Voting, flat tax and basic income: Effects on equality

Bachelor's Project Thesis

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Abstract: I extend an economic model to compare two government agents with regard to income and money distribution in a multi-agent system (MAS) of firms and households. Each month of the simulation households are taxed and receive a universal basic income (UBI) by a government agent. The government agents implement two different processes of determining a flat tax and UBI. Both processes are dependent on voting by the population of households. The first agent is modelled after the voting process of a representative democracy while the second agent models a direct democracy.

Between firms and households two types of relationships exist. Firstly, firms produce items which are sold to households. Secondly, firms employ households to produce items. Each month, item prices and wages are updated based on supply and demand.

The model is used to test which government achieves the highest income equality between households, as determined by the Gini index. It is also evaluated whether flat tax and UBI are effective measures of redistribution, as measured by the Gini index. While overall both governance types produce similar economic metrics the direct government tends towards less redistribution. Under the flat tax and UBI proposal a small effect size on money distribution among households was observed.

1 Introduction

Enabling a strong safety net for individuals to rely on is a key goal of social market economies. In practice safety nets are complex systems. Some key components of a social safety net are access to pension, health care and unemployment insurance. According to the Federal Foreign Office of Germany public social spending accounts for 25.1% of Germany's gross domestic product (GDP) or 996 billion Euros (Auswärtiges Amt, 2020). A portion of this spending can be attributed to managing the complexity of such a system. The Federal Statistical Office in Germany publishes data on the cost and time that bureaucracy imposes on citizens, businesses and public authorities. However this data only estimates the changes in bureaucratic cost compared to the previous year (Destatis, 2012-2018).

To consider an individual eligible for support safety nets usually implement two tests. First, a means test evaluates an individual's financial situation. Second, a work test evaluates an individual's willingness to work. Only so long as both tests are passed support may be received. So long as an individual is receiving support testing continues in regular intervals. Eligibility testing constitutes a large portion of bureaucratic cost for a social safety net. It also puts pressure on the side of support recipients to continuously prove that they are in need.

The introduction of a Universal Basic Income (UBI) into social safety nets could improve on the above mentioned problems. Van Parijs (2004) defines UBI as "... an income paid by a political community to all its members on an individual basis, without means test or work requirement." A detailed discussion of the pros and contras and the possible forms and difficulties of integration into an existing safety net doesn't find space in this work and is covered by Van Parijs (2004). Importantly he stresses that UBI should supplement existing safety net features. As an example, health insurance could hardly be replaced by UBI as medical expenses may far exceed the amount of UBI that an individual would receive in a lifetime. On the other hand UBI has the potential to reduce the complexity of a safety net by replacing some of its inner systems such as unemployment or child benefits. Alongside complexity, bureaucracy is also decreased with no need for means and work tests. Additionally, UBI has the power to incentivize work, to create better jobs and to reduce stigma for those who receive benefits. Lastly, while more individuals will receive benefits compared to a test based system UBI has the potential to be cheaper overall as Van Parijs (2004) lays out. The claim is that finding those who are unwilling to work, those who are rich and those who are poor is costlier than simply paying them.

Enabling a safety net requires funds and therefore depends on taxation. This is also discussed by Van Parijs (2004). Funding UBI could be done from existing safety net money pools. Alternatively some authors propose a separate money pot filled by new tax streams. Beyond taxation other approaches to funding UBI are possible. For example, the U.S. state Alaska has implemented a form of UBI. Here the funds partially originate from dividends on a state run investment fund. In the future further development in automation and artificial intelligence (AI) may be another source of funding with states or nations investing in largely AI run companies. Nonetheless, taxation remains the most important source of funding for social safety nets and hence will be the further focus of this work. For the calendar year 2019 income tax in Germany results in 283 billion Euros of tax income (Bundesministerium der Finanzen, 2019). Accounting for 39% of the total German tax income in 2019, income tax is the largest source of tax income collected from natural people. Therefore as a means of funding a safety net I further investigate income tax by comparing a progressive and flat income tax.

Progressive tax describes a form of income tax where the tax rate is dependent on the income itself (Bundesministerium der Finanzen, 2014). The relationship between tax rate and income is usually not linear but tiered by income thresholds. For example, in Germany singles from the 1. January 2020 may earn up to 9408 Euros annually income tax free. On any Euro additionally earned an income tax of 14% has to be paid. All tiers below an individuals income apply, with the first 9408 Euros being tax free, the next portion of income being taxed at a rate of 14% and so forth. At an income of 55961 Euros the second highest tax tier is reached with a tax rate of 42%. The top tier is set at 45% from 265327 Euros onwards. The progressive systems is not intuitive. The tiering is finite so that the highest thresholds are relatively low. As a result wealthy and rich individuals fall into the same tax tier. Additionally, setting tier thresholds in a fair manner is difficult entering the terrain of voting and setting political direction. Friedman (1996) argues that the wealthier 90% of the population voting for a tax exemption of the poorest 10% is acceptable while the lower 90% imposing higher taxes on the wealthiest 10% without being affected themselves isn't. Of course this argument is debateable; maybe most naively as: in democracy the majority rules. However laws and rules applying equally to all constitutes an important mechanism of self regulation.

A more intuitive alternative to the progressive income tax is described by the flat income tax. Here, the same tax rate applies to all individuals regardless of income. In 2007 the flat tax had found its way into over 20 countries including 5 member states of the European Union (EU) (ECB, 2007). Among the supporters for flat tax systems have been Friedman (1996) and Atkinson (1995). For example, Friedman finds that flat tax would perform equally or better than progressive taxation with regards to tax income and wealth redistribution by reducing incentives for tax avoidance and evasion. With real world examples in place the European Central Bank (ECB) doesn't view flat tax as positively as its academic proponents. The ECB concludes that while the implementation of flat tax has been accompanied by growth in said EU countries, large structural reforms accompanying the onset of a flat tax system make it difficult to isolate flat tax as the key ingredient for the observed growth (ECB, 2007). Another finding is that while flat tax is perceived as more intuitive by taxpayers compared to progressive income tax, a simplification of tax deductions and exceptions is necessary to effectively reduce complexity.

So far I have discussed and argued for UBI and the flat tax. The process of setting an amount of UBI and a tax rate is dependent on voting. In a democracy this voting process depends on agreement between multiple individuals and the information available to them. I will introduce the concepts of representative democracy and direct democracy. In a representative democracy political decisions are made by representatives of some population (Deutscher Bundestag, n. d.). The people vote for political parties or representatives who hold their office for a limited amount of time. Usually representatives come together in an institution such as parliament where votes are held between them. Germany is an example of a representative democracy. In the process of direct democracy a population doesn't transfer the political decision process to representatives but instead they directly cast votes on specific subject matters (bpb, 2018). While not fully a direct democracy, strong elements of direct democracy are found in Switzerland.

In this work I have extended a computer model simulating an economy with flat tax and UBI. The UBI paid to individuals in this model is proportional to the voted tax rate. I use this model to compare two voting processes that determine flat tax and UBI rate. The two voting processes are modelled after representative and direct democracy. The comparison is founded on two metrics of equality. First, the distribution of income amongst households in the model is quantified by the Gini coefficient (FU-Berlin, n.d.). Second, the distribution of liquidity amongst households is also quantified by the Gini coefficient but calculated on the basis of money distribution. Because direct democracy compared to representative democracy is a more accurate representation of a population I hypothesize it to result in a more equal society as indicated by the above metrics. I arrive at the following two research questions: First, "does direct democracy lead to a more equal society as measured by the Gini index compared to representative democracy?" and second, "is the flat tax and universal basic income proposal an effective measure for wealth redistribution?"

2 Preliminaries

The economic model used to test the research question extends a model baseline economy proposed by Lengnick (2013). Lengnick's model consists of two types of agents; firms and households. Firms and households can have two types of relationships. Vendor-customer and employer-employee relations. The relationships are dynamic and may change given the agents' circumstances. In my extension of the model a third type of agent is introduced called the government agent. This agent collects taxes from households and redistributes this tax income as UBI.

