Money Supply in a No-Growth Economy

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Abstract

In the light of climate change and ecological sustainability, the economic growth model is being questioned and criticized.
The first part of this paper researches the effect of a no-growth economy on the money supply in our current monetary system by simulating the money supply in growth and no-growth scenarios. The simulations use nominal monetary mass, adjusted for inflation, as a substitute for economic growth.
The simulations point to a dependency of money supply on the amount of lending which occurs. The latter is tied to economic growth and thereby creates a dependency on economic growth in order to keep the money supply healthy and stable.
The second part of the paper proposes an alternative monetary system where the stability of the money supply is not dependent on economic growth.
Computational simulation is used as a research methodology.

1. Introduction

On September 6, 2018, 238 economists published an open letter [1] in which they urged the EU to step away from an economic model that dictates unlimited growth. On July 8, 2019 the European Environmental Bureau published a report [2] which debunks the notion of 'Green growth', the assumption that we can decouple economic growth from an ever increasing use of resources and increasingly high environmental impact. If these documents are taken seriously, that would mean that we need to transition to a no-growth economy.
However, transitioning towards a no growth economy is in conflict with Article I, sections (ii) and (iv) and Article IV, section 1 and section 1.(i) of the IMF Articles of Agreement [3] which all state that sound economic growth is to be aimed for. In the light of current circumstances regarding climate change and the strains put on our ecological systems these sections need to be put up for questioning. It stands to reason that a deterioration of our ecological and climate systems are not supportive of economic and financial stability due to the costs of their impact. The consequences of that impact would violate the stipulations in Article IV, section 1 and section 1.(i) which state that continuing development must be done to assure that conditions are created which support financial and economic stability.

Even in its current state, with a sustained economic growth, our current system is already struggling to support economic and financial stability. This is made clear by a report. Systemic Banking Crises Revisited [4], from the IMF itself. The report mentions 390 financial crises in the period of 1970 to 2017. As the title of the IMF report suggests, these crises are systemic and therefore the system itself needs to be questioned and, if necessary, redesigned. The latter is a possibility under the current IMF Articles of Agreement because Article I, which states the purpose of the agreements, does not mention a commitment to any defined monetary system, nor do any of the other articles mention a specific technical definition of the way the monetary systems should be implemented in the member states of the IMF, or elsewhere in the world. The only technical references made in the IMF Articles of Agreement are stipulated in Article IX, section 7 and Article XX, section 1. These state that the special drawing rights (SDRs) function as the principal reserve asset of the international monetary system and that these SDRs are interest bearing. This definition does not exclude the introduction of redesigned monetary systems.

This paper examines the suitability of the current monetary system in the light of a post-growth economy. For that a quantitative analysis of a computer simulation of the money supply is executed. Although a stable money supply in itself does not guarantee a well functioning economy, no economy can survive without it. It is therefore a necessary condition to uphold the goal of the IMF to maintain a stable financial and economic system.

2. Simulating the current debt based monetary system

This paper focuses on the situation within the European Monetary Union (EMU). Apart from specific parameters concerning interest rates, minimal required reserves and quantitative easing policies the overall systemic findings can be largely extrapolated to other countries.

Because paper money and coins need to be purchased from the central bank in order to find their way into the economy [5] and the money to pay for these notes is digital, it follows that coins and banknotes are a representation of digital money. The amount of coins and paper money in circulation is therefore on the digital books of banks. This paper only deals with the quantitative analysis of the digital part of the monetary system. The existence of paper money and coins do not have a systemic impact on the simulations used in this paper.

The simulation is based on the paper published by the Central Bank of England [6], which describes money creation in our modern economy. This is in line with the article published by the Deutsche Bundesbank in 2017 [7], the explanatory page of the ECB [8] and the empirical findings in R. Werner - 2014 [9].

2.1 Minimum reserves

The simulation takes into account the monetary policy of the ECB [10] concerning minimum reserves, which dictates commercial banks to have a certain percentage, determined by the ECB, of the amount of their outstanding loans on their reserve accounts with the ECB. This does not mean however that there is a hard limit on the amount of loans that can be issued since more money can always be borrowed. Either from other banks or from the ECB. Interbank lending can grind to a halt as happened with the 2008 financial crisis, thereby eliminating that option to top up reserves of banks with a liquidity shortage. But due to the change in monetary policy at the end of 2008 [11] by the ECB from providing a fixed amount of credit to banks in an auction system to provide unlimited credit at a fixed interest rate, banks can always lend from the ECB as a last resort. Interbank lending is not taken into account in the simulation. The consequence of this choice is that, in the context of the simulations, problems with interbank lending can not have a negative effect on the stability of the money supply, thereby eliminating one of the risk factors.

Although minimum reserves are calculated per bank [12], depending on their balance sheet, the simulation only allows one minimal reserve rate to be set. This choice has been made because the simulation aims to research the systemic behaviour of the money supply and not the stability of single credit institutions. Therefore an average minimal reserve rate applicable to the entire system suffices.

The Basel III agreements announced the Liquidity Coverage Ratio [13] which introduced a minimal required reserve of High Quality Liquid Assets (HQLA). These are assets that can be easily converted into liquidity. For the simulation all financial assets are considered to be HQLA's, thereby more than satisfying the Basel III agreements and eliminating another risk factor from the simulation.

2.2 ECB interest rates on loans

The ECB charges 2 types of interest rates on their loans to commercial banks. The main refinancing operations rate (MRO [14]) and the marginal lending facility rate. In normal circumstances these are positive rates. However, the MRO has been set to 0.0% since March 16, 2016 [15]. On top of that, on March 16, 2016, September 13, 2018 [16] and March 7, 2019 [17] the European central bank announced the availability of Targeted Longer-Term

Refinancing Operations (TLTRO’s [18]), which makes the MRO of 0.00% possible for longer term loans under the conditions stipulated in TLTRO’s.

The simulation allows for one interest rate to be set and the minimum term of a loan is 1 cycle. The simulation also does not require the necessary assets to be present in order to obtain the loan. This makes it, in the context of the simulation, more favorable for commercial banks to obtain loans since there are no restrictions that are imposed in order to obtain a loan from the ECB. This choice has been made because the simulation only deals with the systemic behaviour of the money supply and it not concerned with movement or distribution of assets.

2.3 ECB interest rates on minimal reserves and excess liquidity

The simulation allows for interest rates to be set separately on minimal reserves and excess liquidity, as is in line with ECB monetary policy.

2.4 Money creation

The only options for money creation, besides loans, is the ECB injecting money into the economy through quantitative easing (QE), which they have done from March 2015 to December 2018. Or by issuing so called ‘helicopter money’, putting free money directly on citizen’s accounts or giving central bank funded tax rebates. These are the only methods that create money without adding debt and charging interest. Money creation through loans, QE and helicopter money are all included in the simulation.

3. Simulation model [20]

The simulation model allows for a range of parameters to be set, some of which can not so easily be controlled in the real world. The purpose is to research systemic behaviour of the money supply under a set of conditions. The fact that these parameters are controllable in the simulation but not necessarily so in the real world means that the outcomes of the simulations are best case scenarios.

