial press and other economic influencers. That is, negative media coverage of the EPM by nonpolitical sources. The link between CP and $trust$ is accordingly negative.

Confidence in the national government, $conf_G$, and confidence in EU institution,

$conf_{EUi}$, cover confidence in politicians and political media coverage. If general trust in the government, t_G is low, trusting a new currency implemented by this government might be hard. The link between trust in the government, t_G, and $trust$ is therefore positive. The opposite will be true for the EU institutions, assuming they will not be in support of the EPM. The link from $conf_{EUi}$ to $trust$ is therefor negative.

Foster and Frieden (2017) distinguished baseline factors of confident in governments from factors contributing to rapid change. The introduction process of the EPM is not to last long enough for significant change in the baseline factors. Foster and Frieden (2017) found the short term factors to be unemployment and structural adjustment programs. Assuming there will be no change in structural adjustment program enrollment under the introduction of the EPM, the remaining contributor is unemployment. In Figure 4.2 this is included by negative links from the unemployment rate, u, to confidence in the government, $conf_G$, and confidence in the EU institutions, $conf_{EUi}$. That is, increase in unemployment will reduce public confidence in both the national government and the EU institutions.

Time Delays

Four time delays are added to the model as double lines crossing the link between entities. There are two delays for the wage share variable $w_{@}$, as it will take some time for businesses to start paying mixed wages. Another delay is added on the link between the consumption flow $C_{@}$ and $trust$. Consumers will need to see that the EMP is usable for some time, before it serves as a proof to trust the new currency. The last delay is added between the household money stock, M_H, and the pressure PHF. This represents a time lag between observation and action.

$\boldsymbol{G_{H,@}}$	EPM share of government wages and pensions
$\boldsymbol{G_{F,@}}$	EPM share of government payments to suppliers
$\boldsymbol{M_{H,@}}$	EPM household money stock
$\boldsymbol{PHF}$	Pressure from the household sector on the firm sector to accept payments in EPM
$\boldsymbol{DIG}$	Demand of imported goods
$\boldsymbol{C_{@}}$	Household consumtion in EPM
$\boldsymbol{w_{@}}$	Share of wages payed in EPM in the private market
$\boldsymbol{need}$	The need for more economic activity
$\boldsymbol{u}$	Unemployment rate
$\boldsymbol{trust}$	General trust in the EPM
$\boldsymbol{conf_G}$	General trust in the government
$\boldsymbol{conf_{EUi}}$	General trust in the EU institutions
$\boldsymbol{CP}$	Counterpressure in media from nonpolitical sources

Table 4.1: Model entities for the causal diagram.

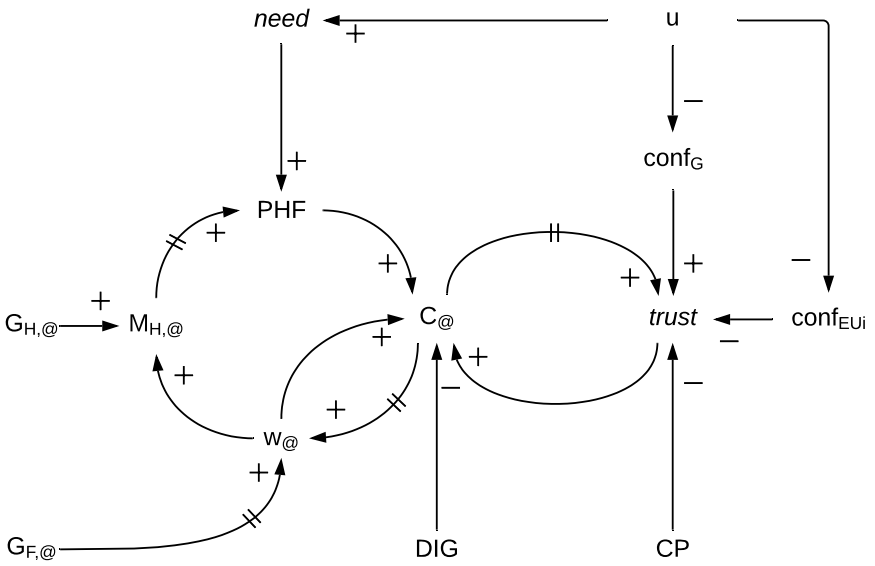


Figure 4.2: The causal diagram.

4.2 Two Currencies in Parallel Circuits

This section develops a block diagram representation of a simple economy with a household sector, a firm sector and a government sector. The government sector includes all levels of government. The model is based on the simple textbook model of the economy by Andresen (2018) presented in Section 3.2.3.

A system of two currencies running in parallel is presented in Section 4.2.2. The model is then extended to include separate money flows for euros and EPMs. Some practical challenges regarding taxation is addressed.

Section 4.3 utilizes the causal model from Section 4.1.1 to include behavioural variables in the model.

4.2.1 A Simple Circulatory System

As in Figure 3.3 we have a circulatory system with households and firms. The household sector consists of a money stock, M_H, and a velocity entity, v_H. Similarly, the firm sector contains the money stock, M_F, and the money velocity, v_F. The velocity variables are replacing the time lags in Figure 3.3. The only other change made to Figure 3.3 is a rename of the workers share output, w, now called β. The result of the continuous time model can be seen in Figure 4.3. An overview over model entities can be found in Table 4.3. All model entities are time dependant, such that M_H is $M_H(t)$ and so forth. With a short term time perspective from the EPM introduction process, the time unit will now be $week$. The table utilizes \$ for the denominations represent money, so that the entities later can be applied for both euros € and EPM @.

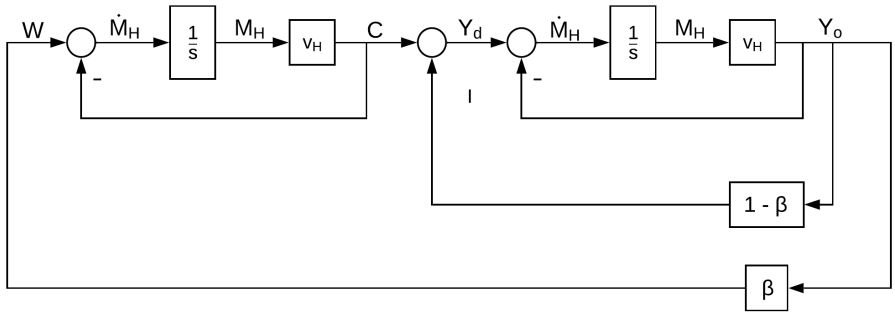


Figure 4.3: A circular economy with firms and households, based on 3.3 by Andresen (2018).

In Figure 4.4 we expand the model with government spending, tax flows and net export. The household sector and the firm sector are presented as black boxes, containing the dynamics of Figure 4.3.

Government spending is included as external inflows, like in Figure 3.4. Government wages and pensions, G_H, is separated from the remaining part of government spending, G_F. The G_H flow is added to the wage flow, W, from the firm sector. G_F is added to the

aggregate demand, Y_d. The national income identity from Equation 3.1 is almost fulfilled by also adding net exports, NX. The only exception is the G_H flow now moved for a more direct inflow into the household sector.

Taxation is simplified to two separate outflows. A household tax rate, α_H, on the wage flow, W, lead to the household tax flow T_H. The remainder of the wage flow, $(1-\alpha_H)W$, flows into the household sector, maintaining stock-flow consistency. The other tax flow, T_F, is a general tax on the firm sector. It is a result of the firm sector tax rate, α_F, on the aggregate demand, Y_d. The inflow of the firm sector is now $(1-\alpha_F)Y_d$. The tax flow variables T_H and T_F are not to be confused with the time lag variables in Figure 3.3.

$\boldsymbol{M_H}$	Households money stock [$]
$\boldsymbol{M_F}$	Firms money stock [$]
$\boldsymbol{v_H}$	Households money velocity [1/week]
$\boldsymbol{v_F}$	Firms money velocity [1/week]
$\boldsymbol{G_H}$	Government wages and pensions [$/week]
$\boldsymbol{G_F}$	Government payments to suppliers [$/week]
$\boldsymbol{T_H}$	Tax flow out of the household sector [$/week]
$\boldsymbol{T_F}$	Tax flow out of the firm sector [$/week]
$\boldsymbol{Y_d}$	Aggregate demand [$/week]
$\boldsymbol{Y_o}$	Aggregate output [$/week]
$\boldsymbol{\beta}$	Workers share of output []
$\boldsymbol{W}$	Wages [$/week]
$\boldsymbol{C}$	Consumption [$/week]
$\boldsymbol{I}$	Investment [$/week]

Table 4.2: Block diagram model entities. All entities are time dependant such that M_H is $M_H(t)$ and so forth.

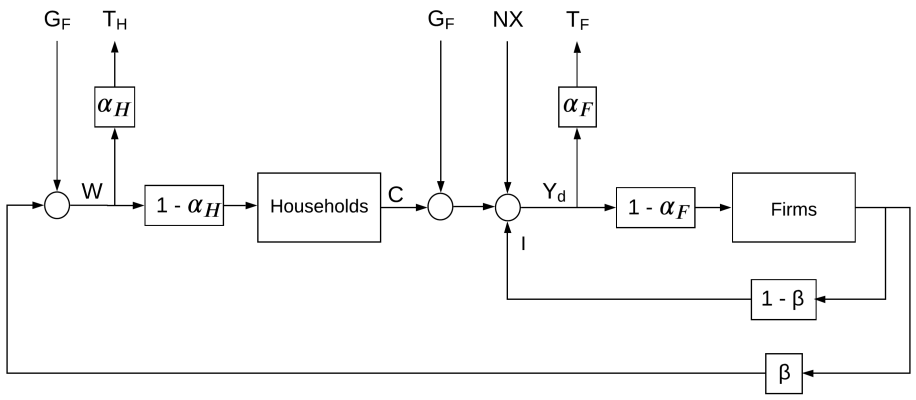


Figure 4.4: A circular economy with inflows of government spending, G_H and G_F, and outflows of taxes, T_H and T_F.

4.2.2 EPM in Parallel with the Euro

The combination of EPM and euro is modelled by two circular economies, as in the figure above (Figure 4.4), in parallel. One for euro and one for EPM. The parameters of the two circuits will be named as in Figure 4.4, but differentiated with additional subscript € for the euro circuit and @ for the EPM circuit. An overview of all model entities can be seen in Section 4.4.

The EPM proposal suggest introducing the new currency by paying government employees, pensioners and suppliers in a mix of euros and EPM. An amount of EPM is added to the government payment in euros, as demonstrated in Figure 4.5. The two government flows $G_{H,€}$ and $G_{F,€}$ flows into the euro circuit, as before. The size of the EPM flow $G_{H,@}$ is found as a share δ_H of the euro flow $G_{H,€}$. Similarly, the rate δ_F is used to find the EMP flow $G_{F,@}$. In the introduction phase of the EPM, the government spending in euro remains as before the introduction. That, and the EPM ratios, δ_H and δ_F, can be adjusted based on how the process develops.

The EPM can be used to pay taxes which will make the currency attractive and help drive the money, according to MMT. In our model the result is two tax streams out of the euro circuit, and two out of the EPM curcuit. Figure 4.5 shows a tax flow in euros $T_{H,€}$ out of the household sector and a tax flow in euros $T_{F,€}$ out of the firm sector. The same way, we have the tax flows $T_{H,@}$ and $T_{F,@}$ out of the EPM circuit. € is used in denominations for both currencies, as 1 @ counts as 1 € in tax payment.

$G_{H,€}$	Euro share of government wages and pensions [€/week]
$G_{F,€}$	Euro share of government payments to suppliers [€/week]
$G_{H,@}$	EPM share of government wages and pensions [€/week]
$G_{F,@}$	EPM share of government payments to suppliers [€/week]
δ_H	Ratio between government wages and pensions in EPM and in euro []
δ_F	Ratio between government payments to suppliers in EPM and in euro []
$T_{H,€}$	Euro tax flow out of the household sector [€/week]
$T_{F,€}$	Euro tax flow out of the firm sector [€/week]
$T_{H,@}$	EPM tax flow out of the household sector [€/week]
$T_{F,@}$	EPM tax flow out of the firm sector [€/week]
γ	Ration between total government spending in EPM and in euro []

Table 4.3: Variables and parameters for the model representing EPM in parallel with the euro.

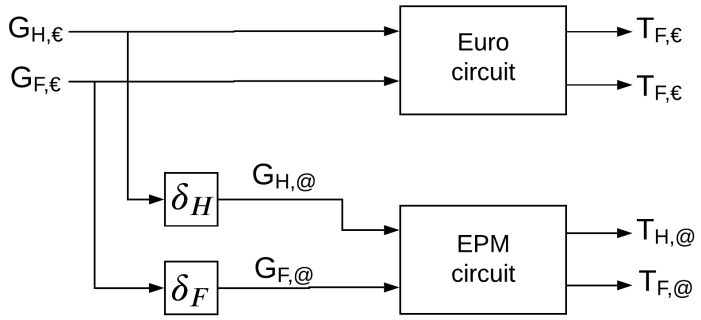


Figure 4.5: EPM circulating in parallel with the euro. Government spending flowing into the two systems, and taxes flowing out.

In tax money 1@ will have the same value as 1€. In the long term the EPM will therefor be able to float at a value just below the euro, assuming the euro will remain the more popular currency. This also prevent the value from exceeding reasonable rates, and then run the risk of crashing. The EPM proposal argues for not starting taxation at the same time as EPM starts flowing into the economy. The EPM will then have the chance to grow, triggering circulation.

Taxes are to be collected in a mix between the currencies similar to the government spending mix. Assuming the euro stays the most attractive currency, the tax payers will want to use as much EPM to pay taxes as possible. The EPM taxation limit will therefore always be maximized. In order to demonstrate how to model the tax flows, some new entities are introduced. $G_€$ is now the total euro government flow, and $G_@$ is the EPM government flow. In order to give general descriptions, which apply to both the household sector and the firm sector γ is also introduced. γ has the same function as δ_H and δ_F, deciding the mix between the two currencies. The mix between collected taxes should be similar to the government spending mix. In the model we will make it exactly the same,γ. When it comes to taxes driving the money, it is the relationship between the total flow in

and the total flow out that matters. The sector tax flows will therefor also be gathered to the general tax flows, $T_{€}$ and $T_{@}$. We have

$$\begin{aligned} G_{€} &= G_{H,€} + G_{F,€} \\ G_{@} &= \gamma G_{€} \\ T_{@} &= T_{H,@} + T_{F,@} \\ T_{@} &= \gamma T_{€} \end{aligned} \tag{4.1}$$

One of the main mechanism to make the EPM attractive is the possibility of using it for tax payment. The EPM proposal argues for the same amount of government spending in euros as before, and adding the EPM on top. This means more money flowing into the economy in total. The government now has to decide between two alternatives

A) Maintaining the same relationship between total government spending and total tax income
B) Reducing total tax income relative to total government spending

By total government spending and total tax income, the euro streams are combined with the EPM streams. Euro government spending remains as before and the EPM government spending are the same for both alternatives. The difference lies in how to distribute the tax flows.