The designed model follows the multi-agent systems (MAS) paradigm. A definition of an agent is presented by Wooldridge (2009). "An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its delegated objectives." As such a MAS houses multiple agents to interact either directly or indirectly through a shared environment. For example negotiation applies in Lengnick's baseline model when a household considers a firm as employer; negotiation could fail because the offered wage may be too low. In the extension of the model multi-agent interaction applies during the tax and UBI voting processes modeled after representative or direct democracy. In his paper Lengnick defends the MAS paradigm against previous non-MAS approaches. Lengnick (2013) argues against what he calls "assumptions of the holy trinity of rationality, equilibrium and greed" in top-down economic models such as the Walrasian auctioneer. The bottom-up approach of MAS doesn't make these assumptions and shows that they are not necessary. The MAS model produces economic phenomena through emergent behavior; this is discussed further in the next paragraph. On the other hand, multi-agent systems introduce new problems of setting a large number of model parameters and initial conditions. I selected Lengnick's baseline economy as a foundation for my work because of its conceptual and computational simplicity compared to other MAS models. EURACE for example is a simulation by Deissenberg, van der Hoog, and Dawid (2009) modelling the economy of the European Union (EU) that is conceptually closer to a real world economy but more complex than Lengnick's model.

Lengnick's baseline model shows ecological validity by reproducing real world economic behaviors. As Lengnick (2013) argues the validating behaviors are emergent in contrast to top-down modelling approaches. Ecological validity is desireable for a model in order for findings made in the model to apply to real world settings. Next I give an overview of the validating findings.

First, Lengnick's model produces a close to real world equilibrium of employment rates between 4.3% and 0%. Lengnick explains that not accounting for structural unemployment in the model is a reason for the equilibrium being lower than empirical data. Second, the baseline economy displays business cycles; these are observed as firms' continuos upward and downward item production rate. Third, the model behaves as real world economies with respect to the relationship between unemployment and the rate of change of wages. The relationship is such that during times of high labour demand the firms compete for employees leading to wage increases at a growing rate. As labour demand is low firms hire less and decrease wages at a slow rate. Thus households' reservation wages are not being met and households are unwilling to work furthering unemployment. This is known as the original Phillips Curve (Phillips, 1958). Fourth, Lengnick's model produces the Beveridge Curve; a relationship between unemployment and vacancies. As vacancies increase unemployment decreases. Fifth, the baseline model displays a right skew in the distribution of firm sizes; in other words there are many small firms and fewer large ones. Sixth, the model shows right skewness in the distribution for the number of firms adjusting their item prices each month. Additionally, Lengnick (2013) cites empirical findings by Nakamura and Steinsson (2008) that show a median between 9% and 12% for firms changing prices; Lengnick's model meets this range displaying a median of 9%. Seventh, empirical data shows that increased GDP is followed by increased prices with some lag; this observation is met by the model. Eighth, in the long run artificially increasing the model's money supply doesn't impact the number of items produced by firms within some time frame. This is in line with empirical observations.

The central measure for economic equality under the given research questions is the Gini coefficient. The Gini coefficient was chosen because of its wide use in macroeconomics and the resulting wide availability of empirical data enabling future comparisons to model data. In this work the Gini coefficient is used to measure the distribution of household incomes and liquidity. In macroeconomics the Gini coefficient is more commonly applied to incomes. This may be because data on incomes is more readily available or because measuring the distribution of incomes indicates a trend for financial equality given a single point in time. In contrast the distribution of money at a single point in time cannot predict how the distribution of wealth will develop over time; multiple time points are needed. Throughout this work the terms Gini coefficient and Gini index are used interchangeably.

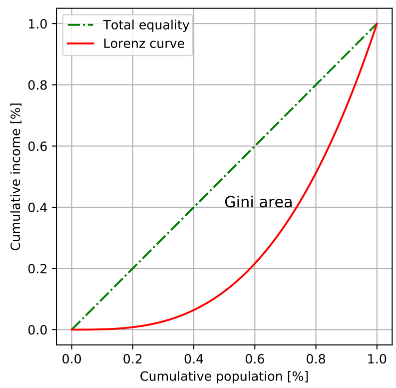

Figure 2.1: Gini coefficient for income distribution.

Figure 2.1 (FU-Berlin, n.d.) illustrates how the Gini coefficient is determined. On the x-axis the figure 2.1 shows the cumulative population in percent; the y-axis indicates the cumulative income in percent. The red curve indicates the distribution of incomes. It is known as Lorenz curve; it's path in this figure is arbitrary serving exemplary purpose. In this example the Lorenz curve indicates that 50% of income is received by around 10% of the population. The dashed green line indicates a totally equal distribution of incomes. Following this line, 50% of income is accounted for by 50% of the population. The Gini area is enclosed by the Lorenz curve in red and the green line of equal income distribution. The Gini coefficient is determined via the Gini area by multiplying with the factor 2 as the axes are normalized to 1. Therefore, a Gini index of 1 describes a totally unequal distribution whereas a Gini coefficient of 0 indicates a totally equal distribution.

3 Methods

3.1 Python reimplementation

For his paper Lengnick (2013) implemented the economic model in the programming language Java. He kindly made this code available on request. The author also pointed me to a project which lead to a rewrite of the model using a simulation building tool that generates JavaScript code (Wagner and Nardin, 2018a). Relying on both code bases I reimplemented the model in Python for three main reasons. Firstly, the Java implementation is written in a C comparable low level style. Im comparison the Python model is written in a higher level style and hence is easier to understand. Secondly, the JavaScript available for download appears incomplete and couldn't be directly run locally. Additionally, the code is written in an unusual format requiring refactoring for extending the model in a common JavaScript style. Third, Python is common in scientific computing and offers libraries for statistics and plotting. This enables integrating the model with the code necessary for analysis. The most considerable downside to an implementation in Python is that the software runs slower compared to the other two programs. However I considered the added simplicity of understanding the code and the scientific framework around Python to outweigh this downside for the purpose of this work. Finally, the Python implementation of the baseline model without government agents consists of 700 lines of code (LOC) while the JavaScript implementation counts 1200 LOC and the Java version is 2100 LOC (Wagner and Nardin, 2018b).

3.2 Model description

In the preliminaries section 2 I have given a short introduction to the model, here I will elaborate on it in more detail. Since the program is written in an object-oriented (OOP) style the description is structured around state variables and methods. Afterwards, an explanation of how taxes may be calculated follows in section 3.3. For the extension of the baseline model that introduces the government agents a pseudo code level of detail will be presented in section 3.4. A full defense of the choices in the baseline model doesn't find place in this work, however I have already discussed its ecological validity in section 2 on top of which the model extension builds.

Table 3.1: Model by agents' state.

Firm	Household	Government
Money	Money	Money
Item price	Employer	Tax rate
Stock size	Preferred vendors	UBI rate
Wage	Reservation wage	
Employees	Daily demand	
Hiring		

The model consists of three types of agents: Households, firms and a government. Following the OOP style each agent corresponds to a separate class. Table 3.1 shows each agent's state variables. The first column indicates that a firm's state is described by its liquidity (money), item price and number of items in stock, the wage paid to employees, a list of employees and the current hiring status of whether to recruit, fire or keep the number of employees constant. A firm may employ an unlimited number of households. The second column in table 3.1 shows that a household's state is described by its liquidity, its employer, a list of preferred vendors, a reservation wage and a daily demand for consumption goods. A household may have one or zero employers. The number of preferred vendors is limited to seven; the preferred vendors may change over time. The third column of table 3.1 shows that a government's state is defined by its liquidity, a flat tax rate and a UBI rate.

The smallest unit of time in the model is a single day while 21 days are considered a month. This choice reflects that the model simulates working days and excludes days off. The model's event loop is structured into actions executed at the beginning of a month, daily actions and actions occurring at the end of a month. Table 3.2 links Python methods for each agent to a time of execution. Next follows a description of these methods.