3.1 Model design

3.1.1 Money pools

Money is divided into 3 pools: bank reserves, money available to the real economy (RIM), which is roughly comparable to M2, and money that has been invested in the financial economy. The reserve pool is the result of money creation by the ECB, the RIM pool is the result of money creation by commercial banks. The pooling together of money this way eliminates any problems that might occur within the boundaries of one of these pools, like failure of payments between economic actors in the real economy for example.This again creates optimal conditions and leads to best case scenarios.

3.1.2 Loans and money creation

When the simulation starts, an initial amount of RIM needs to be set. This is money that has been borrowed from banks. The amount that is created by banks is controlled by 2 parameters:

- Minimum new money: this is the minimum percentage of a loan that is newly created money by a bank.
- Maximum new money: this is the maximum percentage of a loan that is newly created money by a bank.

The remaining amount of the loan, if money creation is less than 100%, is taken from reserves. If the reserves are not sufficient, money is borrowed from the ECB.
The simulation always aims for the lower end of money creation if the reserves permit this.

In the simulation the ECB always creates 100% of the money that is lent to commercial banks.

3.1.3 Debt

All debt and payback of debt is aggregated in the simulations presented in this paper. This eliminates cases where one specific economic actor would not be able to pay back their debt due to a liquidity problem. It is as if everyone can tap into a common pool of money.

To simulate paying off debt, the number of cycles after which a debt has to be repaid needs to be set. Each cycle a part of the debt, equal to the total debt divided by the number of cycles, is paid off. These payback cycles can be set separately for private loans and for banks borrowing from the ECB.

When private debt is paid off, created money is destroyed first. If all created money has been destroyed the surplus is added to the reserve accounts.

3.1.4 Interest

Payback of interest on loans is aggregated. Interest paid to the ECB by banks is taken from their reserves and added to RIM, which is in line with ECB policy if working costs are disregarded and the money available to governments is considered to be part of RIM. Interest paid on private loans is taken from RIM and added to the bank's reserves. Interest the ECB pays to banks can be set at two levels: interest on the minimum reserves and interest on excess reserves. Interest paid by the ECB is created and added to the reserve accounts of banks.

3.1.5 Economic growth

The simulation only deals with money supply and keeping everything in accordance with minimum reserve requirements. A parallel for economic growth, expressed in monetary mass requirements, is constructed. This is not in conflict with actual economic growth.

Economic growth (G) is the combination of demographic growth (Dg) and increased production capacity per capita (Pg). If either one of these increases, without the other one decreasing in such a way that the net result would be negative, we can speak of economic growth.

$G = Dg + Pg$

If RIM would remain stable with a positive Dg, less money would be available per capita, resulting in the necessity for money to increase in value, leading to deflation. Since the ECB wants to keep inflation just below 2%, an increase in RIM is required to support Dg and keep inflation at the desired levels.

If RIM would remain stable with a positive Pg, more products and services have to be able to be bought with the same amount of money, again increasing the value of money and leading to deflation. Therefore, also in this case an increase in RIM is required in order to support Pg.

It can be argued that an increase in the velocity of money could offset the lack of growth in the money supply. That would assume perfect distribution of the monetary mass and a fully connected directed graph, representing economic transactions, where every node is serviced according to its monetary needs. This requirement is highly unlikely to be met in the real world. Therefore, there is a causal relationship between a growing economy and an increased monetary mass, if deflation is to be avoided.

It can be concluded that a minimum required growth in RIM is an adequate expression of economic growth within the framework of the presented simulations. Of course, a growth in RIM does not guarantee economic growth since it is a consequence and requirement, not a cause of said economic growth. However, real economic growth requires RIM to grow in order to avoid deflation. Therefore growth in RIM is an adequate substitute for economic growth in this simulation.

Consequently, a stable or diminishing RIM represents a no-growth economy. 3 growth models are defined:

- Growth: RIM increases on each cycle.
- 0-growth: RIM remains stable.

- De-growth: RIM decreases on each cycle.

This paper only handles growth and 0-growth simulations but researchers can execute de-growth scenarios with the available simulation software.

3.1.6 Inflation

The ECB wants to keep inflation just below 2% and it would deviate too much from reality to ignore the impact of inflation in the simulations presented here. Inflation is a controllable parameter of these simulations.

The simulation allows for growth and inflation to be linked by setting a growth influence parameter. This parameter determines how strongly inflation is affected by growth and is expressed in percentages. If set at 50% for example, then a diversion of 1 percentage point in growth results in a diversion of 0.5 percentage points in inflation. These new values are then used for the next cycle in the simulation.

3.1.7 Savings and financial investments

The model allows for a saving rate to be set. This is the percentage of RIM money that is set aside for savings. A parameter can be set in order to transfer a percentage of these savings to the financial market.

On the savings that are not transferred to the financial markets an interest is gained. Each cycle this interest is transferred from the bank reserves to RIM.

The model allows for an asset trickle rate to be set. This simulates the so called trickle down economy, which supposedly trickles a percentage of the financial world back to the real economy. There are 2 modes that this can operate in:

- Asset growth: in this mode, each time money is invested in the financial market, a percentage of that investment flows back to the real economy.
- Asset capital: in this mode each cycle a percentage of the total amount of money available in the financial market flows back to the real economy.

The simulation does not include profit from financial assets because no money is created or destroyed in the financial market. Only the prices of the financial assets change. These prices, by themselves, do not have an effect on actual money supply.

3.1.8 Bank profit

In the model interest on loans is the only source of income for banks but in the real world banks also generate income from other sources. Therefore a parameter has been introduced which allows to set the percentage of income interest represents. From there the total income of banks is calculated and transferred from RIM to the bank's reserves.

3.1.9 Bank spending

Commercial banks pay wages and buy products and services in the real economy. This is simulated by a spending profile of the commercial banks. The simulation allows for 3 spending profiles:

- A fixed amount per cycle, adjusted for inflation
- A fixed percentage of their profits
- A fixed percentage of their monetary capital (bank reserves + money invested in the financial markets)

Every cycle the amount that the bank spends in the real economy, based on the chosen spending profile, is transferred first from their reserves and, if needed, from their financial investments to RIM.

The model allows to set minimal profits for commercial banks, expressed as a percentage of the income banks receive, thereby potentially reducing real bank spending but not the interest paid on savings. The model also has a parameter which, when not set, allows commercial banks to run a loss.

3.1.10 QE and helicopter money

QE is integrated in the simulation and can be executed in 2 modes:

- A fixed amount, adjusted for inflation
- A fixed percentage of outstanding debt

In order to simulate helicopter money, a QE trickle rate can be set. This is the percentage of QE that trickles through to the real economy and is added to RIM. When setting this percentage to 100% helicopter money is simulated.

3.1.11 Summary

Although the model represents a thoroughly simplified representation of the real world economy it still fulfills all requirements in order to test whether or not our current monetary system is able to support a no-growth economy. The simplifications give us stronger control over the monetary system and, if our current monetary system is capable of supporting a no-growth economy, it has to be possible to define a set of parameters where RIM either remains stable or diminishes without having to implement minimal requirements that are beyond the control of monetary institutions.