Alternative A) would mean an increased total tax income, as the total government spending flow has increased as well. That is, the government is spending the same amount of euros as before and the euro tax income is the same as before. In addition to euro spending, the government is now also spending EPM. If the rate between government spending and tax income should remain, then the government has to claim EPM taxes in addition to the euro taxes.

The only visible, immediate, advantage of the EPM for the public in the introduction process, is the promise of exchanging some of the tax payments they owe in euros for EPM. The result of this would be higher taxes in total, which might not be received well by the public. On the other hand, the pressure from the EU institutions on maintaining a euro tax flow of the same size will be significant.

Alternative B) is more aligned with the EPM proposal. The long term consequences of decreased euro tax flow in the introduction process might outrun the short term consequences of the reduced tax income in euros. The level of confidence in politicians will be affected by the introduction process, and tax rates will play a part of it. The exact immediate dynamics are hard to postulate, but the option of saving euros that were meant for taxes should help driving the money. At the same time, many of the EPM opponents will be sceptical to a lower tax income in euros. If the EPM proposal works as described by Andresen (2020), however, this might all be worth it in the long run. When the EPM is circulating, it will be easier to adjust tax rates depending on how the process develops. If the EPM becomes a functional parallel currency, the EPM tax income will also have a similar function to the euro tax income.

To present both options for our model, Scenario A and Scenario B are introduced.

Scenario A: The euro tax stream remains the same

If alternative A) is desirable, the EPM tax flow can be found by the mix rate γ, as in Equation 4.1.

$$T_{@} = \gamma T_{€} \tag{4.2}$$

This can be implemented by subtracting the flow from the given sectors. That is, exchanging $T_{h,@} = \alpha_{H,@} W_{@}$ with Equation 4.1, and subtracting this from the flow going into the household sector. The $T_{F,@}$ flow and the flow into the EPM firm sector are found the same way. The euro tax flow is found as before, see Figure 4.4.

Scenario B: Decreased euro tax revenue

At outset the government will decide a limit for the size of the EPM tax stream. In the introduction process there is no doubt the value of the EPM will not exceed the value of the euro, and the limit will be maximized. As the EPM is expected to always maintain a value below the euro, this should hold permanently.

Both the mix rate between the two currencies and how to decide the sizes of the two tax flows $T_{@}$ and $T_{€}$, can be adjusted based on the development of the EPM. In Scenario B we will let the mix rate γ decide the upper limit of the EPM tax flow, $T_{@}$. The euro tax flow, $T_{€}$, will be compared to the size of the the euro tax flow without from Scenario A, called $T_{€,0}$. The result is reduction of the euro tax flow, $T_{€}$, by the size of the EPM tax flow, $T_{@}$.

$$T_{€} = T_{€,0} - T_{@} \tag{4.3}$$

The mix rate γ, from Equation 4.1, remains

$$\gamma = \frac{T_{@}}{T_{€}} \tag{4.4}$$

From Equation 4.3 and 4.4 follows

$$\begin{aligned} \frac{T_{€}}{T_{€}} &= \frac{T_{€,0}}{T_{€}} - \frac{T_{@}}{T_{€}} \\ T_{€} &= \frac{T_{€,0}}{1+\gamma} \end{aligned} \tag{4.5}$$

$T_{@}$ can then be found from Equation 4.3

$$T_{@} = T_{€,0} - T_{€} \tag{4.6}$$

The tax flows are implemented as explained in Scenario B, now also with subtraction in the euro loop. The corresponding euro tax flow $T_{€,0}$ can be found by adding an extra euro circuit in parallel.

4.3 Behavioural Variables in the Model

This section serves two purposes. The first is to expand the model from Section 4.2 to include the missing entities and connections from the causal diagram developed in Section 4.1. Most of the entities not included in the model this far are related to behaviour, and will be called behavioural variables. Functions defining relationships between these variables are hard to define, and often varying between specific economies. The model developed is therefore meant as a base for analysis and development. The second purpose is to present a foundation for simple simulations of the EPM proposal. Suggestions for simple relationships between behavioural entities are presented for this purpose.

This far the model includes the two currencies in parallel (see Figure 4.5), each with dynamics as in Figure 4.4. The dynamics of the household sectors and the firm sectors can be seen in Figure 4.3. For each sector, and each currency, there are distinct money velocities. Money velocity is a behavioural variable (see Section 3.2.1), and the key connection between the block model and the causal diagram from Section 4.1. Assuming that euros will circulate as usual in the introduction process of the EPM, only the EPM velocity variables will be studied here. That is, the EPM money velocity of the household sector, $v_{H,@}$, and the EPM money velocity of the firm sector, $v_{F,@}$.

The sigmoid function will be used to define most of the relationships between the behavioural entities. Growth is slowest near the boundaries, and the slope can be defined differently for each relation. Two examples are shown in Figure 4.6. Sigmoid (a) represent a positive correlation, whereas Sigmoid (b) represent a negative correlation. In this chapter they will be referred to as Sigmoid (a) and Sigmoid (b) type functions in order to indicate the direction of the correlation. The properties should then be specified for the particular relation in a particular economy.

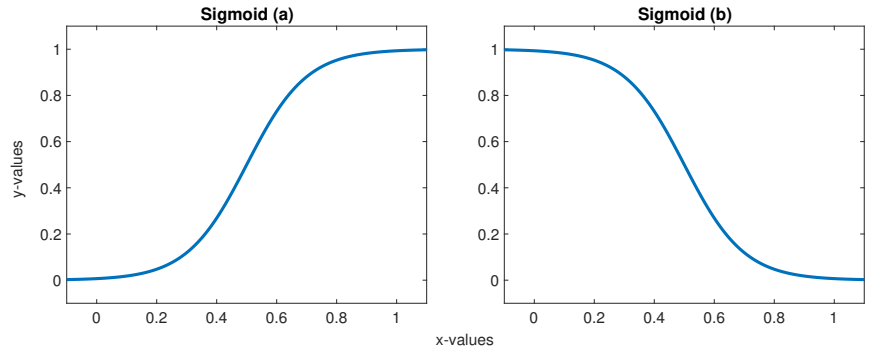


Figure 4.6: Two examples of sigmoid functions between 0 and 1.

There are a lot of variable names in the model by now. For an overview of all the model entities see Section 4.4. The causal diagram can be seen in Figure 4.2. The block diagram in Figure 4.3 might also be helpful.

4.3.1 Trust

The $trust$ entity indicates the level of trust in the EPM. One way of representing this is to define a maximum level of trust, 1, and a minimum level of trust, 0. Sigmoid functions can then define the relationships between $trust$ and the variables and parameters affecting $trust$. In the causal diagram in Figure 4.2 the components of $trust$ are $conf_G$, $conf_{EUi}$, CP and $C_@$. For each entity a function of the relationship to $trust$ is defined, respectively named $trust(conf_G)$, $trust(conf_{EUi})$, $trust(CP)$ and $trust(C_@)$ in Figure 4.7. The resulting outputs can be weighted by significance, and then combined to a value of $trust$ between 0 and 1.

$conf_G$ and $conf_{EUi}$ can be found as functions of the unemployment rate, u. Increased unemployment negatively effects the confidence variables, and the relationships can be defined by a Sigmoid (b) type function (see Figure 4.6). The slopes and the limits of the functions will not be the same. Unemployment affects confidence in the national government more than it affects confidence in the EU institutions. Base line factors does not affect short term change in confidence (Foster and Frieden, 2017), but it will affect the limits of short term change. Over time, base line factors have affected the current state of confidence in the specific economy. If the limits of $conf_G$ and $conf_{EUi}$ are 0 and 1, unemployment can not alone push for the outer limits. The sigmoid functions should therefore be defined with limits between 0 and 1. Whether the specific economy is enrolled in a structural adjustment program, will also affect the functions.

Sigmoid functions can also be used to find $trust$ as functions og $conf_G$ and $conf_{EUi}$. A Sigmoid (a) type function can represent $trust(conf_G)$, and a Sigmoid (b) for $trust(conf_{EUi})$. In this model u and the counterpressure entity CP are exogenous. $C_@$ is the EPM flow out of the household sector (see Figure 4.4). The time delay D_C can be implemented with a first order time delay. The positive link between $C_@$ and $trust$ can be characterized by a Sigmoid (a) type function, and the limits should be defined by the size of $C_@$ in comparison with $C_€$ for the specific economy. $trust$ is found as a combination of the factors described. One way of doing that could simply be to find the average value.

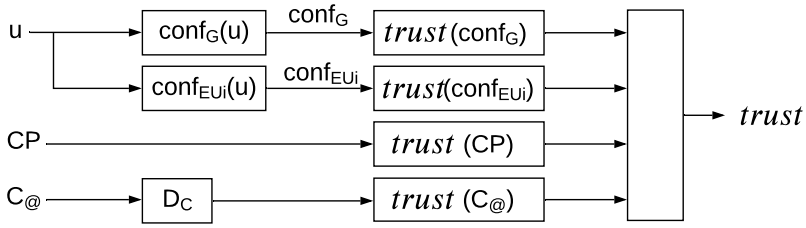


Figure 4.7: Block diagram representation of $trust$.

4.3.2 Need and Pressure

Figure 4.8 shows a simple block diagram representation of how to include $need$ and PHF in the model. The relationships can be defined similarly to what was done in Section 4.3.1.

$need$ and PHF are variables between 0 and 1. PHF as a function of $M_{h,@}$ should be found for the specific economy, comparing the size of $M_{H,@}$ to the size of $M_{H,€}$, and using a Sigmoid (a) type function. A first order time delay can be used for the delay D_{MH}. The components of PHF can be weighted based on significance, and an average function can find the final PHF.

The $need$ entity brings up an issue. It is hard to define what $need$ is in general, and therefore also how it relates to other entities. The same goes for PHF and the vague word, in this context, pressure. Unemployment logically leads to needs that are not met. Andresen (2020) also pointed out too low wages and pensions as contributing factors. This was, however, not included in the causal diagram. The meaning of $need$ in the economy, as well as how it creates pressure and what that pressure does, should be studied further.

A Sigmoid (a) type of function can represent the positive link between u and $need$, with an unemployment rate between 0 and 1. The relation between $need$ and PHF can then be linear.

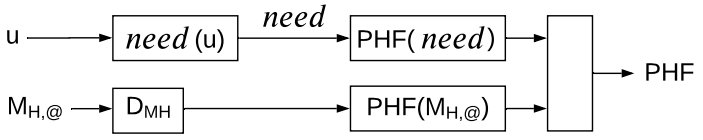


Figure 4.8: Block diagram representation of PHF.

4.3.3 Household Consumption in EPM

The EPM household sector consists of a money stock, $M_{H,@}$, and the money velocity, $v_{H,@}$. The money velocity describes how long money will stay in the sector. Andresen (2018) used the money velocity $\frac{1}{T_H}$ (see Figure 3.3), where T_H is the time lag of the sector. That is, a natural amount of time for money to stay in the sector. Wages are not immediately spent when received, they are usually spread through the month before the next paycheck. Other factors also play in on the time lag. Low confidence in the economy might increase the wish to save money, and high confidence and optimism makes spending more attractive. Regarding the introduction of EPM, some of these factors are included in the causal diagram by relationships to the household consumption variable, $C_@$ (see Figure 4.2). In the block diagram representation, the dynamics will be included in relation to the money velocity, v_H. A household money velocity equal to zero means no outflow out the household sector, hence no consumption. Higher velocities ensures consumption outflow.

Connections in the causal diagram are found as in the previous subsections, and presented in Figure 4.9. $v_{H,@}$ can be defined between 0 and 1. For the introduction process, however, it might be more realistic to let the euro money velocity decide the upper limit. $v_{H,@}(trust)$, $v_{H,@}(PHF)$ and $v_{H,@}(trust)$ can all be defined with Sigmoid (a) type functions. The wage share variable $w_@$ are limited by the rate between government spending in EPM and in euro, γ (see Section 4.3.4).

A demand of imported goods, DIG, will affect the system in several ways. Before the

EPM is accepted as a parallel currency by the public, it will be hard to use EPM in trades of imported goods. The DIG entity only represents the lack of willingness to accept a EPM share in payments of these trades. Other possible consequences are not included. DIG is then defined between 0 and 1, and a Sigmoid (b) type function can be used to find the relation to $v_{H,@}$. A time lag variable $L_{H,@}$ ([weeks]) is also included to represent the natural dispersion of money for practical reasons. Implemented with the relation $\frac{1}{L_{H,@}}$ to $v_{H,@}$. The final $v_{H,@}$ can be found by an average function.

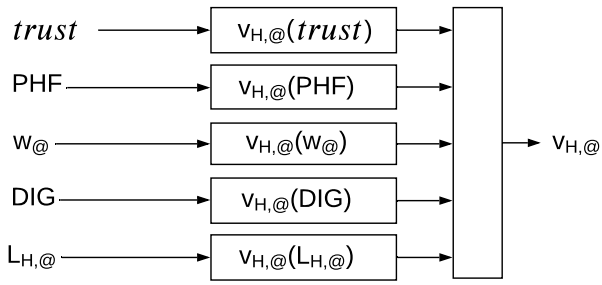


Figure 4.9: Block diagram representation of v_H.

4.3.4 EPM Wage Share in the Private Sector

The EPM wage share in the private sector, $w_@$, is to float naturally. It is expected not to exceed the government EPM share γ, so that

$$0 \leq w_@ < \gamma \tag{4.7}$$

In the causal diagram $w_@$ is composted of relations to $C_@$ and $G_{F,@}$. Consumption in mixed payments leads to a money flow into the EPM firm sector. The EPM money stock, $M_{F,@}$, creates a pressure in the firm sector to spend money by paying wages. This is included in the model as in Figure 4.10. A Sigmoid (a) function can be found to represent the relation.

$G_{F,@}$ adds on the flow into the firm sector which fills up the firm money stock. In additions to that, a flow coming from the government sector sends a signal. Businesses can know that the flow will continue, and to some degree trust it, and they know that the government can keep pushing them to accept mixed payments as long as they like. It is also the government pushing the limits of the mix, and the businesses have less power. It is therefor an extra pressure on businesses to start paying mixed wages. The relation can be defined by a Sigmoid (a) type of function. The final value of $w_@$ can be found as an average of the contributors. Assuming the government flow has a higher impact on the firms willingness to pay mixed wages, the relation to government spending should be weighted higher.

The time delays from the causal diagram, now called D_{MF} and D_{GF}, can be implemented as first order time delays.

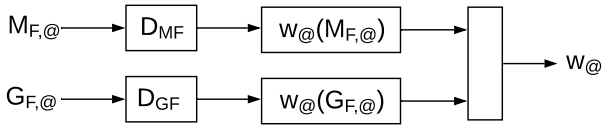


Figure 4.10: Block diagram representation of $w_{@}$.