As table 3.2 shows, in the beginning of a month firms update their wage rate; an increase may be necessary when an employee was searched for last month but not found. Conversely firms decrease wages after a duration of full employment. A wage increase or decrease affects all employees and prospective employees at the same time. Also, firms update their hiring status in order to employ

Table 3.2: Model by agents' methods and time.

Time frame	Firm	Household	Government
Beginning of the month	update_wage() update_hiring_status() update_price()	find_cheaper_vendor() find_stocked_vendor() do_jobsearch() plan_demand()	
Each day	produce_items()	buy_items()	
End of the month	pay_wages() pay_profits() make_layoff_decision()	update_reservation_wage()	vote_tax() collect_tax() calculate_ubi() pay_ubi()

more people when not enough items are produced to meet demand. Conversely, when too many items are in stock workers are fired. Lastly, prices are updated based on stock; low stock means firms increase prices while high stock leads to a price decrease. Also in the beginning of each month, households aim to find better vendors. They go looking for cheaper vendors and aim to replace vendors who were too low on stock to satisfy their demand. Next, unemployed households or households unsatisfied with their wage search for a new employer. Lastly, households plan their demand; this is the number of items that will be consumed each day of the beginning month. The demand is based on a household's money and the average item price amongst its preferred vendors. The government agent doesn't act at the beginning of the month.

The second row of table 3.2 shows, on each day, firms produce items where the produced number of items depends on the number of employees. Also daily, households buy items from firms to satisfy their daily demand. There is no daily action for the government agent.

Row three of table 3.2 shows that at the end of the month firms pay wages to their employees. When unable to pay them fully the wages are cut. When firms make profits a part of these profits are paid out to the entire population of households. The amount paid out is proportional to the money a household has. Lengnick (2013) describes this mechanism as a simplified representation of a stock market. Additionally firms execute their layoff decision of hiring or firing an employee that was made at the beginning of the month. Households may update their reservation wage. Unemployed households lower it over time while employed households will increase their reservation wage when they receive a raise. After firms and households have resolved their actions, the government may vote for a new flat tax rate. While voting takes place at the end of a month it only takes place every 12 months. Each month however, the government collects a flat income tax from all households. A UBI rate is calculated to equally distribute the collected tax income among all households. The government keeps no money to itself; all money that is collected at the end of a month is paid to households after being collected.

3.3 Taxation

Before discussing the government agents in more detail a discussion on how tax rates may be determined is necessary. Atkinson (1995) presents equation 3.1 for optimum taxation in the context of a flat income tax and redistribution through universal basic income.

$$\frac{1}{1-t} = \epsilon * [1 - (1+\eta^2)^{-\gamma} * (1+\epsilon)] \tag{3.1}$$

On the left side of the equation is t, this is the optimum taxation to be calculated. The right hand side is composed of two elements. The term outside square brackets is called efficiency term; the square bracket term is called equity term. Efficiency describes the productivity of an economy. Equity describes how wealth is distributed within an economy. Under Atkinson's proposal, the tax rate therefore is the result of a tradeoff between equity and efficiency. The efficiency term in the equation depends on ϵ. This is the elasticity of labour supply which describes the ratio of change of labour over the change of wage rates (Evers, Mooij, and Vuuren, 2008). As elasticity increases the optimum tax rate t decreases. The equity term depends on η, ϵ and γ. Here, η is a coefficient of variation of incomes similar to the Gini index. The larger η is, the larger is the inequality of incomes within a population. Next, γ is the weight of redistribution; the choice of this parameter is not agreed upon in the literature and reflects how much redistribution is valued. A larger γ leads to higher taxation and more redistribution.

In equation 3.2 Atkinson's equation 3.1 is solved for the tax rate t. However, I was not able to reproduce the numerical examples that Atkinson (1995) presents relying on the presented formula. Given $\epsilon = 0.3, \eta = 0.4$ and $\gamma = 0.5$ the author lists solutions for the equity term as equity $= 0.092$ and for the tax rate as $t = 0.23$. In equation 3.3 it is shown that given his values for ϵ, η and γ the equity term produces a result of -0.21 not in line with Atkinson's findings. In equation 3.4 a tax rate of $t = -2.23$ is computed in contrast to his findings.

$$
\begin{aligned}
\frac{1}{1-t} &= \epsilon * [1 - (1+\eta^2)^{-\gamma} * (1+\epsilon)] \\
\frac{1}{1-t} &= x \\
t &= x * (1-t) \\
t &= x - t * x \\
t + x * t &= x \\
t * (1+x) &= x \\
t &= \frac{x}{1+x} \\
t &= \frac{\epsilon * [1 - (1+\eta^2)^{-\gamma} * (1+\epsilon)]}{1 + \epsilon * [1 - (1+\eta^2)^{-\gamma} * (1+\epsilon)]}
\end{aligned}
\tag{3.2}
$$

$$
1 - (1+0.4^2)^{-0.5} * (1+0.3)] = -0.21 \tag{3.3}
$$

$$
\frac{0.3 * [1 - (1+0.4^2)^{-0.5} * (1+0.3)]}{1 + 0.3 * [1 - (1+0.4^2)^{-0.5} * (1+0.3)]} = -2.23 \tag{3.4}
$$

As a result of the above observations the tax equation as presented by Atkinson cannot be used for the purposes of this work. However the equity term by itself without the inner term $(1+\epsilon)$ does produce reasonable tax values between 0 and 1. Therefore I propose the equation 3.5 for the calculation of tax rates. The variable η^2 is replaced by the Gini coefficient for the distribution of liquidity in the household population. The Gini coefficient in combination with γ as weighting parameter for distribution behaves similar to the Atkinson's descriptions of the equity term. He writes that as γ approaches infinity, the equity term approaches 1 and when γ approaches 0 so does the equity term. Both behaviors are reproduced by equation 3.5.

$$
t = 1 - (1 + Gini)^{-\gamma} \tag{3.5}
$$

The equation serves as foundation for the calculation of taxes by the direct democracy and representative democracy agents. While the Gini coefficient is an economic factor, γ serves as angle point for the voting process. The voting processes are designed such that poor voters tend towards higher values of γ leading to higher taxation and redistribution through UBI. Conversely, rich voters are designed to tend towards low γ, tax and UBI. How this is implemented is shown in the following section 3.4.

3.4 Two government agents

The direct democracy agent and the representative government agent share the same state variables and methods for tax collection, calculating UBI and paying UBI. Each government has the purpose and goal to redistribute wealth by taxation and UBI payments. The extent to which that goal is achieved is quantified by a decrease in the Gini coefficient with regard to income and money distribution. The governments differ in their processes of determining what tax and UBI to set. While both rely on the tax equation 3.5, the way that the household population impacts the parameter γ varies.