The main output of the simulation is the required lending rate. This is expressed as a percentage of the money available in the real economy. This is the amount of money that needs to be lent into existence by banks each cycle in order to keep the monetary supply growing at the desired rate, or stable, in case of a no-growth economy.

A more detailed description of the algorithm can be found in Appendix A.

4. Simulations

This section examines simulation outputs based on several sets of parameters. A focus is put on the calculated percentages because they paint an image of the minimal requirements to keep the money supply stable and sustainable.

The simulations are systemic, meaning that, with the selected parameters, this is how the monetary system will behave in a context of perfect monetary distribution in banking reserves, financial markets and money available in the real economy and where no defaults on loans occur. Any perturbation of these ideal conditions will most likely have a negative impact on system stability.

All simulations are run for 500 cycles with the following fixed set of parameters:

- Initial desired RIM = 100000
- Auto calculate:
    - Initial created RIM
    - Initial private debt
    - Initial bank reserve
    - Initial bank debt
    - Initial created reserves
- Initial private assets = 0
- Initial bank assets = 0
- ECB interest = 1%
- Bank payback cycles = 1
- ECB interest on minimal reserve = 0%
- ECB interest on excess reserve = -0.40%
- Minimum reserve = 4%
- Maximum bank reserve = 5%
- Commercial bank interest = 2.5%
- Private payback cycles = 20
- Banks run at no loss
- Banks spend a maximum 10% of RIM
- Savings rate = 20%
- Savings interest = 0.5%
- % of savings invested in financial assets = 5%

For those who want to run the simulations themselves, on all charts, the X axis represents time, the Y axis represents percentages.

4.1 Growth economies

We are currently still in a growth economy and these simulations run a positive growth model. For all growth simulations the growth target will be based on current RIM, meaning the simulation aims for growth from cycle to cycle. If that growth lags behind, the cumulative effect is disregarded. This is in line with current monetary policies and prognoses.

4.1.1 Simulation 1 - the 'ideal' situation

Additional parameters:

- Lending satisfaction rate = 100%
- Desired growth rate = 1.5%
- Desired inflation rate = 1.9%
- Link inflation to growth = true
- Influence of growth on inflation = 50%
- Minimum new money = 80%
- Maximum new money = 100%
- Interest % of bank income = 80%
- Minimum profit = 20%
- Bank spending mode = % of profit
- Profit spending = 80%
- Asset trickle mode = % of asset growth
- Asset trickle = 5%
- QE mode = no QE

With these settings the following results are obtained:

- Required lending stabilizes at 14.60% of RIM or 13.59% of total money.
- Total debt stabilizes at 130.75% of RIM or 121.64% of total money.
- Money distribution stabilizes as follows:
    - RIM: 93.03%
    - Bank reserves: 6.08%
    - Total financial assets: 0.89% which are all private assets.

If minimum money creation by banks is set to 100%, the numbers become as follows:

- Required lending stabilizes at 14.44% of RIM or 11.17% of total money.
- Total debt stabilizes at 129.29% of RIM or 100% of total money.
- Money distribution stabilizes as follows:
    - RIM: 77.34%
    - Bank reserves: 5%
    - Total financial assets: 17.66%

Banks using their money creation mandate at maximum thus results in a slightly lower debt ratio, slightly lower lending requirements and substantially more money flowing to the financial market from the banks. This effect of banks being able to invest in financial assets starts at 96% minimal money creation by banks. Because financial investment by banks is clearly happening in the real world, the following simulations have minimal money creation set at 98%. For this simulation this results in the following numbers:

- Required lending stabilizes at 14.45% of RIM or 12.22% of all money.
- Total debt stabilizes at 129.99% of RIM or 109.38% of total money.
- Money distribution stabilizes as follows:
    - RIM: 84.14%
    - Bank reserves: 5.47%
    - Total financial assets: 10.39%

4.1.2 Simulation 2 - influence of inflation

In March 2019 the inflation in the Euro zone sat at 1.4% [22]. Adjusting the inflation rate to match those conditions delivers the following results:

- Required lending stabilizes at 15.12% of RIM or 12.09% of all money.
- Total debt stabilizes at 139.30% of RIM or 111.39% of total money.
- Money distribution stabilizes as follows:
    - RIM: 79.97%
    - Bank reserves: 5.57%
    - Total financial assets: 14.46%

Changes are observed in lending requirements, total debt and money distribution. All moving in a direction which would not be desirable if it goes too far. Hence it is understandable that the ECB wants to increase real inflation rates, which has been a mixed bag of successes and failures.

4.1.3 Simulation 3 - lending requirements not met

When keeping the parameters from the previous simulation except for the lending satisfaction rate, a system crash occurs once the lending satisfaction rate is set at 93.75%. The crash occurs after 498 cycles. This indicates that the RIM money supply has dried up. No more money is available for the real economy.
Just before the crash money distribution looked as follows:

- RIM: 0.61%
- Bank reserves: 6.40%
- Total financial assets: 92.99%

The latter consists for more than 99% of financial assets owned by banks.

Although 498 cycles seems to give adequate time for adjustments, the impact of not meeting the required lending grows rapidly. Setting the lending satisfaction rate at 90% results in a crash after 246 cycles, setting it at 80% results in a crash after 143 cycles.

It is clear that a failure to meet the required lending quota results in disastrous effects for the money supply.

4.2 No-growth economies

For all no-growth simulation the growth target will be based on the initial RIM since we want the monetary mass to remain stable, adjusted for inflation.

4.2.1 Simulation 4 - baseline

The parameters used for the initial simulation are the following:

- Lending satisfaction rate = 100%
- Desired growth rate = 0%

- Desired inflation rate = 1.4%
- Link inflation to growth = true
- Influence of growth on inflation = 50%
- Minimum new money = 98%
- Maximum new money = 100%
- Interest % of bank income = 80%
- Minimum profit = 20%
- Bank spending mode = % of profit
- Profit spending = 80%
- Asset trickle mode = % of asset growth
- Asset trickle = 5%
- QE mode = no QE

And delivers the following results:

- Required lending sits at 18.12% of RIM or 12.20% of total money after 500 cycles and has not yet stabilized although the curves do flatten out.
- Total debt sits at 174.58% of RIM or 117.49% of total money after 500 cycles and has not yet stabilized.
- Money distribution is as good as stabilized and looks as follows:
  - RIM: 67.30% of total money.
  - Bank reserves: 5.87% of total money.
  - Financial assets: 26.83% of total money.

The results show that a no-growth economy requires a higher rate of lending than a growth economy would require. This is counter intuitive. A stable, no-growth economy creates far less incentive for taking out loans than a growth economy would do. This vastly increases the likelihood that the lending requirements are not met.

The financial market also starts taking up a bigger role in this scenario.

Since the money mass does not grow and production is assumed to remain stable it is also very unlikely that an inflation rate of 1.4% would be maintainable.

3.2.2 Simulation 5 - no inflation

This simulation runs with the same parameters as the previous one, except for inflation, which is set at 0%.