4.3.5 EPM Velocity in the Firm Sector

The EPM money velocity $v_{F,@}$ represents the money velocity out of the firm sector. An EPM wage share will affect the velocity. When it is more attractive to pay mixed wages, money will flow out of the sector with higher velocity. There are also other factors affecting the velocity. Some of them are practical, as described for the $L_{H,@}$ parameter. How the firm sector reacts to the EPM introduction will be just as important as how the households react. The potential dynamics of the firm sector should be studied further for a clearer model description of the dynamics. In this model a time lag entity $L_{F,@}$ will cover the practical time lag.

The relation between $w_{@}$ and $v_{F,@}$ can be implemented with a sigmoid (a) type function, with $w_{@}$ limits between 0 and γ, and $v_{F,@}$ between 0 and the euro firm velocity $v_{F,€}$. The time lag is implemented as $\frac{1}{L_{F,@}}$. The block diagram representation can be seen in Figure 4.11.

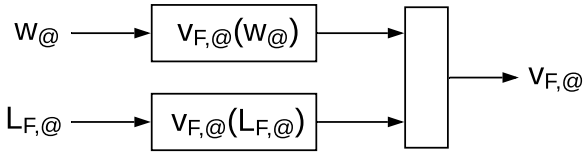


Figure 4.11: Block diagram representation of v_F.

The causal diagram also includes a positive link between $w_{@}$ and $M_{H,@}$. This is represented in the model as follows: Increased wage share, increases the outflow from the EPM firm sector, which again increases EPM wages, $W_{@}$. $W_{@}$ in turn affects the inflow of the household sector, and EPM household money stock, $M_{H,@}$

4.4 Model Entities Overview

This section presents an overview of all model entities.

$\boldsymbol{M_{H,€}}$	Households euro money stock [€]
$\boldsymbol{M_{F,€}}$	Firms euro money stock [€]
$\boldsymbol{v_{H,€}}$	Households euro money velocity [1/week]
$\boldsymbol{v_{F,€}}$	Firms euro money velocity [1/week]
$\boldsymbol{G_{H,€}}$	Government euro wages and pensions [€/week]
$\boldsymbol{G_{F,€}}$	Government euro payments to suppliers [€/week]
$\boldsymbol{T_{H,€}}$	Euro tax flow out of the household sector [€/week]
$\boldsymbol{T_{F,€}}$	Euro tax flow out of the firm sector [€/week]
$\boldsymbol{Y_{d,€}}$	Euro aggregate demand [€/week]
$\boldsymbol{Y_{o,€}}$	Euro aggregate output [€/week]
$\boldsymbol{\beta_{€}}$	Workers share of the euro firm sector output []
$\boldsymbol{W_{€}}$	Euro wages [€/week]
$\boldsymbol{C_{€}}$	Consumption in euros [€/week]
$\boldsymbol{I_{€}}$	Investments in euros [€/week]

Table 4.4: Model entities overview part 2: Euro circuit model entities. All variables are time dependant such that $M_{H,€}$ is $M_{H,€}(t)$ and so forth.

$\boldsymbol{M_{H,@}}$	Households EPM money stock [@]
$\boldsymbol{M_{F,@}}$	Firms EPM money stock [@]
$\boldsymbol{v_{H,@}}$	Households EPM money velocity [1/week]
$\boldsymbol{v_{F,@}}$	Firms EPM money velocity [1/week]
$\boldsymbol{G_{H,@}}$	Government EPM wages and pensions [@/week]
$\boldsymbol{G_{F,@}}$	Government EPM payments to suppliers [@/week]
$\boldsymbol{T_{H,@}}$	EPM tax flow out of the household sector [@/week]
$\boldsymbol{T_{F,@}}$	EPM tax flow out of the firm sector [@/week]
$\boldsymbol{Y_{d,@}}$	EPM aggregate demand [@/week]
$\boldsymbol{Y_{o,@}}$	EPM aggregate output [@/week]
$\boldsymbol{\beta_{@}}$	Workers share of the EPM firm sector output []
$\boldsymbol{W_{@}}$	EPM wages [@/week]
$\boldsymbol{C_{@}}$	EPM consumption [@/week]
$\boldsymbol{I_{@}}$	EPM investment [@/week]

Table 4.5: Model entities overview part 3: EPM circuit model entities. All variables are time dependant such that $M_{H,@}$ is $M_{H,@}(t)$ and so forth.

$\boldsymbol{trust}$	General trust in the EPM []
$\boldsymbol{need}$	The need for more economic activity []
$\boldsymbol{PHF}$	Pressure from the household sector on the firm sector to accept payments in EPM []
$\boldsymbol{u}$	Unemployment rate []
$\boldsymbol{conf_G}$	General trust in the government []
$\boldsymbol{conf_{EUi}}$	General trust in the EU institutions []
$\boldsymbol{CP}$	Counterpressure in media from nonpolitical sources []
$\boldsymbol{DIG}$	Demand of imported goods []
$\boldsymbol{w_@}$	Share of wages payed in EPM in the private market
$\boldsymbol{\delta_H}$	Ratio between government wages and pensions in EPM and in euro []
$\boldsymbol{\delta_F}$	Ratio between government payments to suppliers in EPM and in euro []
$\boldsymbol{\gamma}$	Ration between total government spending in EPM and in euro []
$\boldsymbol{L_H}$	Time lag in the household sector due to practicalities [week]
$\boldsymbol{L_F}$	Time lag in the firm sector due to practicalities [week]
$\boldsymbol{D_C}$	Time delay between $C_@$ and $trust$ [1/week]
$\boldsymbol{D_{MF}}$	Time delay between $M_{H,@}$ and PHF [1/week]
$\boldsymbol{D_{MH}}$	Time delay between $M_{F,@}$ and $w_@$ [1/week]
$\boldsymbol{D_{GF}}$	Time delay between $G_{F,@}$ and $w_@$ [1/week]

Table 4.6: Model entities overview part 3.

Chapter 5

Simulation

In this chapter the model from Chapter 4 is used to study the dynamics of the EPM proposal. A simulation environment based on data from Italy is presented in Section 5.1. Section 5.2 study different taxation strategies. The focus of Section 5.3 and Section 5.4 is the dynamics of $trust$ and $need$. The final section looks at effects of different time lags in the firm sector.

5.1 Simulation Setup

In order to study the dynamics of the EPM introduction process, the model from Chapter 4 is implemented in Matlab and Simulink (see Appendix C). The simulation environment is designed to represent EPM introduction in Italy. Parameters and model functions are based on data from Italy (see Appendix A), but are not intended to give an accurate description of the Italian economy or how to introduce the EPM. The goal is rather to study some of the concepts relevant to an introduction process of a parallel currency. The use of data from Italy aim to demonstrate how the dynamics relates to a real world economy were discussions of a parallel currency is relevant.

This section presents settings and variables chosen for the simulations presented in this Chapter. Changes to the setup will be addressed for the specific section. The model includes the dynamics of the introduction process only. For these simulations the process is defined to last for 50 weeks. Included in this period is a slow response from the firm sector.

5.1.1 The Euro Circuit

The euro circuit is implemented as in Figure 4.4. For this simulation euros will circulate as constant flows, without inflation. With time unit $week$, the aggregate demand, $Y_{d,€}$, is sat to the weekly averaged GDP for Italy in 2019. From Appendix A.3 we get an approximate weekly flow $Y_{d,€} = 35.5$ billion €/$week$.

The following values are also based on the data in Appendix A. $G_{H,€}$ is sat to 30% of GDP, $G_{F,€}$ to 19%, $C_€$ to 60%, net exports $NX_€$ to 3% and investments $I_€$ to 18% of GDP.

The government spending variables, $G_{H,€}$ and $G_{F,€}$, are included as constant inflows. The total outflow of taxes are sat in order to obtain a constant euro flow. In Appendix A.2 we can see that the tax flow in reality is smaller. Figure A.1 shows the different sources of tax streams. The household tax flow is chosen significantly higher than the firm tax flow. Other than that, the simulation tax flows are not coinciding with the numbers in Figure A.1. Tax rates and the investment rate are chosen as follows: $\alpha_{H,€} = 0.4157$, $\alpha_{F,€} = 0.0929$ and $\beta_€ = 0.198$.

$v_{H,€}$ and $v_{F,€}$ are chosen respectively $\frac{1}{2}[\frac{1}{week}]$ and $\frac{1}{20}[\frac{1}{week}]$. Simulation time $t = 0$ will be chosen such that the euro flows have reached constant values. The result is a euro circuit of constant flows. Figure 5.1 shows the resulting flows $Y_{d,€}$, $T_{H,€}$ and $T_{F,€}$.

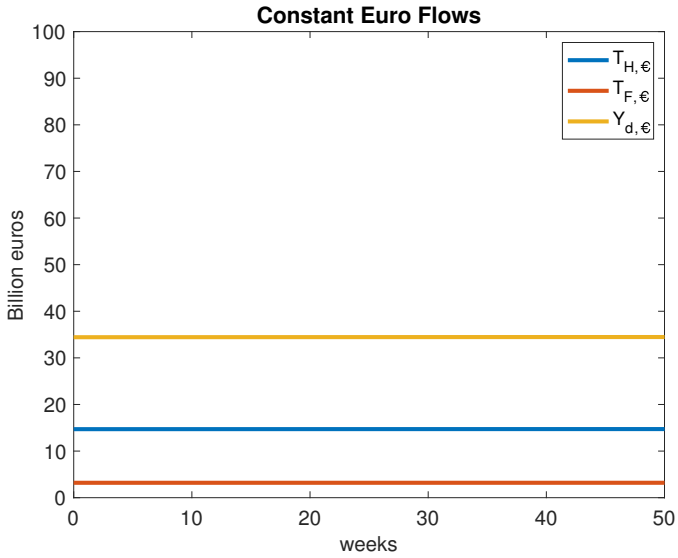


Figure 5.1: Demonstration of constant flows in the euro circuit, here for $Y_{d,€}$ (upper), $T_{H,€}$ (middle) and $T_{F,€}$ (lower).

5.1.2 Taxation Strategies

Two different taxation strategies, assigned to Scenario A and Scenario B, were presented in Section 4.2.2. Section 5.2.1 presents a simulation of Scenario A. For all other simulations in this chapter the chosen strategy is the one belonging to Scenario B. From Equation 4.5 and Equation 4.6 of Scenario B we find the associated tax flows out of the EPM household sector and the EPM firm sector.

$$
\begin{aligned}
T_{H,€} &= \frac{T_{H€,0}}{1+\delta_H} \\
T_{F,€} &= \frac{T_{F€,0}}{1+\delta_F} \\
T_{H,@} &= T_{H,€,0} - T_{H,€} \\
T_{F,@} &= T_{F,€,0} - T_{F,€}
\end{aligned}
\tag{5.1}
$$

The result is a drop in the euro tax flows, as can be seen in figure 5.2, and increasing aggregate demand $Y_{d,€}$.

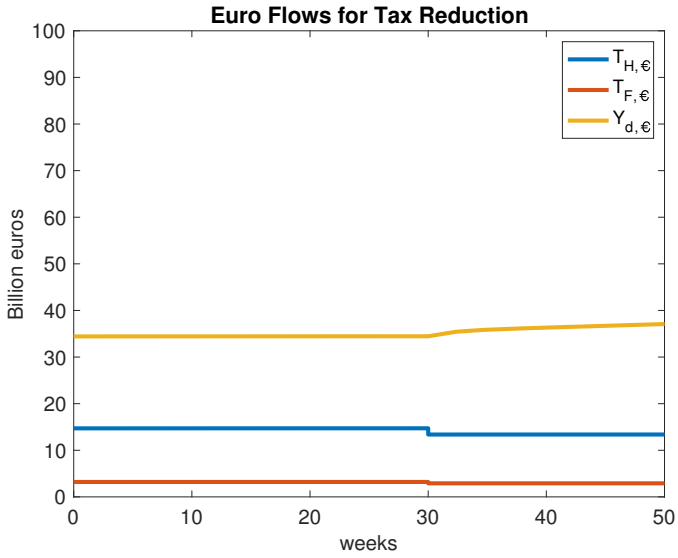


Figure 5.2: Demonstration of a drop in the constant tax flows in the euro circuit, $T_{H,€}$ (middle) and $T_{F,€}$ (lower). $Y_{d,€}$ (upper) increasing as a result.

5.1.3 The EPM Circuit

The EPM circuit is implemented as by the block diagram representations in Chapter 4. Relationships between the behaviour variables are chosen as rough approximates, and limits are chosen in correspondence with suggestions in Section 4.3. The functions are presented in Appendix B.

The $trust$ variable is found by weighting the EPM consumption flow, $C_{@}$, to be almost twice as important as the other variables. $w_{@}(G_{F,@})$ are weighted equally important as $w_{@}(M_{F,@})$. $w_{@}$ is a result of multiplying and scaling the affecting variables, not by the average value. The upper limit for the money velocities $v_{H,@}$ and $v_{F,@}$ are chosen equal to $v_{H,€}$ and $v_{F,€}$.

The first order time lags, D_C, D_{MH}, D_{MF} and D_{GF}, are chosen such that the firm sector is responding slowly to the EPM government inflow, and even slower to a growing

EPM money stock. The initial EPM governemt spending flows are decided by δ_H and δ_F, which both are set to 0.1. The initial EPM money stocks are empty. The model parameters are chosen as follows

$$
\begin{aligned}
NX_{@} &= 0 \\
\beta_{@} &= 0.2 \\
L_H &= 4 \\
L_F &= 10 \\
\delta_H &= 0.1 \\
\delta_F &= 0.1 \\
u &= 0.1 \\
CP &= 0.7 \\
DIG &= 0.9 \\
D_C &= \frac{1}{10s+1} \\
D_{MH} &= \frac{1}{4s+1} \\
D_{MF} &= \frac{1}{30s+1} \\
D_{GF} &= \frac{1}{20s+1}
\end{aligned}
$$

The exogenous variables u, CP and DIG are implemented as constant values. As a result the variables $need$, $conf_G$ and $conf_{EUi}$ will also remain constant in the simulations. $need(u)$ is chosen such that $need = 0.5$ for the constant unemployment rate $u = 0.1$. Confidence in both the national government and the EU is varying significantly (see Figure A.4 and Figure A.5). The potential effects of the fluctuations will not be studied in this thesis, but the simulation environment has pessimistically chosen little trust in the national government. The relationships between the unemployment rate and the two confidences are decided such that for $u = 0.1$ we have $conf_G = 0.1295$ and $conf_{EUi} = 0.35$. See Appendix B for function descriptions.

5.2 Timing the EPM Tax Outflow

In addition to having the honor of driving the money flow, taxes are money flowing out of the system. Since there are no EPMs in the economy at $t = 0$, there will be no time for development if taxes are collected immediately. The first simulation demonstrates this, by setting a tax delay equal to 0 weeks. The results can be seen in Figure 5.3. Figure 5.3 (a) shows an $Y_{d,@}$ flow close to zero, and no growth. The taxes are emptying the EPM circuit immediately. Even with some $trust$ and pressure PHF, the EPM will have no time to grow.