The representative democracy agent introduces an additional state variable not shown in table 3.1 that tracks the composition of a parliament by the number of members per political party. Before the representative agent can initiate voting on a new flat tax a parliament must be in place. The representative democracy relies on the additional method `assemble_parliament()` in order to determine parliament's composition. This process is describe in pseudo code, see algorithm 3.1. House-

Algorithm 3.1 Assemble parliament

1: $hh[] \Leftarrow$ ascending list of hh by income
2: $i[] \Leftarrow \int hh[]$
3: $nI[] \Leftarrow \mathrm{norm}(i[])$
4: $x[] \Leftarrow$ ascending list from 0 to $nI[]$.length -1
5: $nX[] \Leftarrow \mathrm{norm}(x[])$
6: $f \Leftarrow \mathrm{interpolate}(nX, nI)$
7: $numP \Leftarrow$ number of parties
8: $p[] \Leftarrow$ empty list of length $numP$
9: $step \Leftarrow 1/numP$
10: $pCount \Leftarrow 1$
11: **while** $pCount < numP + 1$ **do**
12: $\quad p[pCount] \Leftarrow f(step * pCount) - f(step * (pCount - 1))$
13: $\quad pCount \Leftarrow pCount + 1$
14: **end while**

Algorithm 3.2 Representative flat tax vote

1: $month \Leftarrow$ current month
2: **if** $month \mod 12 \neq 0$ **then**
3: $\quad$ **return**
4: **end if**
5: $tL \Leftarrow 48$
6: **if** $month \mod tL = 0$ **then**
7: $\quad$ AssembleParliament( )
8: **end if**
9: $p[] \Leftarrow$ parliament composition
10: $numP \Leftarrow$ number of parties
11: $mG \Leftarrow$ mean Gini over last year
12: $y \Leftarrow 4$
13: $yStep \Leftarrow y/(numP - 1)$
14: $tax, pCount \Leftarrow 0$
15: **while** $pCount < p[]$.length **do**
16: $\quad tax \Leftarrow tax + (1 - (1 + mG)^{-y}) * p[pCount]$
17: $\quad y \Leftarrow y - yStep$
18: $\quad pCount \Leftarrow pCount + 1$
19: **end while**

holds are abbreviated by hh, income by i and party by p while $step$ refers to a portion size of cumulative incomes. Line 2 shows that $i[]$ is the result of integration over the list of household incomes. The number of parties in parliament is controlled by $numP$ in line 7. I have chosen $numP = 5$ and $step = 0.2$ enabling a division of cumulative incomes into quintiles. The effect of algorithm 3.1 is that party size is proportional to the number of households that form a quintile income group. For example when 20% of incomes are accumulated among the poorest 40% of households then the party representing this group will have a weight of 40% of seats in parliament. Line 6 shows that linear interpolation is used to draw quintiles precisely. An implementation without interpolation is also possible; this approach is presented as listing 7.1 in the appendix section 7. The parliamentary composition of seats is stored in the list $p[]$. After completion of the while loop from lines 11 to 14, $p[]$ holds 5 entries, according to the number of parties. Each entry holds a number which indicates how many households account for 20% of incomes amongst households. The entries are ordered from left to right as poor to rich. The entries in $p[]$ are either decreasing or equal from the beginning to the end of the list. The resulting $p[]$ is used in the voting process of the representative government.

Listing 3.2 shows the pseudo code on how the representative agent votes on a tax rate. Line 7 shows the dependency on the algorithm 3.1 to assemble parliament. Lines 1 to 4 control that tax rate is only adjusted every 12 months. Lines 5 to 8 control that parliament is changed every 4 years. The choice of these parameters is elaborated in section 3.7. The variable $p[]$ results from execution of algorithm 3.2. Line 16 contains the tax equation 3.5 where y in the code is γ in the equation. The behavior of y is such that it begins at 4 and decreases to 0 in steps of 1 with each iteration of the while loop. The party representing the poorest households begins with $y = 4$. The variable $p[pCount]$ in line 16 factors in the weighting of a party. The weights of each party in $p[]$ sum up to 1. Once the while loop is completed, a tax rate has been determined.

Listing 3.3 shows the pseudo code on how the direct agent votes on a tax rate. As in the case of the representative agent, the tax rate is only adjusted yearly, see lines 1-4. In line 7 mY refers to the maximum y or γ as in equation 3.5. The while loop from line 9 to 13 iterates over the number of households. In line 10 y is calculated. The result of y is between 0 and 4 for each household with the poorest household producing $y = 4$ and the richest household producing $y = 0$. Where each household positions itself between both extremes may be interpreted in two ways. First, it can be considered the distance of a household's income from the mean

Algorithm 3.3 Direct flat tax vote

1: $month \Leftarrow$ current month
2: **if** $month \mod 12 \neq 0$ **then**
3:     **return**
4: **end if**
5: $mG \Leftarrow$ mean Gini over last year
6: $hh[] \Leftarrow$ ascending list of hh by income
7: $mY \Leftarrow 4$
8: tax, $hhCount \Leftarrow 0$
9: **while** $hhCount < hh[].\text{length}$ **do**
10:     $y \Leftarrow mY * (hh[hhCount].income - maxI)/(minI - maxI)$
11:     $tax \Leftarrow tax + (1 - (1 + mG)^{-y}$
12:     $hhCount \Leftarrow hhCount + 1$
13: **end while**
14: $tax \Leftarrow tax/hh[].\text{length}$

household income normalized to the range of 0 to 4. Second, it can also be considered as the ratio of a single household income over the sum of incomes with the same normalization to 0 and 4. Line 11 incorporates the tax equation 3.5. In line 14 the sum of voted taxes is averaged to a single tax rate between 0 and 1.

For both the representative and direct government agents an approach of composition between single tax proposals, either party proposals or individual household proposals, into a final tax was chosen. This approach was taken for two main reasons. First, I considered that each party or household should play a role. This is because in democracies legislation is not only the result of majorities but the result of a complex process of negotiation between multiple players on multiple levels that also involves minorities. A majority vote serves as final decision maker but in this model it would not be sufficiently reflective of the prior processes. Second, while a populations' poorer majority is at a number advantage a richer minority has other means of influence. An example may be influence through control over privately owned media.

3.5 Parameters and Materials

A fully detailed list of firm, household and government parameters is listed in the appendix section 7. Most parameters have been chosen following the proposed values by Lengnick (2013). This includes the number of 1000 households and 100 firms being simulated. A further increase of these parameters would be computationally too expensive. Next I will discuss deviations from Lengnick's parameters.

Firstly the number of months simulated were reduced from Lengnick's 7000 months to 600 months. This was done to reduce the runtime of the model making it feasible to run all testing conditions in less than 30 minutes real time without access to remote computing. Initial testing of the model also showed that the simulated economy stabilizes after 200 months following the initial conditions. The burn in duration of 1000 months (included in the 7000 months) chosen by Lengnick therefore didn't seem necessary. Burn in duration refers to the time the model is impacted by unrealistic initial conditions. For each condition a number of 10 repetitions was chosen. Since single runs given the same conditions produce similar results I consider the number of repetitions acceptable in order to not further increase compute time.

A newly introduced parameter into the model is γ as part of the tax equation 3.5 used by the government agents. This parameter is set to be in the range of 0 to 4. I have chosen this range because given a Gini coefficient of 0.3 the tax equation produces a tax rate of 0% given $\gamma = 0$ and a tax rate of 65% given $\gamma = 4$. Empirical data from the EU shows an average Gini coefficient of around 0.3 (eurostat, 2020). Given real world taxation I consider the tax range produced as a result of the range for γ realistic. Another parameter introduced by the representative government agent is the number of parties being 5. The reason for choosing 5 is firstly that quintiles are commonly used in social statistics when presenting economic data (eurostat, 2018). Secondly, multi party systems are common in Europe. The representative government relies on a term length of 4 years. This value was chosen since it is common in real world representative democracies. Lastly, the government agents are set to update the tax rate each year. The term length was not chosen shorter because government decisions should be based on economic data and as such sufficient time is necessary to aggregate said data. A longer interval was not chosen because otherwise the update frequency would be too close to the term length of the representative government. With tax updates and term endings occurring simultaneously the effect of one event could obfuscate the effect of the other.

For reproducibility, randomness in the simulation is controlled by choosing a seed; this seed is also listed in the appendix. Pseudorandom numbers are generated by manipulating a previously given value. The seed serves as an initial value; as a result the sequence of generated numbers that follow the initial value is reproducible. The choice of a seed further provides that a comparison of the experimental conditions is not confounded by randomness as the same randomness will be produced in either condition.

The program implementing the model is developed using Python version 3.8.2. The source code of the developed program is available online on GitHub (Tappe Maestro, 2020). The program relies on modules which are not part of the Python standard library. These modules are Matplotlib version 3.3.1, Numpy version 1.19.1 and SciPy version 1.5.2. Instructions on the installation of the software needed to run the simulation is presented alongside the source code in a readme file. To compute the Gini coefficient the developed program relies on a computationally fast implementation provided by Guest (2017) for the purpose of another work (Guest and Love, 2017).