This delivers the following results:

- Required lending as a percentage of RIM goes into an exponential curve, sitting at 26,204.99% of RIM after 500 cycles.
- Required lending as a percentage of total money stabilizes around 12.34% of total money after 500 cycles.
- Total debt as a percentage of RIM also grows exponentially and reaches 230,641.46% of RIM after 500 cycles.
- Total debt as a percentage of total money sits at 108.62% of total money after 500 cycles and is going down slightly.
- Money distribution looks as follows after 500 cycles:
    - RIM: 0.05%
    - Bank reserves: 5.43%
    - Financial assets: 94.52% and still increasing

Over 99.9% of financial investments are in the hands of banks.

This situation is clearly not tenable in the long run.

4.2.3 Simulation 6 - no inflation, lending requirements not met

For the sake of completeness a simulation is run with the same parameters as the previous one but this time with lending requirements met set at 99.61%. Even this small shortcoming already leads to a crash after 498 cycles.

5. Adding remedies

Growth and inflation can not be controlled in a real economy. Both depend on the willingness of economic actors to invest and borrow money to do so. The next simulations examine whether QE, combined with QE trickle, can stabilize the system and under which conditions this could happen. Growth targets are based on initial RIM in these simulations.

5.1 Simulation 7 - fixed QE with 50% QE trickle

The following parameters are used:

- Lending satisfaction rate = 100%
- Desired growth rate = 0%
- Desired inflation rate = 0%
- Link inflation to growth = true
- Influence of growth on inflation = 50%
- Minimum new money = 98%
- Maximum new money = 100%
- Interest % of bank income = 80%
- Minimum profit = 20%
- Bank spending mode = % of profit
- Profit spending = 80%
- Asset trickle mode = % of asset growth
- Asset trickle = 5%
- QE mode = Fixed QE
- Fixed QE = 1000
- QE trickle = 50%
- QE is bank profit = true

Although helicopter money, which is implemented with the 50% QE trickle parameter is not a popular monetary policy, it does partially counter the effects of 0% inflation and 0% growth. The results are still not what can be called a stable monetary supply but it is clear that numbers are starting to move in the right direction again:

- Required lending as a percentage of RIM goes into an exponential curve, sitting at 36.21% of RIM after 500 cycles.
- Required lending as a percentage of total money sits around 5.21% of total money after 500 cycles.

- Total debt as a percentage of RIM also grows exponentially and reaches 369.47% of RIM after 500 cycles.
- Total debt as a percentage of total money sits at 53.13% of total money after 500 cycles and is going down slightly.
- Money distribution looks as follows after 500 cycles:
    - RIM: 14.38% and going down
    - Bank reserves: 2.66%
    - Financial assets: 82.96% and still increasing

The question now becomes: is there an amount of helicopter money that would stabilize the system at manageable levels?

Setting the QE trickle parameter at 100% for 1000 fixed QE brings us the following after 500 cycles:

- Required lending drops to 0% of both RIM and total money.
- Total debt drops to 0% of RIM and total money.
- Money distribution stabilizes as follows:
    - RIM: 97.62% and still going up
    - Bank reserves: 0%
    - Financial assets: 2.38% and still going down
- Real growth increases to 0.23% but has no influence on inflation.
- Bank profits drop below 0, resulting in banks running a loss.

This scenario would clearly not be appreciated by banks. Setting QE trickle at less than 100% would in any case keep banks out of making losses but it would be hard to control the outcome with so many unknowns in the equation.

5.1 Simulation 8 - relative QE

Another way the simulation allows for helicopter money to be introduced in the economy is by adding it as a percentage of outstanding private debt. The following parameters are used:

- Lending satisfaction rate = 100%
- Desired growth rate = 0%

- Desired inflation rate = 0%
- Link inflation to growth = true
- Influence of growth on inflation = 50%
- Minimum new money = 98%
- Maximum new money = 100%
- Interest % of bank income = 80%
- Minimum profit = 20%
- Bank spending mode = % of profit
- Profit spending = 80%
- Asset trickle mode = % of asset growth
- Asset trickle = 5%
- QE mode = % of private debt
- Relative QE = 2%
- QE trickle = 50%
- QE is bank profit = true

This leads to some very uncharacteristic results:

- Required lending enters a downwards curve which sits at 1.29% of RIM or 0.33% of total money after 500 cycles.
- Accordingly, debt also enters a downwards curve and sits at 13.97% of RIM or 3.58% of total money after 500 cycles.
- Money distribution looks as follows at 500 cycles:
    - RIM: 25.61% and moving down towards equilibrium
    - Bank reserves: 0.18% and moving down towards equilibrium
    - Financial assets: 74.21% and moving up towards equilibrium

Over 99.9% of financial assets are in the hands of banks. Income and profits for banks coming from RIM are on a continuous downward slope, which is to be expected if the amount of lending diminishes. Of course, this is under the assumption that the income from interest continues to represent 80% of a bank's total income. It is however more than likely that this would shift. That would result in more money being pulled from RIM towards the banks which would then transfer it to the financial markets, thereby shifting even more money away from the real economy.

This scenario shifts the lion's share of the total monetary mass towards the financial markets while at the same time severely reducing debt in the real economy. The question to ask here is: how would economic actors in the real economy react to this? Would it create an incentive to invest more in the financial markets, thereby shifting the balance of money distribution even more towards the financial markets? Would that incentive constantly increase, thereby jeopardizing the money supply to the real economy or would it level off at some point? Does it level off at a point where there is still enough money available in the real economy or would additional lending be required? What would the impact of the renewed lending requirement be on the stability of the system?

5.1 Simulation 9 - relative QE, lending requirements not met

Helicopter money seems to be a surefire way to stabilize the money supply. Even when setting the lending satisfaction rate at 50%, the system remains stable and even leads to some surprising results:

- RIM: 43.46%
- Bank reserves: 0.12%
- Financial assets: 56.42%, which is almost entirely in the hands of banks.

Not meeting the lending requirements results in relatively more money being present in the real economy versus the financial markets, which brings the two more in equilibrium. As expected, bank profits from RIM are on a continuous downward slope. Again under the assumption that income from interest would remain relatively stable in regards to total income. Which is a very unlikely scenario.

Increasing the relative QE to outstanding debt rate shifts the RIM and financial asset percentages in favor of RIM and creates the need for a completely revamped business model for banks since their income from loans could potentially drop to 0.

Here the same questions need to be asked though. How will this impact the incentive to invest money in the financial markets and how will that affect the entire system?

6. A fallible system

Although helicopter money implemented through relative QE appears to be a way to stabilize the system, it also introduces a whole range of new uncertainties. The question needs to be asked whether it is a good idea to apply what is basically a patch to an inherently unstable system.

Already in 2012, the European branch of the Club of Rome published a report [23] in which they made the link between our current monetary system and environmental and social sustainability. They ascribed the following qualities to the current system:

- It causes boom and bust cycles in the economy
- It produces short-term thinking
- It requires unending growth
- It concentrates wealth
- It destroys social capital

The simulations presented here add fuel to the fire and make it clear that the current monetary system, with current day monetary policies, is highly sensitive in a no-growth context and keeping it stabilized is a nigh impossible task. Especially when taking into consideration that the most crucial parameter, namely the amount of lending, can not be controlled by central banks or any other authority for that matter. Lending is influenced by the state of the economy, profit margins of banks and the need for loans, which in its turn is dependant on economic growth. All these parameters are out of control of central banks and the IMF.