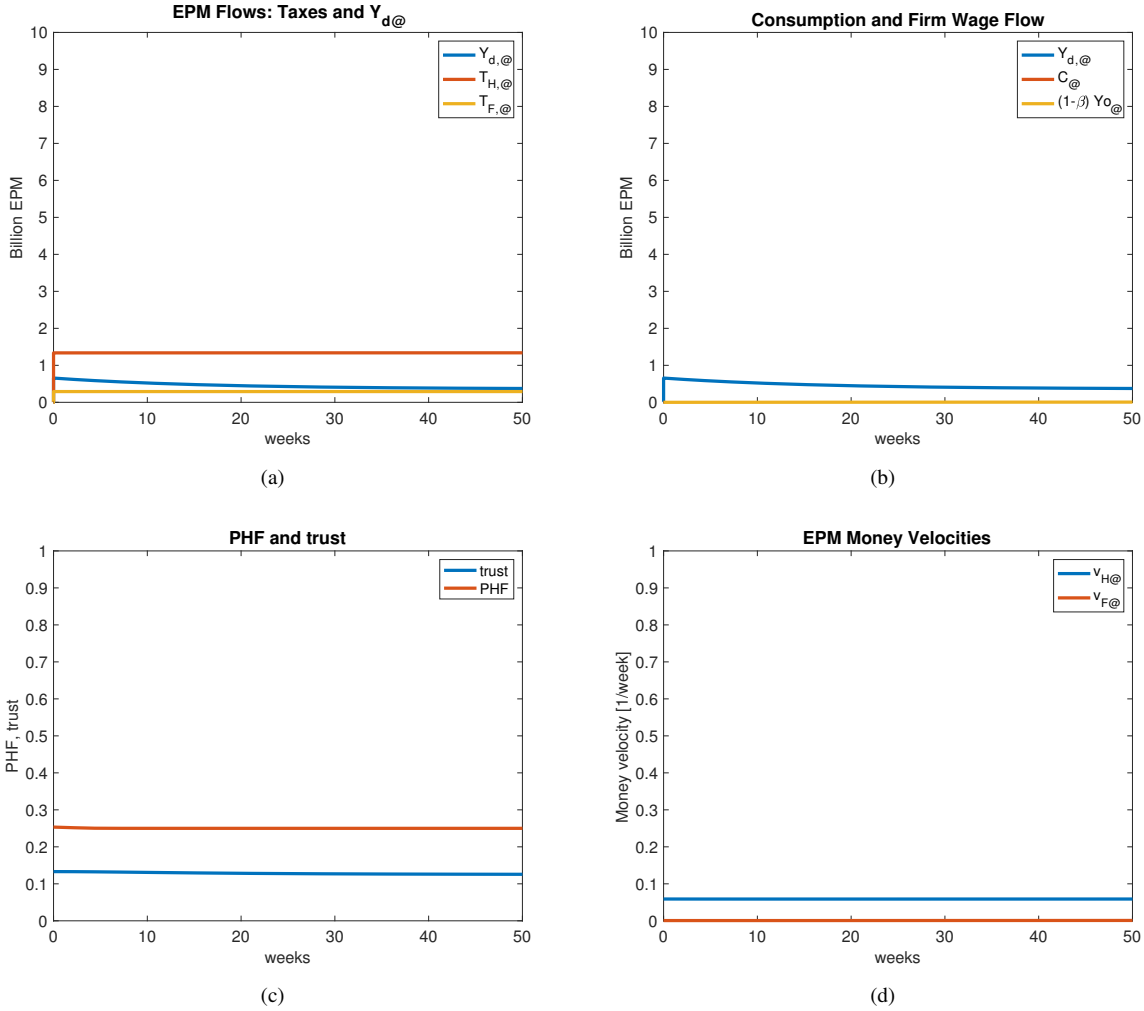
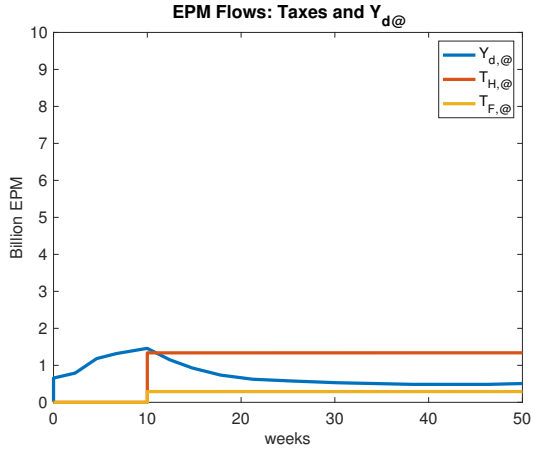
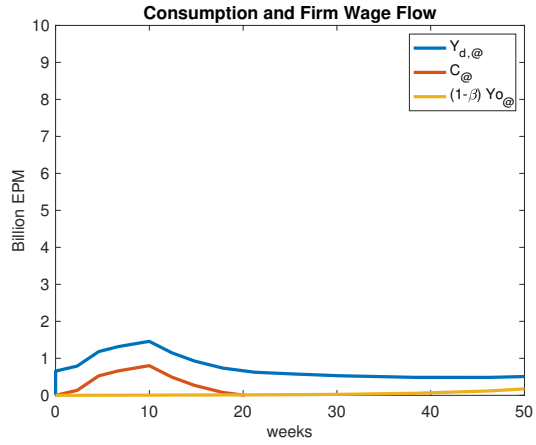


Figure 5.3: Plots from a simulation of a tax delay of 0 weeks.
(a) $T_{H,@}$ (upper), $T_{F,@}$ (lower) and $Y_{d,@}$ (middle).
(b) No significant outflows from the household sector nor the firm sector.
(c) Constant values for PHF (upper) and $trust$ (lower).
(d) Money velocities $v_{H,@}$ (upper) and $v_{F,@}$ (lower).

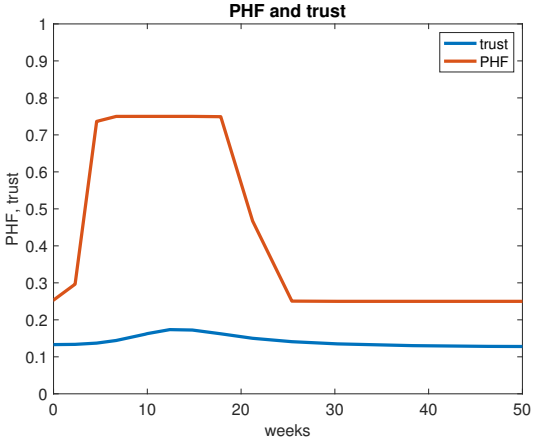
In Figure 5.4 the tax delay is increased to 10 weeks. The pressure PHF in Figure 5.4 (c) increases quickly as the household money stock, $M_{H,@}$ fills up. The $trust$ does not increase much before taxation starts, and the pressure PHF falls. The money velocity firm sector, $v_{F,@}$, stays at zero until about week 49, and the household money velocity, $v_{H,@}$, remains low and constant after the drop in PHF. The result is an increased consumption flow, $C_@$, before taxation, whivh then falls and remains low.



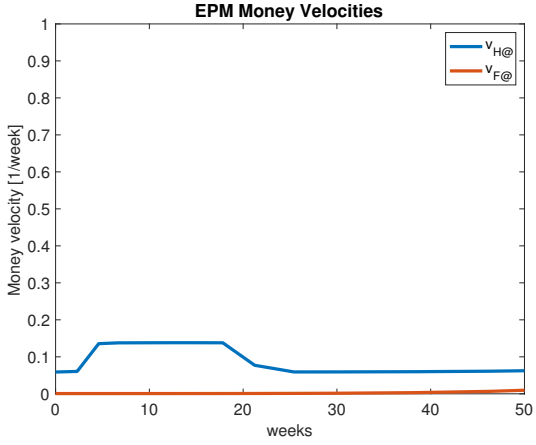
(a)



(b)



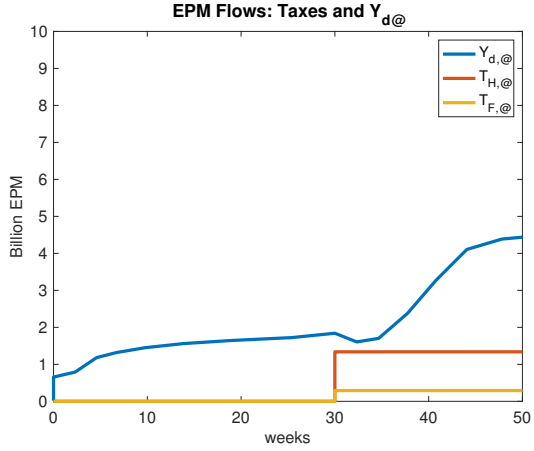
(c)



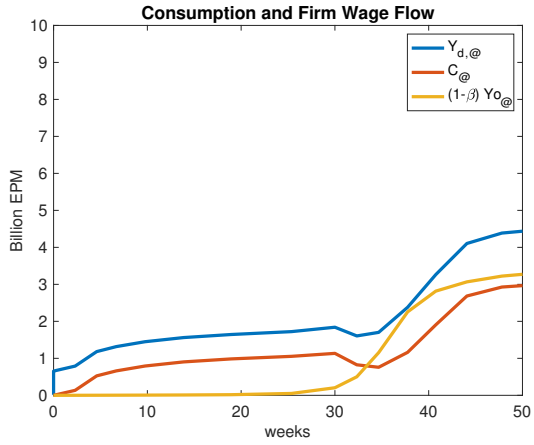
(d)

Figure 5.4: A tax delay of 10 weeks.
(a) $T_{H,@}$ (upper at $t = 20$), $T_{F,@}$ (lower) and $Y_{d,@}$ (middle at $t = 20$).
(b) $Y_{d,@}$ (upper), $C_@$ (middle) and $(1 - \beta)Y_{o,@}$ (lower).
(c) PHF (upper) and $trust$ (lower).
(d) Money velocities $v_{H,@}$ (upper) and $v_{F,@}$ (lower).

Plots from a tax delay of 30 weeks can be seen in Figure 5.5. The pressure PHF grows quickly and remains constantly high. The $trust$ grows more slowly and drops with the fall in the consumption flow, $C_@$, after taxation start. After about 30 weeks, the firm sector start spending EPM. The $(1 - \beta)Y_{o,@}$ flow represent the EPM wage flow out of the firm sector. $trust$ increases together with both money velocities, $v_{H,@}$ and $v_{F,@}$. The result is a growing EPM flow. Figure 5.6 shows the same simulation for 100 weeks, where $Y_{d,@}$ can be seen to keep growing at a roughly constant growth rate.



(a)



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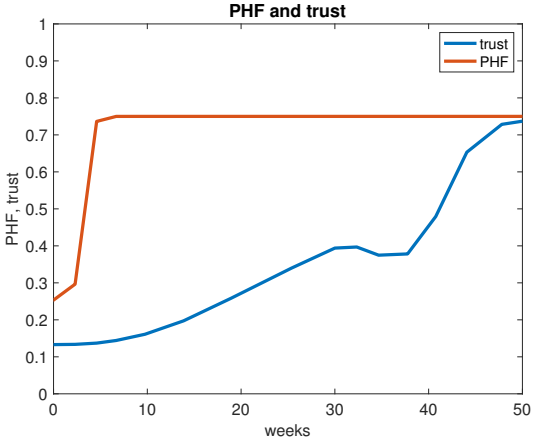

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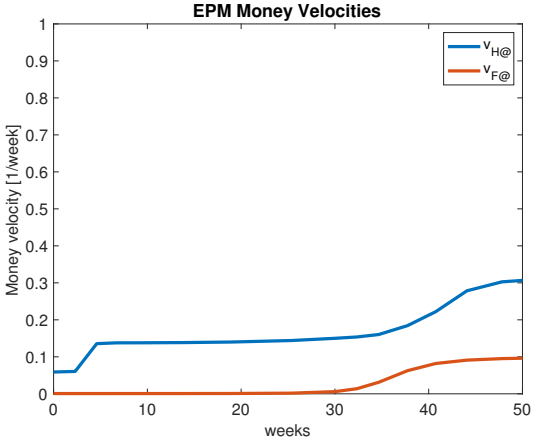


(d)

Figure 5.5: A 30 weeks tax delay.
(a) $Y_{d,@}$ (upper), $T_{H,@}$ (middle) and $T_{F,@}$ (lower).
(b) $Y_{d,@}$ (upper), $C_@$ (middle at $t = 10$) and $(1 - \beta)Y_{o,@}$ (lower at $t = 10$).
(c) PHF (upper) and $trust$ (lower).
(d) Money velocities $v_{H,@}$ (upper) and $v_{F,@}$ (lower).

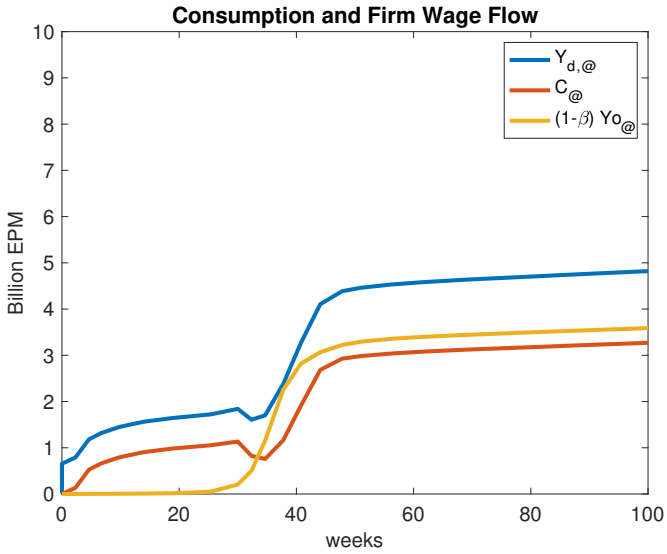


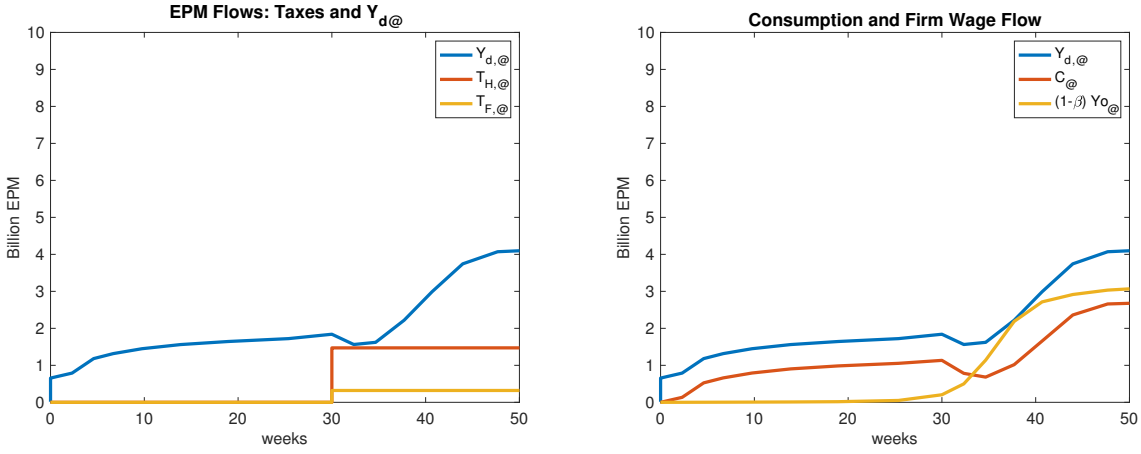
Figure 5.6: A tax delay of 30 weeks with a simulation time of 100 weeks. $Y_{d,@}$ (upper), $C_@$ (middle at $t = 10$) and $(1 - \beta)Y_{o,@}$ (lower at $t = 10$).