3.6 Procedure

The model is run in three conditions. Firstly, without a government agent in place; this is equivalent to the baseline model of Lengnick (2013). The run without a government serves as baseline to validate that the redistribution performed by the governments is effective. Second and third runs are done with the representative and the direct government agents in place. For each condition 600 months are simulated with 10 repetitions per government agent. For each condition the default number of 100 firms and 1000 households were used. The program implementing the model can be controlled by command line arguments to set the number of months, runs, firms and households and also the type of government. Code listing 1 shows the command line arguments provided to the program for each condition.

Listing 1: Command line arguments

```
python3 main.py --months 600 --runs 10 --gov none
python3 main.py --months 600 --runs 10 --gov rep
python3 main.py --months 600 --runs 10 --gov dir
```

3.7 Analysis

The behavior of the model is analyzed by a statistics module that is integrated into the Python program; the module lives in the program files `statistician.py`, `stat_run.py` and `stat_runs.py`. The statistics module listens to events in the simulation and writes the data to Python dictionaries containing NumPy arrays. NumPy is a Python library that handles array, vector and matrix operations. As data from the model is recorded it is transformed into other representations, specifically averages, sums and coefficients; these representations are also stored. After a single run has been completed the statistics module is capable of creating figures to visualize the data of a single run. When multiple runs are simulated the statistics module can calculate averages and standard errors aggregating the data of multiple runs; afterwards the statistics module may also visualize these results. For processing in other environments the statistics module is enabled to write all generated data to file.

4 Results

I present a series of results for three experimental conditions. First, the simulation is run with no government in place. Second and third the direct and representative government agents are active in the simulation. The simulation was run over the course of 600 months. All months are included in the figures. No data points were excluded as outliers. The first 200 months are part of a burn in period resulting from the initial conditions of the simulation until the model approaches a state of equilibrium.

Figure 4.1 shows two metrics of economic equality with no government agent in place. Without a government taxation and redistribution by UBI don't take place. Along the x-axis time in months is shown. Along the y-axis equality is given in a range from 0 to 1. Here, 0 indicates a uniform distribution of income or money whereas a value of 1 represents that all income or money is concentrated to a single household. The red line graph shows the Gini coefficient for household money whereas

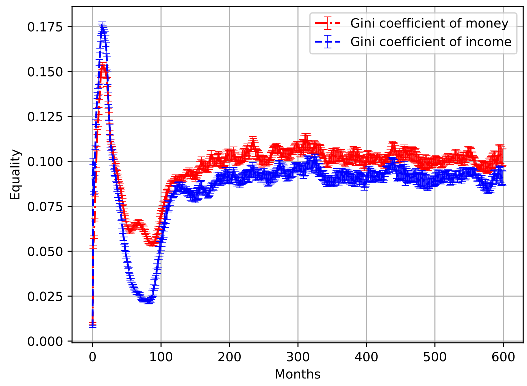

Figure 4.1: No government. Gini coefficients of income and money distribution among households.

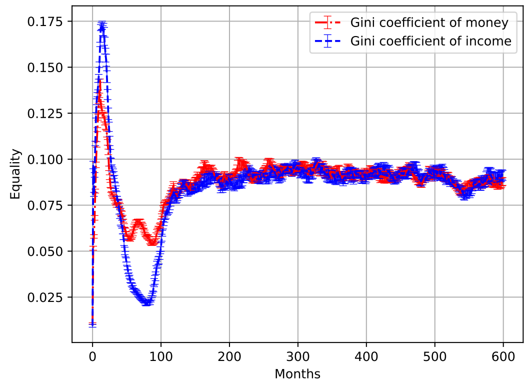

Figure 4.2: Representative government. Gini coefficients of income and money distribution among households.

the blue graph shows the Gini coefficient for household income. Both lines are generated from averaging data over 10 runs; as such error bars are presented. During the burn in period both coefficients show initial peaks to 0.15 and 0.175 within the first 20 months. The peaks are followed by dips to 0.05 and 0.025 at around 90 months time. Subsequently both graphs approach a point of equilibrium at around 200 months. The equilibrium for money distribution as measured by the Gini coefficient lies around 0.1. The equilibrium for income distribution as measured by the Gini coefficient is found at around 0.09. The above observations serve as baseline to analyse the effects of the representative and direct government agents on equality.

Figure 4.2 shows the same equality metrics as the previous figure 4.1. However figure 4.2 is produced with the representative government agent in place. With regard to the burn in phase, this figure shows a lower peak for the money coefficient at around 0.14 while the peak of the income coefficient ist identical at 0.175. The following dips are similar in value to the no government setting. The Gini coefficient of money distribution produces an equilibrium at around 0.9; this is lower than the equilibrium produced without a government agent. The Gini coefficient of income distribution is similar at 0.9 between the representative government and the no government setting.

Figure 4.3 again shows the Gini coefficient with regard to money and income amongst households.

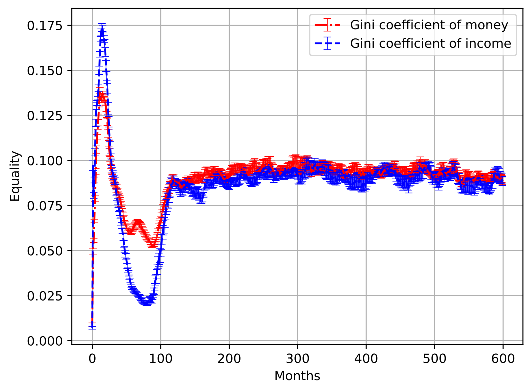

Figure 4.3: Direct government. Gini coefficients of income and money distribution among households.

For this figure the direct democracy government agent was used. The curves are similar to figure 4.2 produced by the representative agent. For the Gini income curve no differences are visible with regards to the burn in phase nor the equilibrium. The direct government's Gini money curve goes into equilibrium slightly above the representative governments' at around 0.095.

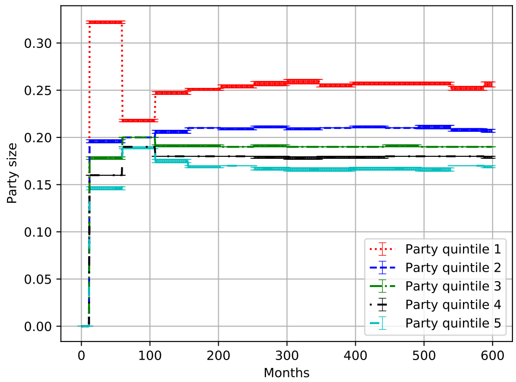

Figure 4.4: Representative government. Parliamentary composition.

Figure 4.4 shows the parliamentary composition of the representative government agent over time. The x-axis shows time in months. The y-axis shows the ratio of parliamentary seats occupied by a single party where 1 means all seats and 0 none. Party quintile 1 represents the poorest 20% of the household population while party quintile 5 represents the richest 20% with regards to income. When comparing this figure with the previous figure 4.1 showing the Gini coefficients then the effects of varying equality levels on parliamentary composition become apparent. Where the Gini coefficients peak within the first 20 months of the burn in phase, indicating a decrease in equality, the quintile 1 party also peaks in seats. Similarly, the dip following the peak can be observed. With regards to parliamentary composition this shows as parties becoming equal in size around a value of 20% seats in months 80-100. An equilibrium in party sizes can also be observed after 200 months. The quintile 1 party finds its equilibrium at around 26% seats indicating that the poorest 26% of households account for 20% of the total income received by households.

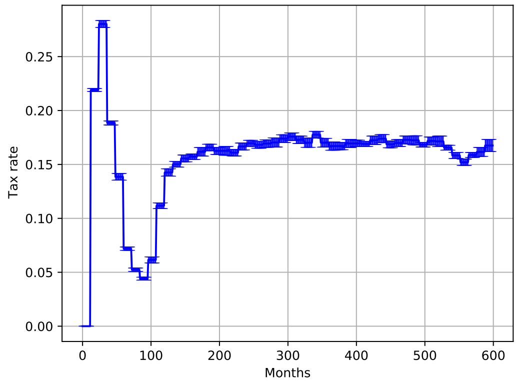

Figure 4.5: Representative government. Tax rate.