On top of that, the Basel III agreements introduced liquidity measures which are meant to stabilize the banking sector but come at the cost of economic growth. Specifically by setting tougher requirements for commercial banks who operate at the international level. These measures avoid a failure in liquidity as has happened in the 2008 financial crisis but jeopardize the main source of the money supply at the same time.

A solution seems to be to implement the very unorthodox measure of helicopter money but that could have unforeseeable consequences if the rest of the system remains as it is today.

7. A proposal for a sustainable monetary system

The following is a description of a monetary system which is designed with the following characteristics in mind:

- Provide an inherently stable money supply
- Retain stability with a growing, non-growing and shrinking economy
- Avoid extreme concentration of monetary capital

The full model is described in the SuMSy white paper [24]. What follows here is the technical description of how the money supply functions.

Three principles lie at the core of SuMSy:

- Money is not created from debt.
- There is no interest. Not on deposits nor on loans.
- Demurrage is charged on deposits with a high balance.

7.1 Money creation

Money is created for 2 purposes:

- To pay for a guaranteed income for every living citizen.
- To top up budgets for projects and services which are deemed indispensable to run a well functioning society. These are called projects for the common good.

This can be compared to helicopter money in the current system.

7.2 Demurrage

Demurrage is charged on every account in the system. However, it is not necessarily charged on the full sum a person holds in their account(s). A demurrage free buffer is given to every

living individual. Demurrage is only charged on the amount the individual has in surplus of this demurrage free buffer.
Demurrage is then charged in tiers, as with most taxes on labour income.
The demurrage is transferred to the projects for the common good, providing them with a budget.

7.3 Money destruction

When a project for the common good receives more money from demurrage than is needed, the surplus is used to pay for the guaranteed income, thereby decreasing the need to create new money for that purpose. If more money than is needed to pay for the guaranteed income flows in, that surplus is taken out of circulation and is destroyed.

7.4 Summary

This construction eliminates debt as a counterpart for credit from the system. All money now exists as a debt free entity. Because lending is no longer the source of money, the profit driven incentive of money creation, which exists in our current system, is taken out of the equation.

Although lending no longer has an influence on the money supply, it can still take place. Those who have balances over their demurrage free buffer have an incentive to lend it to others in order to protect it from that demurrage. Even at no interest, which would be enforced in SuMSy, the incentive would be there in order to avoid a loss due to demurrage.

A detailed description of the simulation can be found in Appendix B.

7.5 Simulations

All simulations are started with the following common parameters:

- Iterations: 500
- Start at saturation: false
- Initial money mass: 100,000,000

- Initial population: 1,000,000
- Guaranteed income: 2,000
- Demurrage tiers: 5
    - > 50,000 : 1%
    - > 250,000 : 5%
    - > 1,000,000 : 10%
    - > 5,000,000 : 50%
    - > 10,000,000 : 90%
- Common good spending mode: per capita
- Common good budget: 1,000

These settings always produce an equilibrium balance, the deposit balance where income equals demurrage, of 270,000.

7.5.1 Simulation 10 - Zero growth, zero inflation

When both population growth and inflation are set to 0%, the system stabilizes with the following results:

- Money mass per capita: 270,000
- Demurrage per capita: 3,000
- Money creation per capita: 0
- Percentages of money mass:
    - Income: 0.74%
    - Demurrage: 1.11%
    - Common good spending: 0.37%
    - Money creation: 0%

This indicates that there is an average of 270,000 available per person to spend in the real economy.

7.5.2 Simulation 11 - Zero growth, non zero inflation

Some argue that giving people a guaranteed income, more often referred to as a basic income, would lead to inflation. Therefore this simulation examines the effect of inflation on the systemic behaviour of the model.

Inflation is set at 1.5%. The system stabilizes with the following results:

- Inflation adjusted money mass per capita: 141,799.18
- Inflation adjusted demurrage per capita: 904.43
- Inflation adjusted money creation per capita: 2,095.58
- Percentages of money mass:
    - Income: 1.41%
    - Demurrage: 0.64%
    - Common good spending: 0.71%
    - Money creation: 1.48%

This indicates that there would be less, inflation adjusted, money available for the same amount of goods and services. In real terms, more money would be available, of course. The question needs to be asked whether inflation would occur. Higher prices would lead to higher income for the seller, which would lead to more money in their accounts. That would then lead to more demurrage being paid, which would result in diminishing results from higher prices. It is very likely that this would put a systemic brake on price inflation, especially if demurrage tier indexation lags behind inflation increases.

When the same simulation is run with a population shrinking at the same rate as the inflation rate, the effect on the inflation adjusted monetary mass per person is neutralized.

7.5.3 Simulation 12 - Zero growth, deflation

Deflation is the bane of the current economic system. Here SuMSy is simulated with deflation.

Deflation is set at 1.5%. The system stabilizes with the following results:

- Deflation adjusted money mass per capita: 384,428.55
- Deflation adjusted demurrage per capita: 8,854.24
- Deflation adjusted money creation per capita: -5,854.24
- Percentages of money mass:
    - Income: 0.52%
    - Demurrage: 2.3%
    - Common good spending: 0.26%
    - Money creation: -1.52%

When the same simulation is run with a population growing at the same rate as the deflation rate, the effect on the deflation adjusted monetary mass per person is neutralized.

7.6 Interpreting the numbers

As can be deducted from the simulations above, changes in population have the same effect on the average nominal amount of money per capita as inflation and deflation have. A growing population has the same effect as inflation and a shrinking population has the same effect as deflation. Running the simulations with inflation set at 0% and population growing or shrinking confirms this.

7.6.1 Behavioural influences

Because demurrage and diminishing returns on higher income both introduce new behavioural influences it is hard to draw definite conclusions from the inflation and deflation simulations. It can be assumed that diminishing returns on income due to demurrage could have a dampening effect on inflation of prices.

The debt, necessary to keep the current money supply healthy, is absent in SuMSy. Money supply can be guaranteed without needing to meet any supplemental conditions. An income for every citizen is guaranteed too, thereby guaranteeing a level of financial security that is unknown in today's society. Add demurrage to that mix and it can be concluded that from a behavioral aspect we are treading into completely new waters.

No research has yet been done in a situation that includes all of these contexts but some indication towards what it might look like is given by the demurrage currency experiment in Wörgl in 1932 - 1933 and the basic income experiments that have been executed around the world.

Although the experiment in Wörgl [25], which was based on the economic theories of Silvio Gesell, was rather short lived, the results were clear. The new Shilling, with the demurrage, had a velocity about 3 times as high as the regular Shilling. The mayor of the town managed to complete all of his planned projects and on top of that new houses, a ski jump and a new bridge. In a time of recession, the economy of Wörgl was booming and unemployment was a thing of the past.