5.2.1 Taxation Scenario A

The simulations presented so far have been executed for taxation Scenario B, where some of the euro tax flow is exchanged for an EPM tax flow. Resistance towards euro tax reduction is to be expected. Taxation Scenario A might therefore be an option. The euro flows will remain as in Figure 5.1, and the EPM tax flows can be implemented as in Equation 4.2. For the household sector and the firm sector that is

$$\begin{aligned} T_{H,@} &= \delta_H T_{H,€} \\ T_{F,@} &= \delta_F T_{F,€} \end{aligned} \tag{5.2}$$

The resulting EPM flows can be seen in Figure 5.7. The tax flows increases, compared to Scenario B (see Figure 5.5). A result of this is reduced growth rates of the EPM flows. Nevertheless, the dynamics are very similar to the dynamics of Scenario B.



(a) (b)

Figure 5.7: Taxation Scenario A.
(a) $Y_{d,@}$ (upper), $T_{H,@}$ (middle) and $T_{F,@}$ (lower).
(b) $Y_{d,@}$ (upper), $C_@$ (middle at $t = 10$) and $(1 - \beta)Y_{o,@}$ (lower at $t = 10$).

5.3 Trusting the New Currency

The $trust$ variable is dependant on confidence in the government, confidence in the EU institutions and counterpressure in media, which are all hard to predict. How much each of these impact the $trust$ in the EPM is also uncertain. In the simulations so far, the EPM consumption flow, $C_@$, has been weighted to have a significantly higher impact on $trust$ than the other entities. The reason for this is the assumption that observing the EPM i usable has a higher impact on $trust$ than attitudes. In the following simulation the effects of the the factors of $trust$ will be weighted equally.

Figure 5.8 shows EPM flows with a 30 weeks tax delay. The results are similar to the previous simulation for a 30 week tax delay with $C_@$ weighted to be more important than the other factors. The difference is clearer in Figure 5.9 where $trust$ is lower, and growing slower. This leads to a lower money velocity for the household sector, $v_{H,@}$, and also a slight decrease in the money velocity for the firm sector, $v_{F,@}$. The pressure is, however, still high, which assures consumption and a EPM wage share growth to almost the same extent.

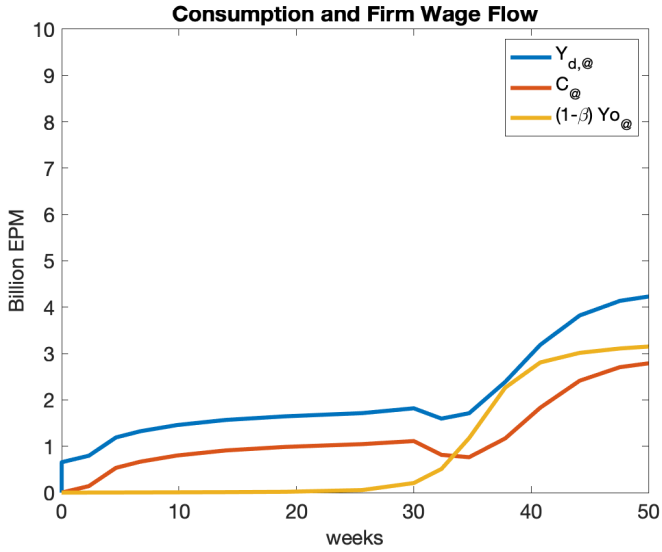
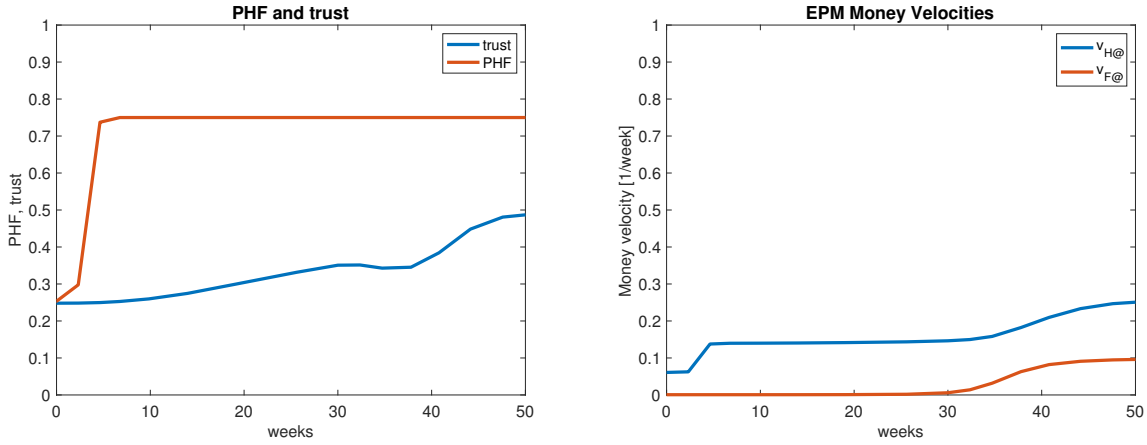


Figure 5.8: $Y_{d,@}$ (upper), $C_@$ (middle at $t = 10$) and $(1 - \beta)Y_{o,@}$ (lower at $t = 10$).



(a) (b)

Figure 5.9: (a) Slower $trust$ growth.
(b) $v_{H,@}$ (upper) and $v_{F,@}$ (lower).

5.4 The Need of Economic Circulation

An assumption made for the simulations is a significant need for more circulation in the Italian economy. Figure 5.8 and Figure 5.9 shows the result of a simulation with a lower $need$. The trust is the same as for the simulation in Section 5.3, as well as the rest of the simultion environment. $need$ is reduced from 0.5 to 0.125.

The simulation shows that the EPM proposal might also work for a slow growth in $trust$ combined with low $need$. There are several reasons for this. Figure 5.9 shows a relatively high pressure PHF even though the $need$ is low. This is caused by a growing household money stock, $M_{H,@}$. Whether this is realistic or not is a topic briefly visited in Chapter 6. The relatively high pressure PHF contributes to the consumption flow $C_@$. After taxation in week 30, the consumption drops. Firms have by then started spending EPM, and contributes to money circulation. $trust$ increases, and so does the EPM flows $C_@$ and $Y_{d,@}$.

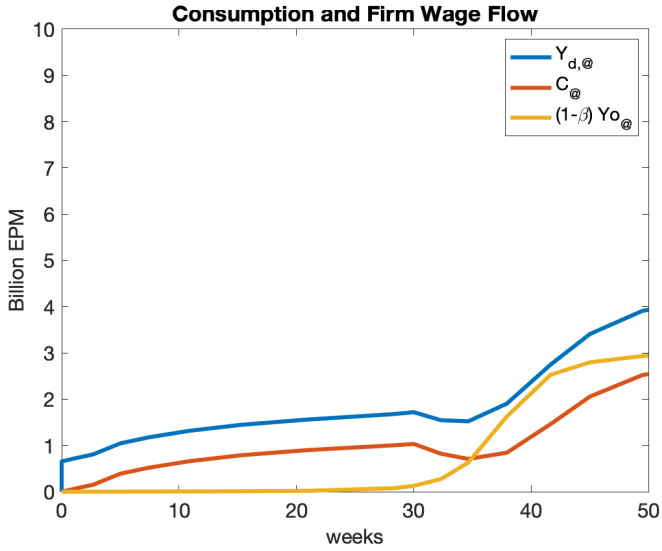
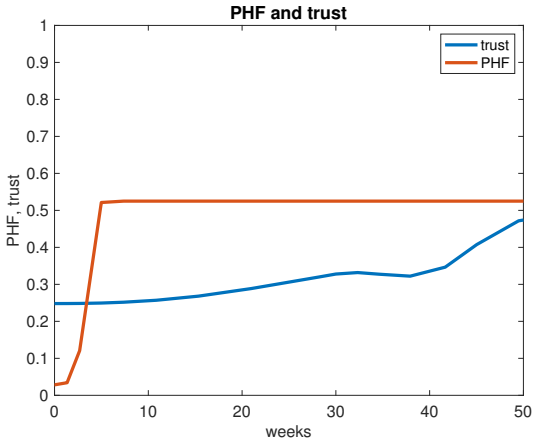
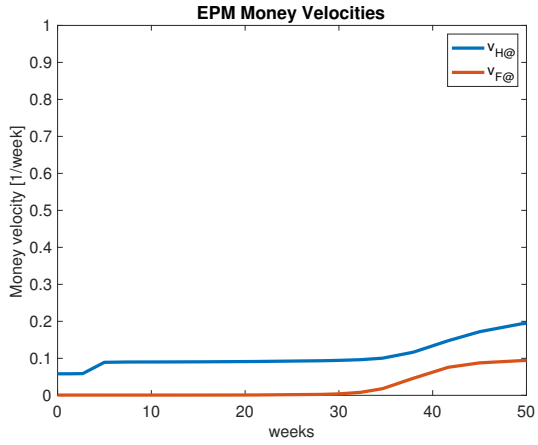


Figure 5.10: $Y_{d,@}$ (upper), $C_@$ (middle at $t = 10$) and $(1 - \beta)Y_{o,@}$ (lower at $t = 10$).



(a)



(b)

Figure 5.11: (a) $trust$ (upper at $t = 0$) and PHF (lower at $t = 0$).
(b) $v_{H,@}$ (upper) and $v_{F,@}$ (lower).

5.5 Mixed Wages in the Private Sector

The time lags of the firm sector are chosen with the assumption of slow response. It will take time for businesses to pay mixed wages, and for businesses to trade in mixed payments among themselves. There are two forces pushing for acceptance of the EPM in the firm sector. The first being the household sector wanting a way of spending the EPM. The other being the government pushing businesses to accept mixed payment. The firm sector now has a growing money stock and a serious signal from the government that the EPM will be a part of the economy. The firm sector response time might therefore not be as slow as assumed in the previous simulations.

Figure 5.12 and Figure 5.13 shows why this is important. The first plot shows the private sector wage share $w_@$ for the simulation environment of Section 5.2. The tax delay is 30 weeks (see Figure 5.5), and the wage share time lags are $D_{MF} = \frac{1}{30s+1}$ and $D_{GF} = \frac{1}{20s+1}$. In the second Figure the time lags are reduced to $D_{MF} = \frac{1}{10s+1}$ and $D_{GF} = \frac{1}{4s+1}$. As one might expect, the wage share $w_@$ starts growing earlier in the second simulation.

Figure 5.14 shows the effects on the EPM flows. Compared with the results in Figure 5.5, the EPM grows faster. By week 40 the $Y_{d,@}$ has reached the same level as for week 50 in the first simulation. When the firm sector starts paying mixed wages earlier, the wage flow out of the firm sector $(1-\beta)Y_{o,@}$ grows earlier, affecting both the consumption flow, $C_@$, and the $Y_{d,@}$ flow.

There are two main conclusion to draw from these observations. The response time of the firm sector should be considered when planning the length of the introduction process. Similarly, the firm sector response is relevant to finding an appropriate taxation delay.

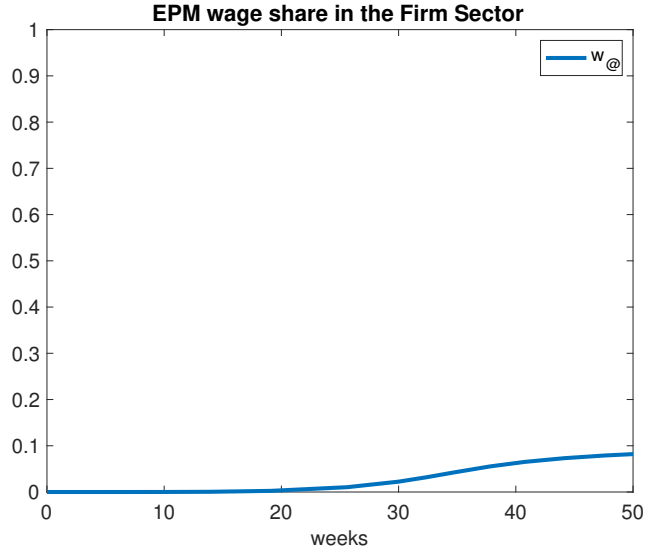


Figure 5.12: $w_{@}$ for firm sector time lags $D_{MF} = \frac{1}{30s+1}$ and $D_{GF} = \frac{1}{20s+1}$.

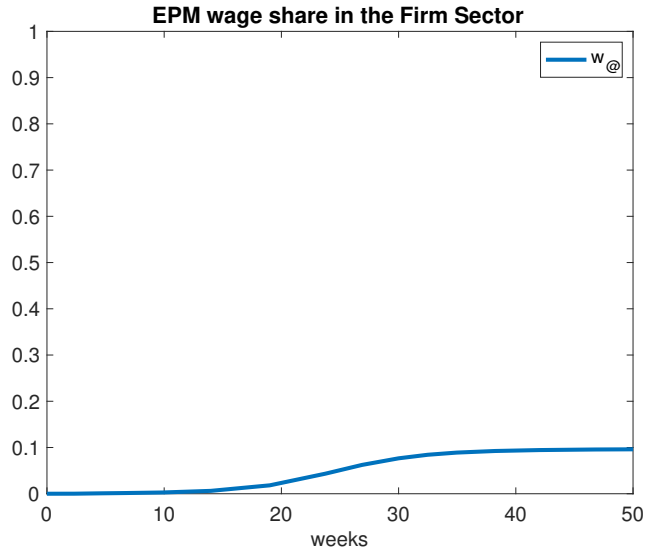


Figure 5.13: $w_{@}$ for firm sector time lags of $D_{MF} = \frac{1}{10s+1}$ and $D_{GF} = \frac{1}{4s+1}$.