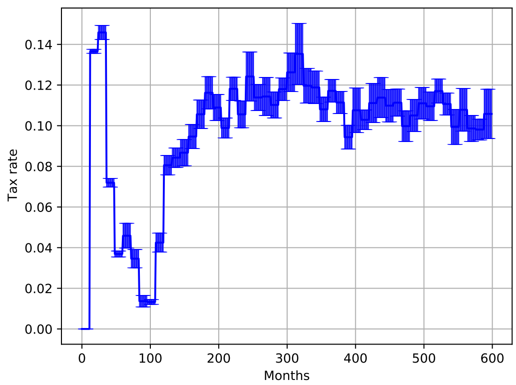

Figure 4.6: Direct government. Tax rate.

Figures 4.5 and 4.6 show tax rates over time for the representative and the direct democracy governments respectively. The x-axis of both figures gives time in months while the y-axis shows the tax rate between 0 and 1. Both graphs show that the tax rates follow the peak and dip of equality during the burn in period shown by the Gini coefficients in previous figures 4.1, 4.2 and 4.3. The peak at month 20 of the representative government is higher at 28% taxation compared to the direct government at 14.5%. The dip at month 90 of the direct government is lower at 1.5% compared to the representative government's tax at 5%. Beyond month 200 the representative government displays an average tax rate equilibrium of 17.5%. The representative government shows little variation around this tax rate. The direct government produces an equilibrium at 11%. Additionally there are regular fluctuations between 10% and 12% as indicated by the larger standard error. The direct government enters a tax rate equilibrium beyond month 400; this is 200 months later than the representative government.

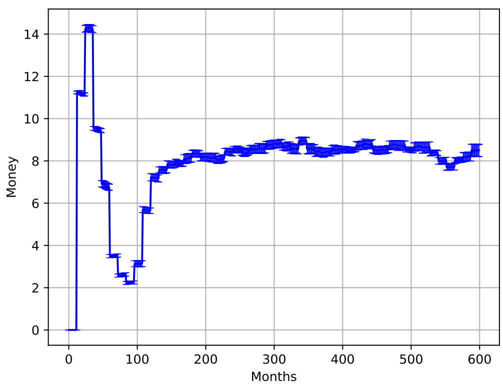

Figure 4.7: Representative government. UBI rate.

Figures 4.7 and 4.8 show UBI rates for the representative and direct governments respectively. The x-axis displays time in months, the y-axis shows the amount of money paid. Noticeably both graphs closely follow the course of the previously presented tax curves for each government type. The representative government's UBI peaks at 14 for month 20 and is lowest at month 90 at 2. An equilibrium

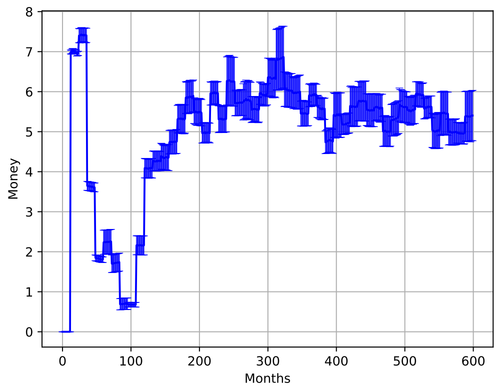

Figure 4.8: Direct government. UBI rate.

is entered beyond month 200 at 8.5 money units. The direct government's UBI shows a burn in phase peak of 7.5 money units followed by a dip to 0.75 money units. Beyond month 200 the UBI averages at 5.5 money units; this is 3 money units lower than the representative government. The direct government also shows stronger variation from 4.75 to 6.25 money units. The lower UBI and stronger variation of tax rates is in line with the tax rate observations shown in figure 4.6.

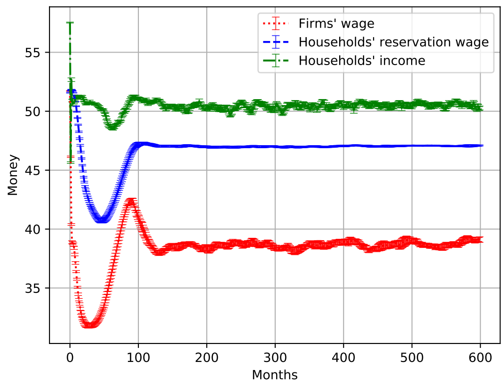

Figure 4.9: No government. Firms' wage rate and households' reservation wage and income.

Figure 4.9 shows the average wage paid by firms, the average reservation wage expected by households and the average household income. On the x-axis time in number of months is shown. The y-axis indicates the amount of money. I have not included the corresponding graphs for the representative and direct government agent here since they are not noticeably distinguishable from the no government setting. This implies that between no government, the representative and the direct government no effect on firms' wage rates, households' income or their reservation wage was found. Both excluded figures 8.1 and 8.2 can be found in the appendix 8. Figure 4.9 is shown nonetheless to put the tax and UBI rates previously presented into perspective. The representative government displays an average UBI rate of 8.5 monetary units. As the households' income finds equilibrium between 50 and 51 money units the monthly paid UBI is equal to 17% of households' average monthly income; this is the observed tax rate equilibrium for the representative government. The same relationship holds for the representative government with a UBI equilibrium around 5.5 monetary units. Here the monthly UBI relates to 9% of households' average monthly income. This is 2% below the observed tax rate; this difference is likely explained by the strong variation associated with the direct government. As a consequence of the observed relationships, households receiving higher than average incomes pay more in taxes than they receive in UBI payments. In contrast households earning less than average receive more UBI than they pay in taxes. The difference between the firms' average wage rate and households' income visible in figure 4.9 is explained by firms' profit payments which are added to wage payments as household income; UBI is not included in this income measure as no taxes are deducted from UBI. The average reservation wage of households finds an equilibrium above the average wage paid by firms, this is to be expected.

As can be seen in figures 8.3 and 8.4 listed in the appendix section 8, households on average possess 97 monetary units in both government conditions while firms possess 35 monetary units on average. As such, the UBI payments account to near 9% of households' average liquidity for the representative government and near 6% for the direct agent. Additionally, there is no observable difference in employment rates between either of the governments or no government, see figures 8.5 and 8.6 in the appendix 8. In either setting employment rates of around 98% can be observed. With regard to firms' item pricing the three experimental settings also behave similarly to each other. For each setting, the item price equilibrium is situated at 0.81 monetary unites per item, see figures 8.7 and 8.8 in the appendix section 8. Given the findings of similar income and liquidity between settings a similar item price means that households are able to satisfy similar demands between settings.

5 Discussion

5.1 Conclusion

In this work two research questions were developed. First, "does direct democracy lead to a more equal society as measured by the Gini index compared to representative democracy?" and second, "is the flat tax and universal basic income proposal an effective measure for wealth redistribution?" First it was hypothesized that, direct democracy would result in a more equal distribution of wages as measured by the Gini index compared to representative democracy. This hypothesis supports itself on the assumption that direct democracy offers a higher resolution of inequality within a population. The second hypothesis is the assumption that the flat tax and UBI proposal is an effective measure for redistribution. This hypothesis is founded on limited empirical data. The results show no significant difference between direct democracy and representative democracy with regard to equality as measured by the Gini index in the presented model. Multiple metrics were similar between the representative and the democratic government agents: the Gini index based on income, households' employment rate and households' ability to satisfy demand. Differences between both governments were small. The differences include a slightly higher Gini money index and a lower tax rate and UBI both with higher variation for the direct government compared to the representative one. These finding are contrary to the first hypothesis of more redistribution under the direct government agent. Additionally, while an effect of redistribution by flat tax and UBI on the Gini coefficient is observable compared to when no redistribution takes place the observed difference is small. The effect was observed with regard to the distribution of money but not with regard to the distribution of incomes.