It can be argued that an exact duplication of the scrip money used in Wörgl would today lead to massive over consumption due to the 'hot potato' effect of the currency. People were constantly looking for new ways to spend their money, in order to avoid paying for the stamp that needed to be applied, including paying their taxes early. And this marks the main difference between the currency system deployed in Wörgl and what is proposed here: the scrip money could not be used as savings without the cost of the demurrage stamps, SuMSy provides a limited cost free savings allowance.

No record of inflation in Wörgl is known.

The basic income experiments have led to various results in terms of entrepreneurship and productivity. The experiment in the Otjivero-Omitara area in Namibia [26] has led to economic growth, higher school attendance and a reduction of crime rates. Ofcourse, an experiment in a poor, isolated area can not be used to be representative for a similar scheme in a rich Western country.

In Finland a basic income experiment was done with 2000 unemployed residents who received 560 Euros per month. The preliminary results [27] indicated no difference in getting employment between the test group and the control group. As for perceived quality of life, however, the test group scored 0.56 points higher than the control group, on a scale from 0 to 10. Even though the experiment delivers interesting results, no hard conclusions can be drawn on what the effect would be if it were applied to the entire population and not only to 2000 unemployed individuals spread out throughout the nation.

It can be concluded that the behavioural aspects of SuMSy are currently largely unknown and only educated guesses based on the aforementioned experiments can be made until further research has been performed.

7.6.2 Quantitative interpretations

From a quantitative angle, the elements that are responsible for the money supply need to be considered separately.

7.6.2.1 Guaranteed income

Guaranteed income linearly scales with the population due to the fact that the available guaranteed income for the entire population is exactly tied to the size of the population. Each new individual born adds one guaranteed income to the money supply, each individual that dies removes one.

7.6.2.2 Projects for the common good

These need to be divided into 2 categories:

- Service oriented projects that are tied to the size of the population, such as health care, education and garbage collection.
- Projects with a high structural cost which does not scale tightly with the size of the population. The monetary system itself is one such project.

Projects of the first type are clearly closely linked to the size of the population in terms of cost. The same can not be said of projects of the second type. Those projects either have a fairly fixed cost, thereby reducing their cost per capita if the population grows. Or they have a heavy structural cost which is fairly fixed and a cost component which is more strongly tied to the size of the population. Free public transport is an example of the latter.

Both types of projects have hard upper and lower limits in terms of cost due to the limitations in time and resources. Even with highly efficient production systems only a finite amount of products or services can be produced in a given time and no matter what is on offer, consumption of those products and services by an individual is also finite.

Therefore it can be concluded that the aggregated budgets for the common good also loosely scale with the size of the population although not as close as the budget for the guaranteed income.

This explains why a diminishing population has a similar effect as deflation and a growing population has a similar effect as inflation.

8. Relation to current literature

The proposed model may seem unorthodox and extravagant but shows some resemblances to already existing proposals and policies.

8.1 The Chicago Plan Revisited [28]

After the great depression a number of leading thinkers, headed by Henry Simmons and Irving Fisher proposed a drastic monetary reform in what became known as the Chicago plan. It it they proposed to separate the money and credit functions of the banking system and a 100% reserve backing through government created money. This government created money is similar to the money creation mechanism in SuMSy. Both are created without simultaneously creating debt and the deposits in the system also have a 100% reserve backing, which in SuMSy is the money itself. The main difference with the Chicago Plan is that in SuMSy there is no positive interest. Not on accounts nor on loans.

8.2 Modern Monetary Theory [29]

In 1990 Bill Mitchell coined the term Modern Monetary Theory (MMT), which is based on the works of Georg Friedrich Knapp and Abba Lerner. MMT states that a sovereign state can issue as much money as is needed to maintain employment and reach its goals such as combating climate change, all in disregard of debt. This is similar to the money creation mechanism for projects for the common good in SuMSy. A point where SuMSy differs from MMT is that money creation is not by central banks issuing money to a nation's treasury when there is a need, which creates deficits for governments, but money is created by the system on demand when a project for the common good is in need of extra budget without creating debt. The fear of inflation in MMT due to the increase of monetary mass, which is put forward by some critics, is at least partially countered by demurrage in SuMSy.

8.3 Doughnut Economics [30]

In her book Doughnut Economics, Kate Raworth briefly talks about the link between interest bearing money and growth (Chapter 7, Financially Addicted), which makes money a commodity without limits. This is in contrast with the natural world where nothing grows forever. In the chapter Kate hints at a demurrage based monetary system to solve this growth pressure. This paper presents a worked out model for that.

8.4 Current monetary policy of the ECB

Parts of SuMSy are actually already in effect when only taking ECB monetary policy towards commercial banks into account.

- The current zero interest rates on bank mandatory bank reserves is in line with the abolishment of positive interest rates in SuMSy.
- The negative interest rate on surplus reserves is similar to the demurrage charged on balances exceeding the demurrage free buffer.
- QE can be interpreted as a limited form of guaranteed income for commercial banks.
- The income of ECB which is not used to pay for its operations or to create reserves to cover future losses, is distributed to the national banks. These banks can use some of that money to fund their work but usually it is forwarded to the government of that country [21]. This can be interpreted as a form of guaranteed income for the member states of the Eurozone.

This means that, although the proposed system might be seen as unorthodox at first glance, it is already partially implemented at the level of commercial banks and governments by the ECB.

8.5 Laws and Monetary Policies

An economy does not exist in a void. It is intrinsically linked with legislation and politics. Therefore, in order for a system like SuMSy to be implemented, there is a need for a change in legislation. The legislation concerning the monetary system is currently managed by the ECB through the Banking Union [31] since November 2014, using the Single Supervisory Mechanism (SSM) and the Single Resolution Mechanism (SSM). This legislation also forces a single currency and a single banking system upon the member states of the EU. This leaves no room for experiments with alternative systems and serves as an institutionally created disincentive to develop and promote such systems due to the cost of navigating the existing legislation in order to make such an experiment feasible. It would greatly benefit the economic system if legislation was passed that allows experiments with new economic models on a controlled scale. This would remove the institutional roadblock to innovation in our economic systems.

Apart from this there are also institutional roadblocks to move towards a no-growth economy. These are present in the Articles of Agreement of the IMF, Article I, sections (ii) and (iv) and article IV, section 1 and section 1.(i), and in the Stability and Growth Pact (SGP) of the European Commission. The IMF document literally mentions economic growth as a goal. The guidelines for the SGP [32] mention long term potential growth, GDP growth and a growth oriented goal several times. In accordance to that, legal mechanisms and guidelines have been put in place to continuously stimulate or even force this growth. The current debt based monetary system being the biggest hidden player for the latter. These mechanisms stand in the way of creating a sustainable, stable, no-growth economy.

9. Conclusion

Our current monetary system is systemically dependent on uncontrollable factors, specifically the willingness of economic actors to borrow money from banks, and becomes highly sensitive to perturbations in the context of a no-growth economy. Adding the probability of interbank lending issues and the complexities of a real economy to the mix only exacerbates the problems presented here. It is normal and logical that the stability of an economy is dependant on the stability of the underlying monetary system(s) but it is not normal, nor desirable, that the stability of the monetary system(s) is dependant on the state of the economy. Change is difficult however because legislation and monetary guidelines cement the current system and its growth directed imperative in place.