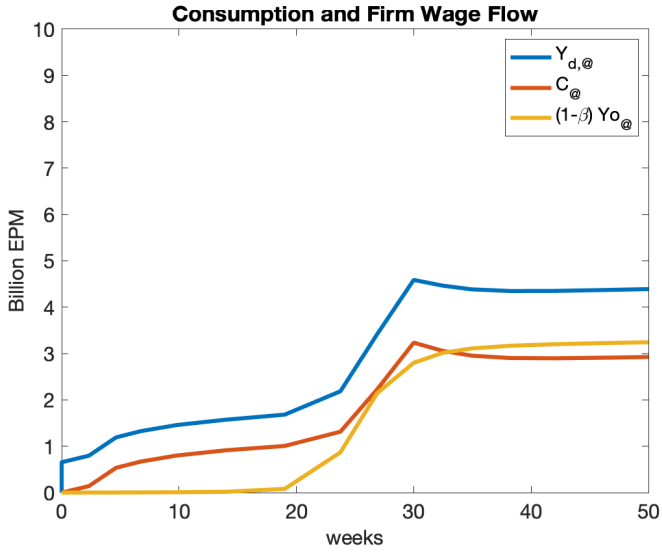


Figure 5.14: EPM flows $Y_{d,@}$ (upper), $C_@$ (middle at $t = 10$) and $(1 - \beta(Y_{o,@}$ (lower at $t = 10$) for firm sector time lags of $D_{MF} = \frac{1}{10s+1}$ and $D_{GF} = \frac{1}{4s+1}$.

Chapter 6

Discussion

6.1 Taxation

The simulations presented in Section 5.2 demonstrates the effects of letting the EPM grow several weeks before starting the tax flows. The implemented model functions are rough drafts of reality, and the simulations can not give any exact knowledge of the ideal tax delay. The simulations still presents some valuable observations regarding the tax delay.

The simulation of a 10 week tax delay (see Figure 5.4) shows an increasing consumption flow, $C_{@}$, before taxation starts. High pressure from the household sector on the firm sector, PHF, drives the money, while $trust$ remains low. The firm sector does not have the time to start spending EPM. When taxation starts the household money stock is reduced, and so is the pressure PHF. Consumption in mixed payments does not last long enough for $trust$ to increase significantly. The result is reduced EPM consumption until it dies out.

With a taxation delay of 30 weeks the simulation shows that $trust$ grows with an increasing consumption flow $C_{@}$. The combination of a higher $trust$ and a growing EPM wage share in the private sector, $w_{@}$, (see Figure 5.12), ensures EPM circulation after taxation as well. The pressure PHF does not drop when taxation start as a result of a greater household money stock.

There are two contributions to draw from this. Filling up the money stocks before taxation start will maintain a high pressure and encourage businesses to spend the EPM. The other contribution is the importance of studying the time lags. A deeper understanding of the real world time lags can help decide on a good taxation timing. That is both for the relationship between EPM consumption, $C_{@}$, and $trust$, and for the time lags of the firm sector.

The time lags chosen for the simulation environment are assuming a slow firm sector. Changing the wage mix might takes time, but it also might not. From the consideration of this second alternative in Section 5.5, it is clear that the response time of the firm sector should be relevant for the tax delay. If the EPM wage share in the private sector, $w_{@}$, is introduced at a earlier stage, the EPM flow $Y_{d,@}$ will grow faster.

Section 5.2 also showed that both taxation strategies from Section 4.2.2 can work. Comparing the simulations should not be done too gravely, however. The reason being that the different responses to the two scenarios are not included in the model. Scenario B represents the case where an EPM tax flow replace some of the euro tax. This might lead to more resistance from the EU institutions and EU supporters, and increase a feeling of insecurity about the economic situation. At the same time, exchanging some of the tax obligations in euros for EPM is presumably attractive among the public. In taxation Scenario A the euro tax remains as before the EPM, and EPM tax claims are added on top. The EPM might not be as attractive as in Scenario B. A total tax obligation in EPM on top of euro tax obligations is probably not encouraging the same way a euro tax cut is.

If the EPM is to be introduced it is not necessary to know the exact dynamics beforehand. The simulations shows that the exact behaviour is hard to predict. At the same time, they demonstrate the concepts and that different scenarios can be studied in simulations. Doing this simultaneously with the implementation, makes it possible to make suitable changes to the different situations that might occur along the way.

6.2 Italian Trust in the EPM

The political situation in Italy is complex and fluctuating. Confidence in the national government is low, which can make it difficult to get the public to trust a new currency introduced by the same government. At the same time, enforced austerity and other structural adjustments by the EU institutions have reduced confidence in the EU.

It is hard to predict how confidence in institutions will affect the trust in the EPM, but the public observing a possibility of mixed payments might be more important. If the EPM can be used in payments, the confidence in supporting or counteracting institutions should not matter as much.

A question arising from the simulations in Chapter 5 is how much does the consumption flow $C_@$ matter to the $trust$? The Simulation in Section 5.3 shows that when the household consumption $C_@$ is weighted equal to the other contributing factors, $trust$ grows slower. This observation makes the question relevant to the topic of taxation timing addressed in Section 6.1. If $C_@$ is more important to $trust$ than the other factors, the EPM will grow faster which again will affect the timing of taxation.

Before the EPM is circulation, the other factors will matter. The Simulation in Section 5.3 also shows that, in the case of Italy, the confidence factors and media coverage does contribute to the initial $trust$ level. When $C_@$ is weighted equal to the other factors, the initial $trust$ is even higher. There is no EPM consumption yet and therefore little reason for the public to assume it will work.

The Simulation presented in Section 5.4 studies the effects of reducing the $need$. In Chapter 4 the $need$ entity was discovered to be a model weakness. The economic situation in Italy, and other countries in the euro area, makes it clear that there is a need of economic improvements. Exactly how and what this implies is, however, not clear. The simulation of the a reduced $need$ reflects the model weakness, and introduces an additional simulation weakness. After the drop in $need$, the pressure PHF is still relatively high. To what degree this reflects reality is hard to tell.

One possibility is that growing money stocks are enough for people to pressure businesses to accept mixed payments. It is also possible that a higher $need$ is necessary for the pressure to reach a significant level. A conclusion to draw from here is that the concepts of $need$ and pressure should be considered before introducing the EPM. They are important to the dynamics of the introduction process and relevant when deciding when to start taxation and revel.

The practicality of digital money also deserves a mention here. There will be no paper EPM to mix up with euros in the wallet. It is easy to use, and easy to implement. A low degree of hassle for both the general consumer and businesses can contribute to trusting the currency. Equally important is it that no printed money is a part of making the EPM a legal means of payment.

6.3 Revisiting the Causal Diagram

The simulations have shown how dynamics between behavioural and economic variables are important when deciding on taxation strategies, as well as the length of the introduction process. The block model developed in Chapter 4 started out with outlining the causal diagram. The dynamics simulated in Chapter 5 are all reflected in the causal diagram.

One thing this demonstrates is the importance of the causal diagram development. Both the block model and the simulations contributes to a deeper understanding of practical dynamics. Faults in the causal diagram will be reflected in the model and simulations. The causal diagram is easy to read, which presents opportunities for specialists of different backgrounds to cooperate on the development. This should be considered relevant for a system dependant on social behaviour.

The block diagram and the simulations also discovered model weaknesses pointing back to the causal diagram. The pressure PHF and $need$ should be investigated more thoroughly. It is not clear how they affect each other nor economic behaviour. The model development brought up questions on how to claim taxes in EPM. The causal diagram does not include behavioural responses to different taxation strategies. The money velocities came out as important contributors to the dynamics, and are central in the block model. Including money velocities in the causal diagram would make the relevance clearer.

Chapter 7

Conclusion

This thesis has developed a model of probable dynamics of the introduction process of a parallel electronic currency in a euro crisis country. A causal diagram, based on the EPM proposal, investigated the behavioural mechanisms of an introduction process. The diagram served as a base for developing a continuous time model of the EPM in parallel with the euro. Data from Italy was used to format a simulation environment in order to study the dynamics. The simulations were not intended to predict an exact introduction process in Italy, but they did confirm that the proposal will work. The results from the simulations showed the significance of the behavioural variables in the model.

The project consists of three main contributions. The first is the model which can be used to study the dynamics of an introduction process. The second contribution is an investigation of introducing tax payments in EPM. Simulations demonstrated the importance of not starting taxation right away. The EPM money stocks should grow enough for pressure to build up. If there is enough pressure for businesses to start accepting payments in a mix of EPM and euros, observations of this possibility will increase trust in the new currency. The EPM taxes should be exchanged with euro taxes to a limit matching the rate between government spending in euros and in EPMs. If this is not an option, the EPM tax can also be added on top of the euro tax. The behavioural dynamics connected to this should then be added to the model.

The third main contribution is a presentation of the social dynamics at work. Simulations demonstrated how behavioural variables will determine the development of the EPM. They are therefore necessary to study when planning an introduction process. There are especially two factors that matters when planning the length of the period between EPM injection and taxation start. The first being how quickly the EPM gains trust. The second is how much time it takes for businesses to start paying mixed wages. The same factors also determine the length of the introduction process as a whole.

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Varoufakis, Y., Jun. 2019. Fiscal Money Can Make or Break the Euro | by Yanis Varoufakis. Section: Economics & Finance.
URL https://www.project-syndicate.org/commentary/italy-parallel-payments-system-versus-greece-plan-by-yanis-varoufakis

Appendix A

Data from Italy

This appendix presents economic data from Italy. The data is gather from a number of different sources using different strategies for collection, calculation and presentation. The numbers presented might not correspond precisely with neither each other or the real world situation. The purpose of this appendix is to give approximations of some economic factors in the Italian economy.

A.1 Government Spending

G_1: Social Spending and Compensation of Employees

Government spending on social benefits and compensation of employees, G_1 accounted for 29.9% of the Italian GDP in 2019 (ECB-Statistical-Data-Warehouse, 2020). The same expense averaged at 29.66% of GDP between 2015 and 2019.

G_2: Government spending excluding G_1

Government spending excluding spending on social benefits and compensation of employees, here called G_2, accounted for 18.8% of the Italian GDP in 2019 (ECB-Statistical-Data-Warehouse, 2020). The average between 2015 and 2019 was 19.42% of GDP.

A.2 Government Revenue and Taxation

Tax income and government revenue (as percentage of GDP) for Italy between 2010 and 2019 is presented in Figure A.1 (ECB-Statistical-Data-Warehouse, 2020).

1. General government - revenue

	Total	Current revenue										Capital revenue		Memo: Fiscal burden
			Direct taxes	Indirect taxes	Taxes on products	VAT	Other taxes on production	Net social contributions	Employers [1]	Households [1]	Sales		Capital taxes	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2010	45.7	45.3	14.1	13.8	10.9	6.0	2.9	13.3	9.0	4.1	2.2	0.4	0.2	41.4
2011	45.6	44.9	13.8	14.0	11.1	6.0	2.9	13.1	8.8	4.0	2.3	0.6	0.4	41.3
2012	47.6	47.3	14.8	15.1	11.3	5.9	3.8	13.3	8.8	4.2	2.3	0.3	0.1	43.3
2013	48.1	47.5	14.9	14.8	11.2	5.8	3.6	13.4	8.8	4.3	2.5	0.6	0.3	43.4
2014	47.9	47.5	14.6	15.2	11.5	5.9	3.7	13.2	8.7	4.2	2.5	0.4	0.1	43.1
2015	47.8	47.2	14.7	14.9	11.4	6.1	3.5	13.2	8.7	4.3	2.5	0.6	0.1	42.9
2016	46.7	46.3	14.6	14.3	11.6	6.0	2.7	13.0	8.5	4.3	2.5	0.4	0.3	42.2
2017	46.3	45.9	14.4	14.3	11.5	6.2	2.8	13.0	8.5	4.3	2.5	0.4	0.1	41.8
2018	46.2	46.0	14.0	14.4	11.4	6.2	2.9	13.2	8.7	4.3	2.5	0.2	0.1	41.7
2019	47.0	46.8	14.4	14.4	11.5	6.2	2.9	13.5	8.9	4.4	2.5	0.2	0.1	42.4

Source: ESCB.
1) Data refer to actual social contributions.

Figure A.1: Government revenue as percentage of GDP for Italy (ECB-Statistical-Data-Warehouse, 2020)

A.3 GDP

Quarterly GDP for Italy can be seen in Figure A.2. Total GDP for 2019 was approximately 1795 billion € (TheGlobalEconomy.com, 2020b).

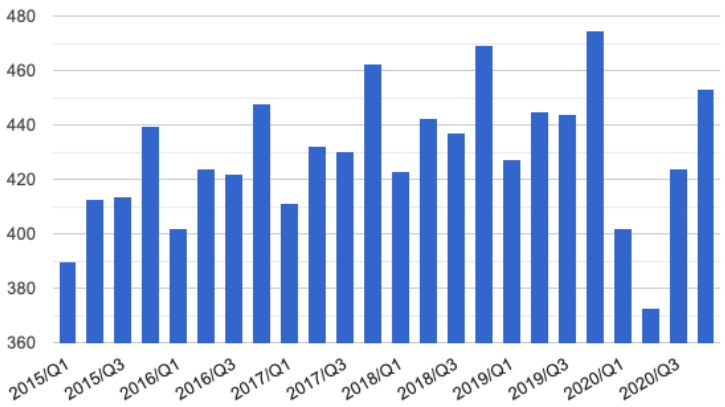


Figure A.2: Quarterly GDP [billion euro] for Italy from 2015 to 2020 (TheGlobalEconomy.com, 2020a)

A.4 Household Consumption

Household consumption accounted for 60.4% of GDP in Italy in 2019 (TheGlobalEconomy.com, 2019b).

A.5 Capital Investments

In 2019 capital investments made up 18.08% of GDP in 2019 (TheGlobalEconomy.com, 2019a).

A.6 Net Exports

Net exports accounted for 3.05% of GDP in Italy 2019 (TheGlobalEconomy.com, 2019c).

A.7 Unemployment

Figure A.3 shows the unemployment rate in Italy between 2015 and 2020 (TheGlobalEconomy.com, 2020b). In 2019 the average rate was 9.96%.