5.2 Problem discussion

The absence of a strong observable effect between the direct and representative government conditions is to some extent illuminated by the little effect that redistribution for both governments has on the model. While the Gini coefficient with regard to money distribution is slightly impacted between conditions other metrics such as employment rate or item price aren't. Given the small effect size it is difficult to present founded arguments for how the internal workings of the government agents explain the observations. In section 2 I describe economic findings validating the model. Specifically, unemployment is discussed as being low compared to empirical data. Lengnick (2013), the original author of the model extended for this work, argues that this is in part explained by the absence of structural employment in the model. Similarly, the Gini index produced by the model, also when no redistribution takes place, is lower than what is found in empirical data (eurostat, 2020). This leads the argument that the model does not produce sufficient levels of inequality in order to satisfyingly enable a comparison between the two developed government agents whose purpose is reducing inequality.

5.3 Future outlook

More inequality in line with empirical data is not straight forwardly introduced into the model. Adding additional systems which would model the given example of structural unemployment are contrary to the baseline nature of the model and its simplicity. A simpler solution could be provided by addressing the parameter settings. For the extension of Lengnick's model I have relied on the parameters provided by the original author where possible. A more unequal income distribution could be achieved by for example an increase in the technology level of firms leading to a single employee household producing more items. Testing in this direction shows that the duration of the burn in phase is increased and that during the burn in phase higher Gini coefficients are observed; however after the burn in phase, the Gini coefficient returns to sub empirically supported levels. Because parameter choice is considered a general difficulty of multi-agent systems (MAS) the outcome of this initial test is not surprising.

Lastly, while the research question couldn't be positively answered I consider equality, more direct participation and a better representation of a population important for the future of democracy. I only compared representative and direct democracy in this work however advances in technology and data collection at an increasing rate seem to invite a yet more direct form of participation that could be called data democracy. Perhaps the first attempt at an implementation of a heavily computerized approach to governance is described by Eden Medina (2011) in her book about Chile's 1970s Allende government.

This work discussed direct democracy as a more direct means of political participation, multi-agent systems as a testing playground and the flat tax UBI proposal as means of providing a social safety net while reducing complexity and bureaucracy. Each component may hint a how democracy will develop when data, algorithms and artificial intelligence become involved in political decision making.

References

A. B. Atkinson. *Public economics in action : the basic income/flat tax proposal.* (Ser. The lindahl lectures). Oxford University Press., 1995.

FAZIT Communication GmbH in cooperation with the German Federal Foreing Office. Auswärtiges Amt. *Tatsachen über Deutschland: Starker Sozialstaat*, 2020. URL `https://www.tatsachen-ueber-deutschland.de/de/deutschland-auf-einen-blick/starker-sozialstaat`. [Accessed July 2020].

Bundeszentrale für politische Bildung. Subdivision of the German Federal Ministry of the Interior. bpb. *Direct democracy*, 2018. URL `https://www.bpb.de/nachschlagen/lexika/politiklexikon/17361/direkte-demokratie`. [Accessed August 2020].

German Federal Ministry of Finance. Bundesministerium der Finanzen. *Income tax rate and its cold progression*, 2014. URL `https://www.bundesfinanzministerium.de/Web/DE/Service/FAQ_Glossar/Glossar/Functions/glossar.html?lv2=b980f293-bb4b-47f1-8e4d-5303a4e1fd1a&`

lv3=d48defc7-10b9-4dfe-bd46-39c33be69d20#glossard48defc7-10b9-4dfe-bd46-39c33be69d20. [Accessed August 2020].

German Federal Ministry of Finance. Bundesministerium der Finanzen. *Tax income by tax type and authorities*, 2019. URL https://www.bundesfinanzministerium.de/Content/DE/Standardartikel/Themen/Steuern/Steuerschaetzungen_und_Steuereinnahmen/2020-01-31-steuereinnahmen-kalenderjahr-2019.pdf. [Accessed August 2020].

C. Deissenberg, S. van der Hoog, and H. Dawid. Eurace: a massively parallel agent-based model of the european economy. *Applied Mathematics and Computation*, 204:541–552, 2009.

German Federal Statistical Office. Destatis. *Trend in the annual compliance costs*, 2012-2018. URL https://www.destatis.de/EN/Themes/Government/Bureaucracy-Costs/Tables/compliance-costs.html. [Accessed July 2020].

Federal parliament of Germany. Deutscher Bundestag. *Representative democracy*, n. d. URL https://www.bundestag.de/services/glossar/glossar/R/repraes_demo-247326. [Accessed August 2020].

European Central Bank. ECB. Flat taxes in central and eastern europe. *ECB's Monthly Bulletin*, pages 81–83, 2007. URL https://www.ecb.europa.eu/pub/pdf/other/mb200709_focus10.en.pdf. [Accessed August 2020].

eurostat. *Glossary: Income quintile group*, 2018. URL https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Income_quintile_group. [Accessed August 2020].

eurostat. Gini coefficient of equivalised disposable income - eu-silc survey, 2020. URL http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_di12&lang=de. [Accessed August 2020].

M. Evers, R. Mooij, and D. Vuuren. The wage elasticity of labour supply: a synthesis of empirical estimates. *De Economist*, 156:25–43, 2008. doi: 0.1007/s10645-007-9080-z.

M. Friedman. A 1962 flat-tax proposal revisited. *Wall Street Journal*, 1996. URL https://miltonfriedman.hoover.org/friedman_images/Collections/2016c21/WSJ_02_09_1996.pdf.

Freie Universität Berlin. FU-Berlin. *Gini coefficient*, n.d. URL https://www.lai.fu-berlin.de/e-learning/projekte/vwl_basiswissen/Umverteilung/Gini_Koeffizient/index.html. [Accessed August 2020].

O. Guest. Using the gini coefficient to evaluate deep neural network layer representations. Blog post, 2017. URL http://neuroplausible.com/gini. [Accessed August 2020].

O. Guest and B. C. Love. What the success of brain imaging implies about the neural code. *Elife*, 6, 2017. doi: https://doi.org/10.7554/eLife.21397.

M. Lengnick. Agent-based macroeconomics: A baseline model. *Journal of Economic Behavior & Organization*, 86:102–120, 2013.

E. Medina. *Cybernetic Revolutionaries: Technology and Politics in Allende's Chile*. (Ser. Acls humanities e-book). MIT Press., 2011.

E. Nakamura and J. Steinsson. Five facts about prices: a reevaluation of menu cost models. *The Quarterly Journal of Economics*, 123(4), .: 1415–1464, 2008.

A. W. Phillips. The relation between unemployment and the rate of change of money wage rates in the united kingdom, 1861-1957. *Economica*, 25:283–299, 1958. doi: https://doi.org/10.1111/j.1468-0335.1958.tb00003.x.

R. Tappe Maestro. *Bachelor-Thesis-Data-Democracy*, 2020. URL https://github.com/Wehzie/Bachelor-Thesis-Data-Democracy. [Commit 8472427c131e8ceff43cd98dc5b10203af19a032].

P. Van Parijs. Basic income: A simple and powerful idea for the twenty-first century. *Politics & Society*, 32(1):7–39, 2004.

G. Wagner and L.G. Nardin. *Lengnick's Baseline Economy. Download.*, 2018a. URL https://sim4edu.com/sims/20/

LengnickBaselineEconomy-1. [Accessed February 2020].

G. Wagner and L.G. Nardin. *Lengnick's Baseline Economy. Description.*, 2018b. URL https://sim4edu.com/sims/20/description.html. [Accessed August 2020].

Michael Wooldridge. *An Introduction to MultiAgent Systems (2nd ed.)*. John Wiley & Sons Ltd, 2009. ISBN 978-0-470-51946-2.