It is not wise to build our future economy on a monetary system that can so easily be brought down by factors out of the control of our financial institutions.

The current model needs constant monitoring and the current day tools to control stability are inadequate at best. Especially in the context of the no-growth economy which is called for by the 238 economists who submitted their open letter and by environmentalists who are worried about the impacts of climate change and the destruction of our environmental ecosystems. Applying the non orthodox measure of helicopter money brings stability to the system but then why not build on that and remove those elements that cause instability?

The Club of Rome proposes keeping the current system and add other systems to the monetary eco-system in order to increase overall stability of the monetary ecosystem. I strongly disagree with this approach for the long term. When it was discovered that DDT was toxic to humans it was concluded that its use should be phased out, at least in Europe. The disadvantages of the substance far outweighed the advantages. The same can be said about the current monetary system. Is it a sign of good policy to keep a clearly failing system alive and then build an entire world economy on that system, even when it’s mixed with other systems? That would be the equivalent of keeping DDT in the mix of pesticides used in agriculture.

A choice needs to be made and that choice must not fall in the trap of the sunken investment bias. It is not because the system worked in the past and that a lot of time and money has been invested in it that it is still the best choice for the future. We can not build a new planet but we can build a new monetary system. The system proposed in this paper is meant to serve as a basis for further discussion and research and puts an extra alternative on the table. I know making a switch of this magnitude does not happen overnight. A careful transition will need to take place where, at least for a while, both systems live next to each other. The current ECB monetary policy towards commercial banks can already be looked at for initial data. If we are serious about tackling the future challenges of our society then this discussion needs to start now.

Appendix A

Simulation algorithm [33]

The simulation is initialized with the following set of parameters:

- Number of cycles
- Desired initial RIM: the amount of money that is initially available in the real economy. This is be lent into existence by banks.
- Lending satisfaction rate: when this parameter is set below 100%, the required lending rate is not satisfied. Only the percentage of the required lending, set by this parameter, will be lent into existence each cycle.
- The next set of parameters can either be set manually or calculated from the desired initial RIM and lending satisfaction rate:
    - Initial created RIM: if not set manually this equals desired initial RIM, adjusted for lending satisfaction rate. If lending satisfaction rate is set at 90% for example, only 90% of the initial loan is satisfied and only 90% of desired initial RIM is created.
    - Initial debt: if not set manually this equals initial created RIM.
    - Initial bank reserve: if not set manually this equals the required minimal reserve needed for the initial created RIM.

    - Initial bank debt: if not set manually this equals the initial bank reserve.
    - Initial created reserves: if not set manually this equals the initial bank debt.
- Initial private assets: the amount of money present in the financial market, invested from the private market.
- Initial bank assets: the amount of money present in the financial market, invested by banks.
- Desired growth rate: the rate at which RIM should grow.
- Growth target: this determines how growth is calculated. It determines the target amount for RIM at the end of a cycle. This can happen in 2 ways:
    - Based on current RIM: current RIM is used to determine the target RIM at the end of the cycle.
    - Based on initial RIM: each cycle the target RIM is calculated from the initial desired RIM. This means that the actual desired growth rate between cycles can increase if the target keeps falling short each cycle.
- Desired inflation rate
- Link inflation to growth: whether or not a deviation in growth influences inflation.
- Influence of growth on inflation: how strongly growth influences inflation. This is set in percentages. When it is set at 100%, when growth deviates from its desired setting, inflation will deviate an equal amount.
- ECB interest: interest the ECB charges on bank loans.
- Bank payback cycles: the number of cycles after which a loan needs to be paid back by the bank. The total amount is divided by the number of cycles it takes to pay back the loan and each cycle one slice is settled.
- ECB interest rate on minimal reserve
- ECB interest rate on excess reserve
- Minimum reserve: the minimum reserve banks need to have in their reserve accounts.
- Maximum bank reserve: the maximum reserve banks are willing to keep in their reserve accounts. All surplus is invested in the financial markets.
- Minimum new money: minimum percentage of a private loan that consists of newly created money.

- Maximum new money: maximum percentage of a private loan that consists of newly created money. If this is less than 100% then banks will always use some of their reserves to lend out.
- Interest % of bank income: the share of income that interest on loans represents for banks. If less than 100% then additional bank costs are calculated and transferred from RIM to bank reserves each cycle.
- Commercial bank interest: interest charged on private loans.
- Private payback cycles: the number of cycles after which a loan needs to be paid back to the bank. The total amount is divided by the number of cycles it takes to pay back the loan and each cycle one slice is settled.
- No loss: whether or not commercial banks can run at a loss.
- Minimum profit: minimum percentage of their income that banks keep as profit. This has precedence over spending and can therefore have a negative effect on spending.
- Bank spending mode: this is one of 3 modes:
  - % of profit: set profit spending percentage.
  - % of capital: set capital spending percentage.
  - Fixed: set fixed spending amount.
- Spending max % of RIM: an upper limit for bank spending expressed as a percentage of RIM.
- Asset trickle mode: this determines how money flows from the financial markets to the real economy.
  - % of asset growth: a percentage of the growth of the financial markets flows back to the real economy.
  - % of asset capital: a percentage of the total amount of money available in the financial markets flows back to the real economy.
- Asset trickle: the percentage that flows from the financial markets to the real economy.
- QE mode: determines if and how QE is executed.
  - No QE: no QE. Disregard all other QE parameters.
  - Fixed QE: set the fixed QE amount. That amount is adjusted for inflation.
  - % of private debt: set relative QE percentage. A percentage of private debt is injected into the economy.

- QE trickle: the percentage of QE that trickles through to the real economy.
- QE is bank profit: QE that does not trickle through to the real economy is considered profit for banks. This can have an effect on bank spending.
- Savings rate: percentage of RIM that is set aside for saving. This amount is still part of RIM and therefore does not diminish RIM.
- Savings interest: interest paid by banks on savings.
- % of savings invested in assets: the percentage of savings that are invested in assets. This is transferred from RIM to the financial market and therefore diminishes RIM.

Once the parameters are set the simulation runs for the desired amount of cycles. The length of a cycle is not determined by the algorithm itself. It is up to the user of the simulation to determine the time period one cycle represents and adjust the parameters accordingly. During the first cycle the simulation is initialized. Each consecutive cycle the following steps are executed:

- Check if RIM is > 0. If not report a crash and the number of cycles the simulation has run. End the simulation.
- Copy data from the previous cycle
- Determine asset trickle based on the amount of money that was available in the financial market at the end of the previous cycle.
- Calculate interest on savings from the previous cycle.
- Calculate desired growth and determine target RIM for this cycle.
- Transfer interest from bank reserves to RIM. Subtract this amount from bank profit.
- Calculate debt payoff, interest and bank costs.
- Pay off loans. Take money out of RIM. When the amount of created money is > 0, first destroy it. Any surplus is added to bank reserves.
- Pay interest and bank costs. Transfer this money from RIM to bank reserves and add to bank income and bank profit.
- Generate interest from the ECB. If positive, add it to bank reserves, bank income and bank profit. If negative, take it from bank reserves, subtract it from bank profit and add it to RIM.