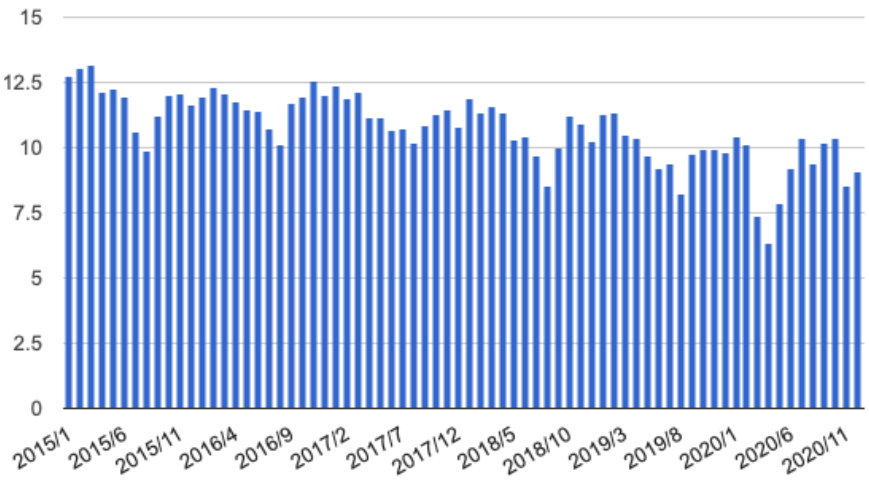
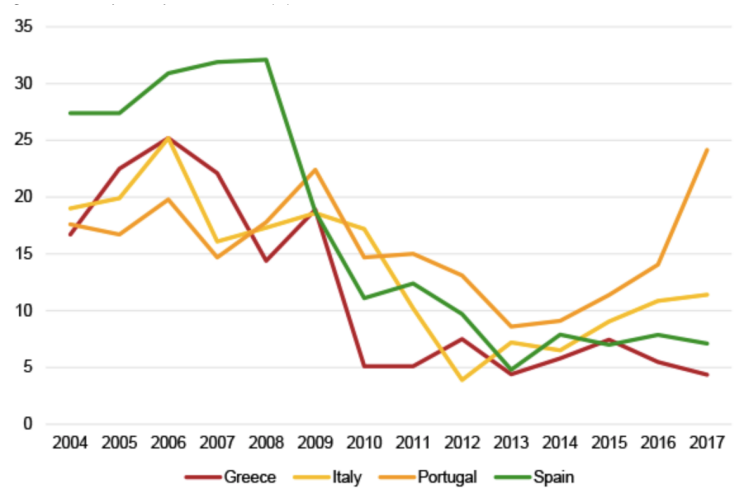


Figure A.3: Unemployment rate in Italy between 2015 and 2020 (TheGlobalEconomy.com, 2020b).

A.8 Trust in Political Institutions

Figure A.4 shows the trust in political parties in Italy, Greece, Spain and Portugal between 2004 and 2017 (Toygür, 2018). Trust in the EU in the same countries can be seen in Figure A.5.



Source: the author, based on Eurobarometer public opinion surveys.

Figure A.4: Trust in political parties in Greece, Italy, Spain and Portugal between 2004 and 2017 (Toygür, 2018).

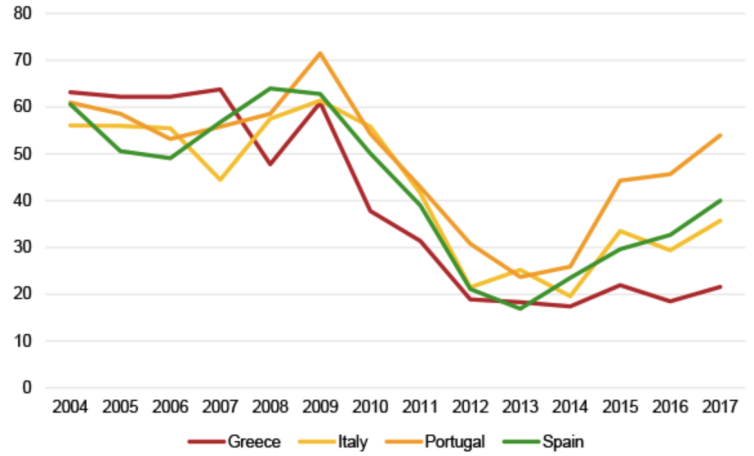


Figure A.5: Trust in EU in Greece, Italy, Spain and Portugal between 2004 and 2017 (Toygür, 2018).

Appendix B

Behavioural Functions

This Appendix presents specified functions used for simulations in Chapter 5.

$$
\begin{aligned}
D_C &= \frac{1}{10s+1} \\
D_{MH} &= \frac{1}{4s+1} \\
D_{MF} &= \frac{1}{30s+1} \\
D_{GF} &= \frac{1}{20s+1} \\
conf_G(u) &= 0.02 + \frac{0.29}{1+e^{25((x-0.08)}} \\
conf_{EUi}(u) &= 0.15 + \frac{0.4}{1+e^{30(x-0.1)}} \\
trust(conf_G) &= \frac{1}{1+e^{-12(x-0.4)}} \\
trust(conf_{EUi}) &= \frac{1}{1+e^{10(x-0.5)}} \\
trust(CP) &= \frac{1}{1+e^{-10(x-0.5)}} \\
trust(C_{@}) &= D_C * \frac{1}{1+e^{-4(x-0.5))}}
\end{aligned}
$$

$$
\begin{aligned}
need(u) &= \frac{1}{1+e^{-30(x-0.1)}} \\
PHF(need) &= need \\
PHF(M_{@}) &= D_{MH} * \frac{1}{1+e^{-5(x-1)}} \\
w_{@} &= D_{MF} * \delta_F \frac{-0.0008162555}{1+e^{-0.2(x-20)}} \\
w_{@} &= G_F * \delta_F \frac{1}{1+e^{-20(x-0.4)}} \\
v_{H,@}(DIG) &= \frac{v_{H,€}}{1+e^{10(x-0.6)}} \\
v_{H,@}(L_H) &= \frac{1}{L_H} \\
v_{H,@}(PHF) &= \frac{v_{H,€}}{1+e^{-10(x-0.6)}} \\
v_{H,@}(trust) &= \frac{v_{H,€}}{1+e^{-10(x-0.6)}} \\
v_{H,@}(w_{@}) &= \frac{v_{H,€}}{1+e^{-1000\delta_F(x-0.6\delta_F)}} \\
v_{F,@}(L_F) &= \frac{1}{L_F} \\
v_{F,@}(w_{@}) &= \frac{v_{F,€}}{1+e^{-1000\delta_F(x-0.5\delta_F)}}
\end{aligned}
$$

Appendix C

Simulink Implementation

The model from Chapter 4 was implemented in Simulink, with parameters and functions presented in Chapter 5 and Appendix B. This Appendix presents a Matlab script for setting up the model parameters, and figures giving an overview of the Simulink implementation.

C.1 System Parameters in Matlab

```
%% Model Parameters
% Simulations of an Electronic Parallel Currency
% Thea Allum Granbakken
% March 2021

% A Delay for Setting up the Euro Loops
euro_delay = 300;

% --- Euro Circuit ---
% Net exports in euros
NX = 1.035;
% Government speding in euros
G_H_euro = 10.35;
G_F_euro = 6.555;
% Euro money velocities
vh_euro = 1/2;
vf_euro = 1/20;
% Tax rates and the investment rate
alpha1 = 0.4157;
alpha2 = 0.0929;
beta_euro = 0.198;

```

```
% --- EPM Circuit ---
% EPM share of government spending
gamma = 0.1;
delta_H = 0.1;
delta_F = 0.1;
% EPM investment rate
beta_epm = 0.2;

% Unemployment rate
u = 0.1;
% Counterpressure
CP = 0.7;
% Demand of imported goods
DIG = 0.9;
% Time lags
LH = 4;
LF = 10;

% Interval between EPM injection and taxation
tax_interval = euro_delay +30;

%% ----- Simulation -----
simulation = sim('EPM_sim')
```

C.2 Figures from Simulink Implementation

C.2.1 Simulink Overview

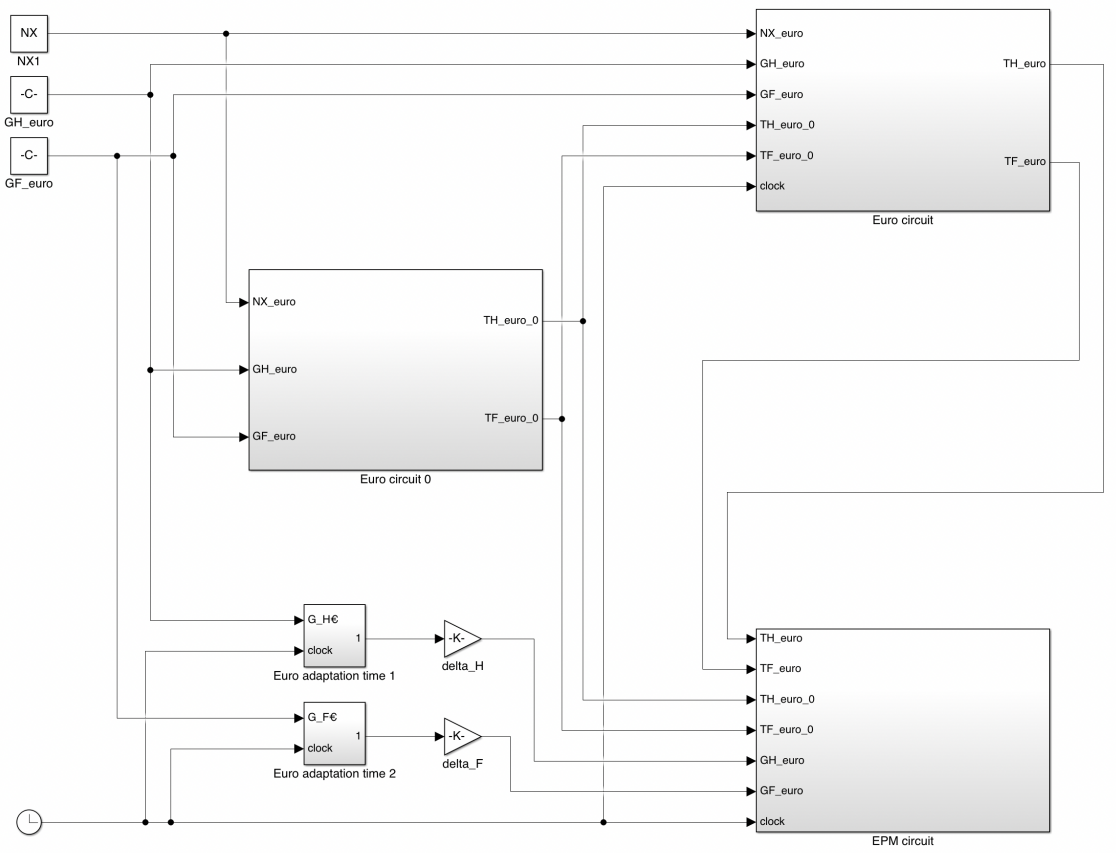


Figure C.1: Euro reference circuit and the EPM circuit in parallel with the euro circuit.

C.2.2 Simulink Euro Circuits

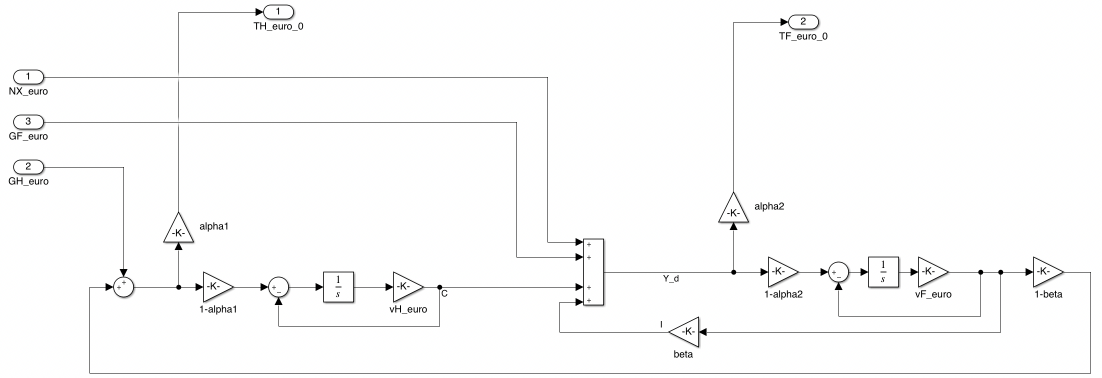


Figure C.2: Euro reference system.

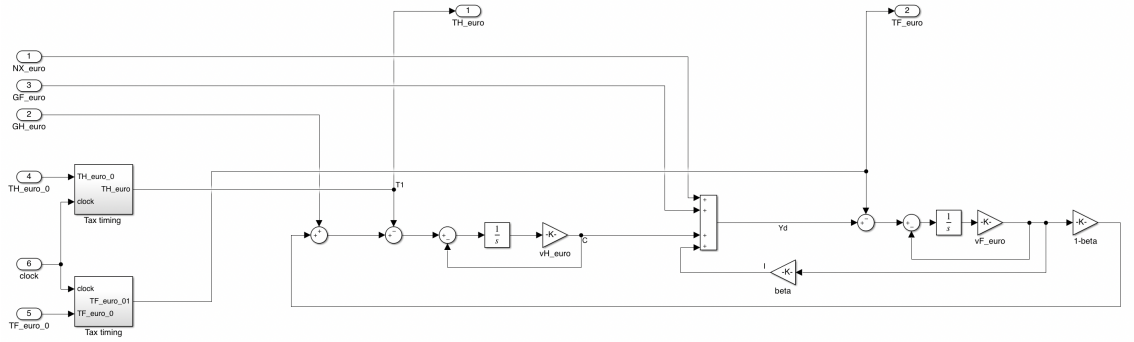


Figure C.3: The euro circuit.

C.2.3 Tax Timing In the Euro Circuit

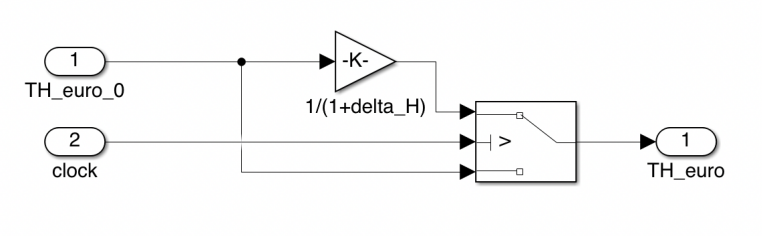


Figure C.4: Household sector euro tax flow in Simulink.

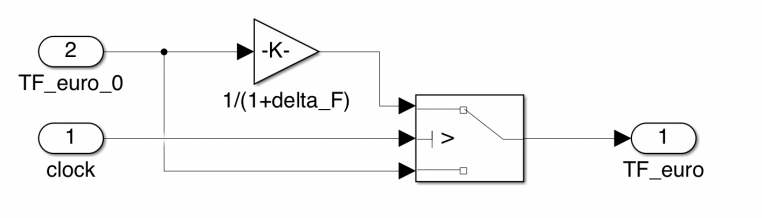


Figure C.5: Firm sector euro tax flow in Simulink.