- Pay bank debts and interest to the ECB. If reserves are inadequate, sell financial assets if possible. If those are not sufficiently available, take out a new loan from the ECB. Subtract these amounts from bank profit.
- Trickle assets from the financial market to RIM.
- If QE is active, inject QE. Add the injected QE to bank reserves and trickle a percentage equal to QE trickle through to RIM. Subtract this trickle from bank reserves. If QE is bank profit, add the QE remaining in bank reserves to bank income and bank profit.
- Determine bank spending based on spending mode, minimum profit and maximum % of RIM spent by banks. Transfer this amount from bank reserves to RIM. If bank reserves are not adequate, sell financial assets and transfer that money to RIM. If banks can run at a loss, ECB loans can be taken out in order to satisfy spending.
- Determine how much RIM needs to grow in order to raise it to target RIM determined by desired growth rate.
- Determine how much money is saved, based on current RIM and how much of that money is transferred to the financial markets. Subtract the latter from RIM and add it to the financial markets.
- Lend money, adjusted by lending satisfaction rate, in order to increase RIM to the desired level. If lending satisfaction rate is < 100% this will fail to reach that level. Determine how much new money is created and how much is taken from reserve. Add the amount of created money to the created money variable and to RIM, transfer the rest from the bank reserves to RIM. Add the total amount lent to private debt.
- Adjust bank reserves according to the new debt levels. If bank reserves are below the required minimum, borrow new reserves from the ECB. If bank reserves are above the desired maximum reserves, invest in financial assets. In the latter case, transfer the surplus from the bank reserves to the financial markets.

Simulation output

The simulation generates the following output for each cycle:

- Amounts (can be deflated):
    - Bank reserves

    - Created bank reserves (by the ECB)
    - Bank reserve growth
    - RIM
    - Created RIM (by banks)
    - Actual growth
    - Actual inflation
    - Bank income
    - Bank spending
    - Bank profit
    - Bank debt to ECB
    - Amount paid off to ECB
    - Interest paid to the ECB
    - Amount borrowed from the ECB
    - Private debt
    - Private debt paid off
    - Private interest paid
    - Required lending (in order to satisfy growth)
    - Actual lending (if lending satisfaction rate does not equal 100%)
    - Savings interest
    - Asset trickle
    - QE trickle
    - Total inflow into RIM (bank spending + interest paid to ECB + savings interest + asset trickle + QE trickle)
    - Bank financial investments
    - Private financial investments
    - Total financial investments
    - Money available in the financial markets (this can be less than the amount of investments due to asset trickle).
- Percentages:
    - Inflow in the real economy. Expressed as percentage of RIM.
        - Savings interest
        - ECB interest paid by banks

        - Asset trickle
        - QE trickle (helicopter money)
        - Bank spending
        - Total inflow
    - Outflow in the real economy. Expressed as percentage of RIM.
        - Debt payoff
        - Interest paid
        - Banking costs
        - Total outflow
    - Money distribution expressed as a percentage of total money
        - RIM
        - Bank reserves
        - Total financial assets
    - Private debt
        - Percentage of RIM
        - Percentage of total money
        - Bank reserves as a percentage of debt
    - Bank debt
        - Percentage of bank reserves
        - Percentage of total money
    - Required lending
        - Percentage of RIM
        - Percentage of total money
    - Actual lending
        - Percentage of RIM
        - Percentage of total money
    - Bank lending
        - Percentage of bank reserves
        - Percentage of total money
    - Created money
        - By banks as percentage of RIM
        - By ECB as percentage of bank reserves

        - By banks as percentage of total money
        - By ECB as percentage of total money
        - Total as percentage of total money (this should be 100% at all times)
    - Bank profit and spending
        - Profit as percentage of income
        - Profit as percentage of RIM
        - Spending as percentage of profit
        - Spending as percentage of RIM

Appendix B

Simulation algorithm

Due to its nature, the parameters in this model are different from the one that simulates our current monetary system. Interest is no longer implemented and money creation is now dependant on population size and budgets allocated to the common good instead of being dependant on lending.

The full set of parameters with which the simulation is initialized is the following:

- Number of iterations
- Initial population: the initial size of the population
- Population growth: the rate at which the population grows
- Start at saturation: when the injection of new money, which is the sum of the total guaranteed income for the entire population and the total budget for the common good, is equal to the total amount of demurrage, the system has reached saturation. The same amount of money is flowing into the economy as is flowing out. This parameter gives the option to start at this saturation point.
- Initial money mass: the initial money mass with which to start the simulation. This parameter will not be used if the simulation starts at saturation.
- Guaranteed income: the guaranteed income that will be injected for each member of the population.

- Inflation rate: the inflation rate to apply to the guaranteed income, the budget for the common good and the demurrage tiers.
- Demurrage tiers: the number of demurrage tiers (1 to 5).
- Demurrage tier 1 - 5: description of the demurrage tier. Lower end above which demurrage is charged and percentage of demurrage charged. This rate only applies for the amount of money above the lower end of the tier number up to the lower end of the next tier number. For the last tier, dependant on number of tiers chosen, the rate applies to everything above the lower end of the tier.
- Common good spending mode:
  - Fixed: a fixed amount is spent, regardless of population size.
  - Per capita: a fixed amount per population size is spent.
- Common good budget: the amount available for common good services. If a per capita spending mode is chosen, this amount is multiplied with the population size.

The initialisation happens during the first cycle of the simulation. After that the following steps are executed during each cycle:

- Copy the previous money mass.
- Copy the previous inflation rate.
- Calculate demurrage on the available money mass and move this amount from the current money mass to a common good holding account.
- Calculate per capita demurrage.
- Grow the population.
- Apply the inflation rate to the guaranteed income, common good budget and demurrage tiers.
- Add population size * guaranteed income to the money mass. Add this amount to the created money for this cycle.
- Determine whether additional money needs to be created to pay for the common good. If the demurrage collected from the previous cycle is larger than the needed budget, this is a negative number. Add the amount to the money created for this cycle. This can result in negative money creation.
- Add the complete common good budget to the money mass.
- Calculate per capita balance.

- Calculate per capita money creation. This can be a negative number.

Simulation output

All amounts can be adjusted for inflation.

The algorithm produces the following results:

- Equilibrium balance: this the per capita balance where income, from guaranteed income and spending for the common good, equals the per capita demurrage fee. This balance is only calculated for the initial cycle. It's inflation adjusted amount does not change during the simulation since the guaranteed income, common good spending and demurrage tiers are all equally affected by inflation.
- Population per cycle.
- Total money mass per cycle.
- Money mass per capita per cycle.
- Demurrage per cycle.
- Demurrage per capita per cycle.
- Money creation and destruction per cycle.
- Money creation and destruction per capita per cycle.
- Percentages of total money mass:
    - Income percentage
    - Demurrage percentage
    - Common good spending
    - New money

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