C.2.4 Simulink EPM Circuit

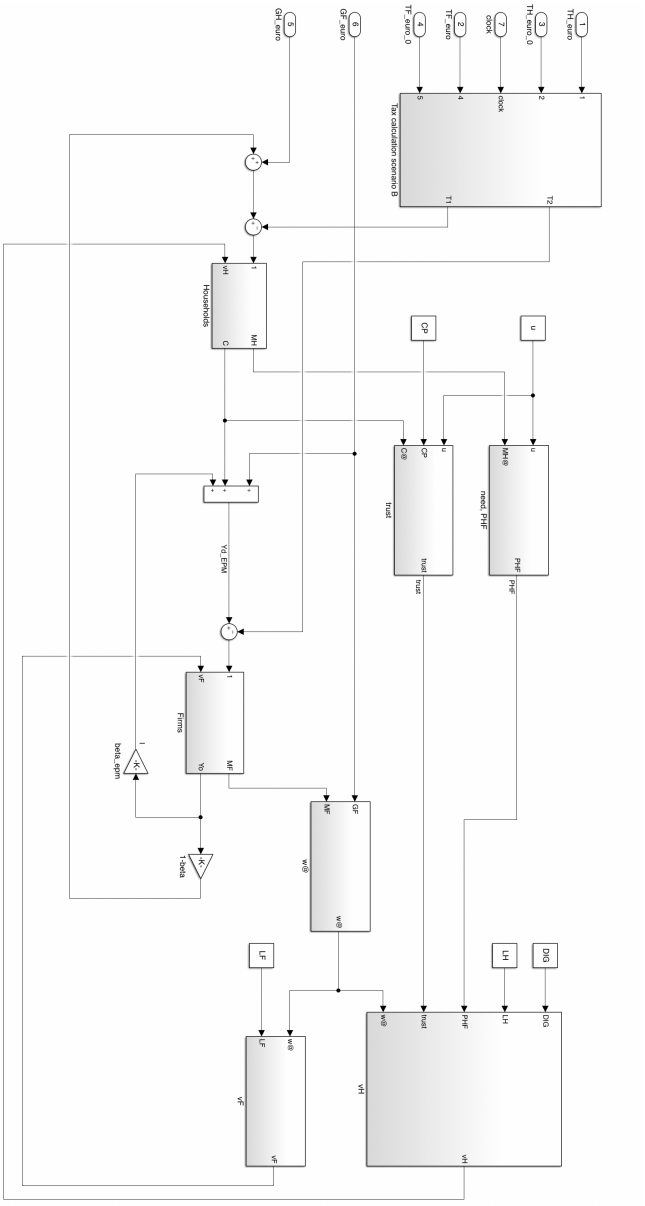


Figure C.6: The EPM circuit.

C.2.5 Taxation Alternatives

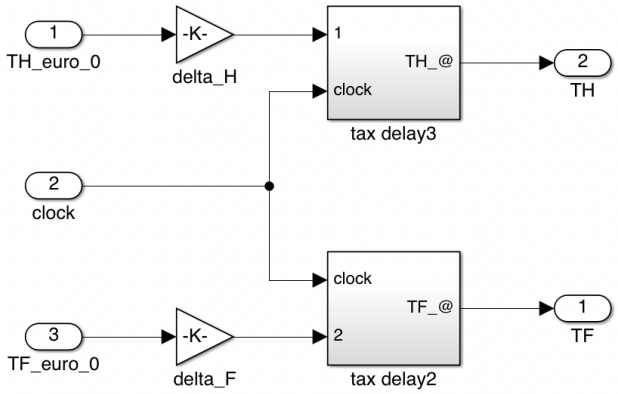


Figure C.7: Taxation Alternative A) in Simulink.

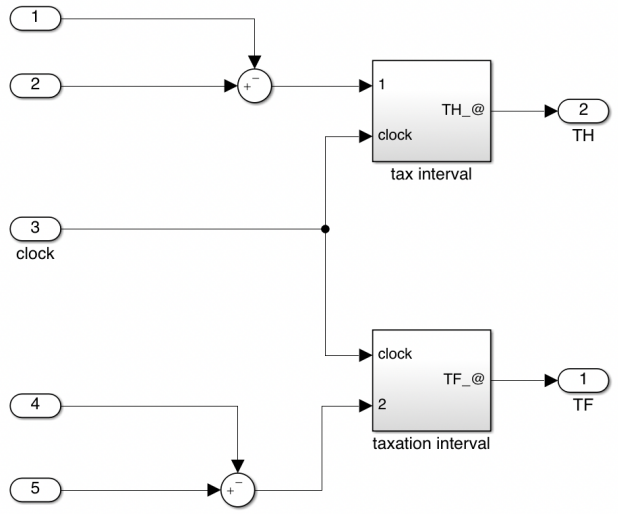


Figure C.8: Taxation Alternative B) in Simulink.

C.2.6 Behavioural Variables

See Appendix B for function descriptions.

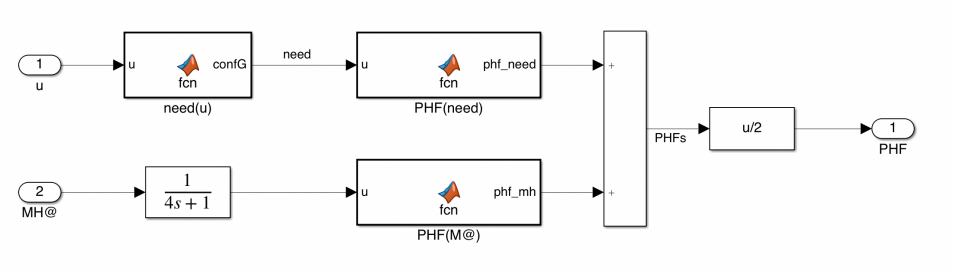


Figure C.9: Need and PHF in Simulink.

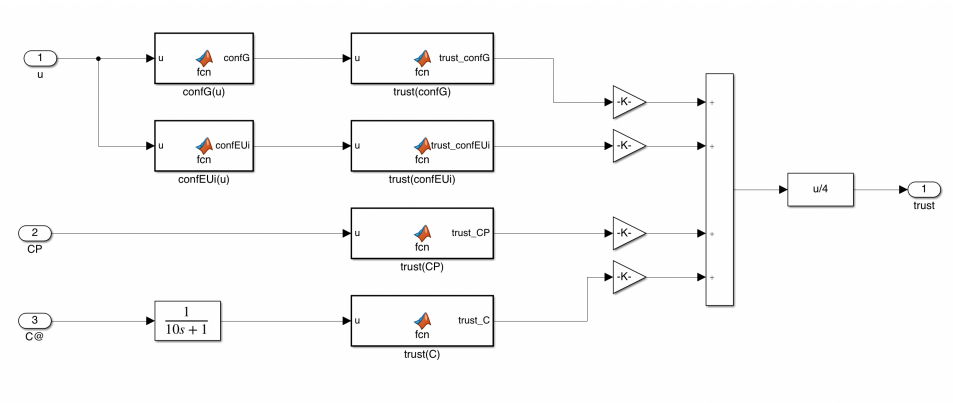


Figure C.10: Trust in Simulink.

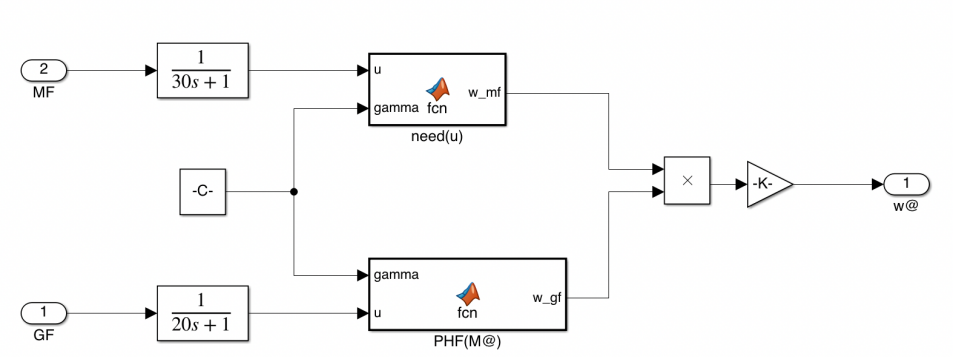


Figure C.11: Private EPM wage share $w_{@}$ in Simulink.

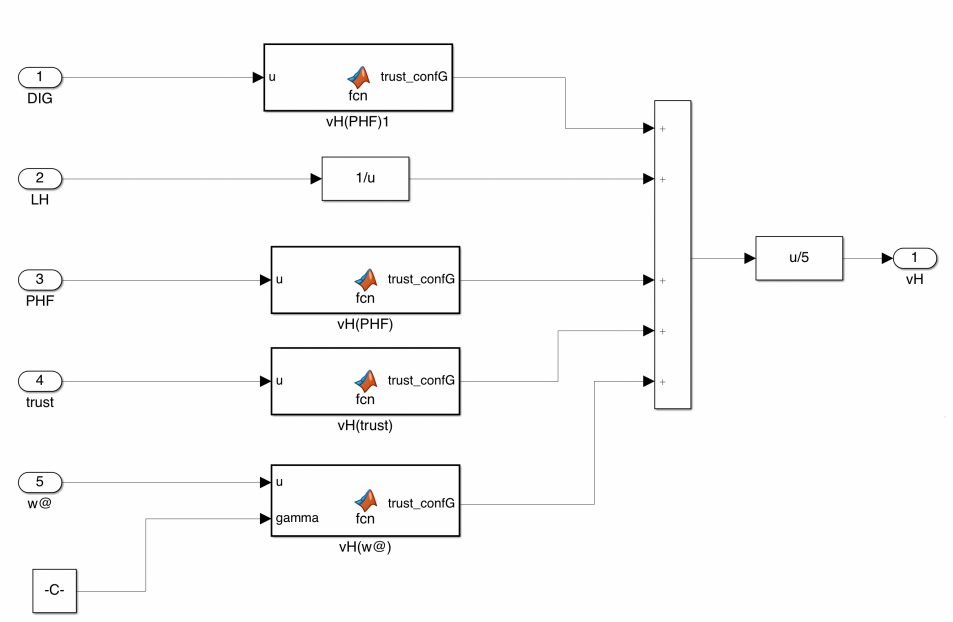


Figure C.12: Household sector EPM money velocity in Simulink.

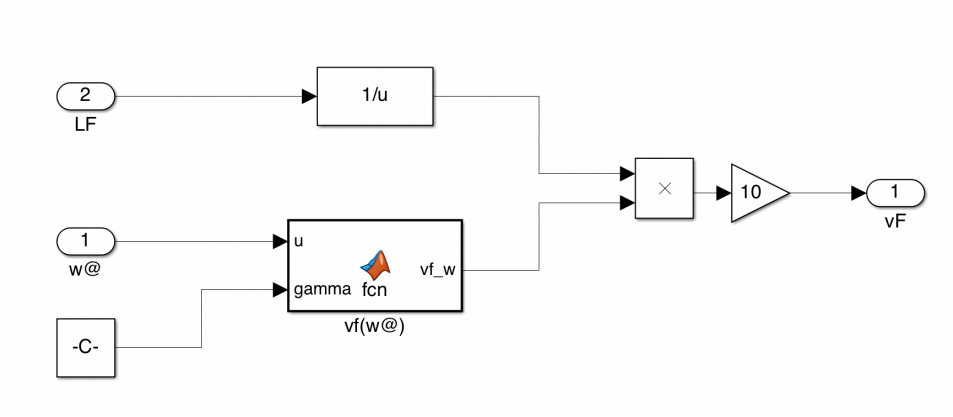
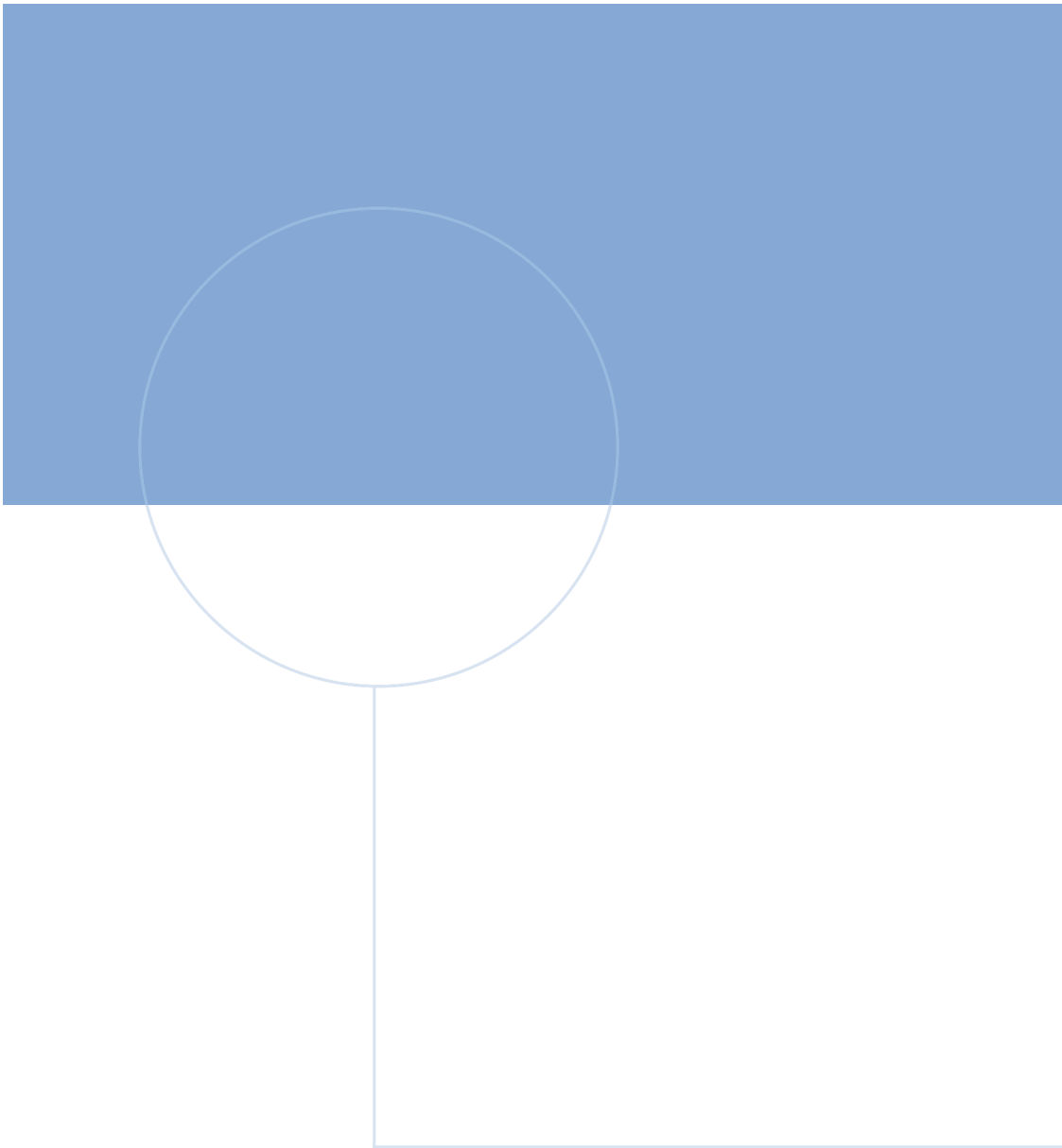


Figure C.13: Firm sector EPM money velocity in Simulink.



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