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In a more indirect way the student association Cover in Groningen helped me develop the idea for this work. Inspired by the course Data Analytics and Communication I got to write a dystopian article about how data could change democracy for the DisCover magazine. That process lead me to approach Professor Grossi with this thesis idea. Last I would like to thank the rest of my family, friends and especially my grandpa. A la orden capitán.

Algorithm 7.1 Assemble parliament

```
i ⇐ sum of hh incomes
numP ⇐ number of parties
step ⇐ i/numP
hh[] ⇐ ascending list of hh by income
p[] ⇐ list of numP zero entries
iCount, pCount, hhCount, prevIndex ⇐ 0
while hhCount < hh[].length do
    iCount ⇐ iCount + hh[hhCount].income
    if iCount ≥ step then
        iCount ⇐ 0
        p[pCount] ⇐ (hhCount − prevIndex)/hh[].length
        pCount ⇐ pCount + 1
        prevIndex ⇐ hhCount
    end if
    hhCount ⇐ hhCount + 1
end while
```

7 Appendix A

The algorithm 7.1 is an alternative implementation to algorithm 3.1 presented in section 3. The algorithm presented here doesn't rely on interpolation to determine the number of households making up an income quintile.

Table 7.1 shows the chosen firm parameters used in all testing conditions. When applicable parameter values were used as provided by Lengnick (2013). The left column shows the name of the parameters as found in the Python implementation produced as part of this work. When applicable the second column shows the notation used by Lengnick throughout his work. The third column indicates parameter values. The right column gives a short description of each parameter. These descriptions are also found as comments in the program code (Tappe Maestro, 2020). The last two rows of the table describe averages because firms are initialize as the sum of the given parameter and a pseudorandom number between -0.5 and 0.5.

Table 7.2 shows the chosen household parameters used across all tested conditions. The abbreviation hh describes household or households. When applicable parameter values were used as provided by Lengnick (2013). The left column shows the name of the parameters as found in the Python implementation produced as part of this work. When applicable the second column shows the notation used by Lengnick throughout his work. The third column indicates parameter values. The right column gives a short description of each parameter. These descriptions are also found as comments in the program code (Tappe Maestro, 2020).

Table 7.3 shows parameters for time and the government agents used across all conditions; additionally the seed for generating pseudorandom numbers is shown. When applicable parameter values were used as provided by Lengnick (2013). The left column shows the name of the parameters as found in the Python implementation produced as part of this work. The center column shows parameter value. The right column gives a short description of each parameter. These descriptions are also found as comments in the program code (Tappe Maestro, 2020).

Table 7.1: **Firm parameters.**

Code	L	Val	Description
num_firms		100	total number of firms
months_lo_wage	γ	24	duration (months) after which wage is decreased when all positions filled
wage_adj_rate	δ	0.019	rate at which wages are adjusted
inv_up	$\overline{\phi}$	1	rate at which number of items in stock are considered too many
inv_lo	$\underline{\phi}$	0.25	rate at which number of items in stock are considered too few
price_up	$\overline{\varphi}$	1.15	rate at which prices are considered too high
price_lo	$\underline{\varphi}$	1.025	rate at which prices are considered too low
price_adj_rate	ϑ	0.02	rate at which prices are updated
price_adj_prob	θ	0.75	probability at which prices are updated
tech_lvl	λ	3	technology parameter influences an employees item production rate
buffer_rate	χ	0.1	rate at which a firm builds a money buffer
lo_wage_months		1	duration (months) of full employment after which wages are decreased
init_money		0	firm's starting balance
init_reserve		0	firm's starting savings
init_items		50	firm's starting inventory
init_avg_price		1	firm's average starting price
init_avg_wage		52	firm's average starting wage

Table 7.2: Household parameters.

Code	L	Val	Description
num_hh		1000	total number of households
lower_vendor_price	ξ	0.01	percent by which a new vendor's prices must be cheaper, normalized to 1
unemployed_ask_num	β	5	number of firms an unemployed household asks for a job each month
repl_employer_prob	π	0.1	probability that a hh satisfied with its wage asks another firm for a job
cost_decay	α	0.9	rate at which monthly expenses decay relative to wealth
repl_vend_price_prob	ψ_{price}	0.25	probability of replacing a firm a hh buys from due to high prices
repl_vend_inv_prob	ψ_{quant}	0.25	probability or replacing a firm a hh buys from due to little inventory
lo_res_wage_unemployed		0.1	hh's reservation wage decrease rate during month of unemployment
demand_sat		0.05	hh is satisfied with buying a little less percent of items it planned to buy
init_money		100	hh's starting balance
num_vendors		7	number of firms a hh buys from
rw_change_employed		1	reservation wage change during month of employment
rw_change_unemployed		0.9	reservation wage change during month of unemployment
rw_change_fired		1	reservation wage change at moment of being fired

Table 7.3: Seed, time and government parameters.

Code	Value	Description
random.seed(15532)	15532	seed for generating pseudorandom numbers
days_in_month	21	number of working days in a month
months_in_year	12	number of months in a year
tax_gamma	4	tax voting relies on this factor that expresses will for redistribution
tax_adj_freq	12	frequency of updating tax rate
rep_num_parties	5	number of parties in representative parliament
rep_term_length	48	representative government's term length in months

8 Appendix B

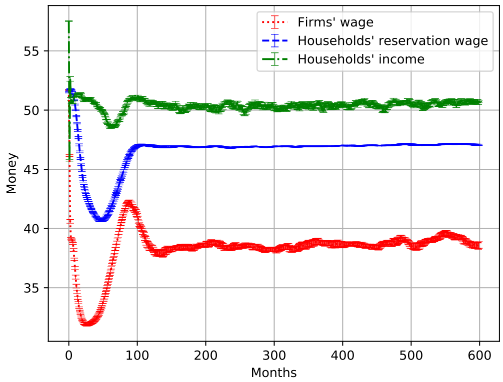

Figure 8.1: Representative government. Wage rate, reservation wage and income.

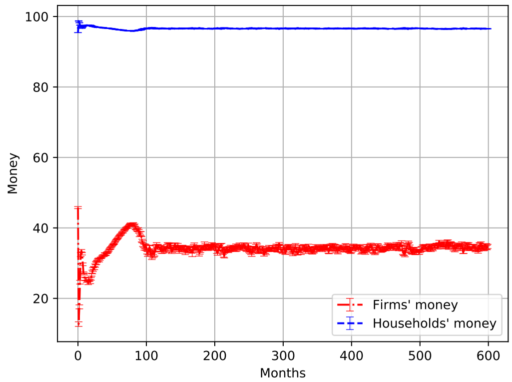

Figure 8.3: Representative government. Household and firm money.

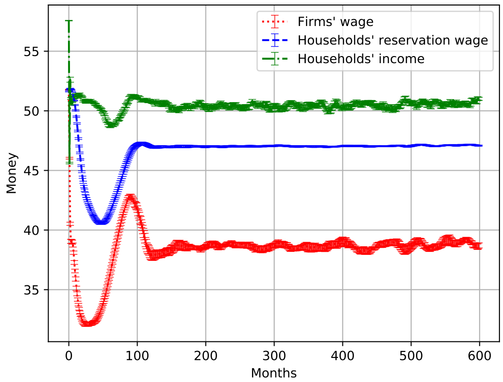

Figure 8.2: Direct government. Wage rate, reservation wage and income.

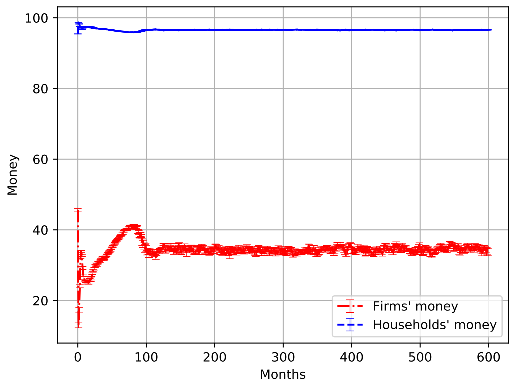

Figure 8.4: Direct government. Household and firm money.

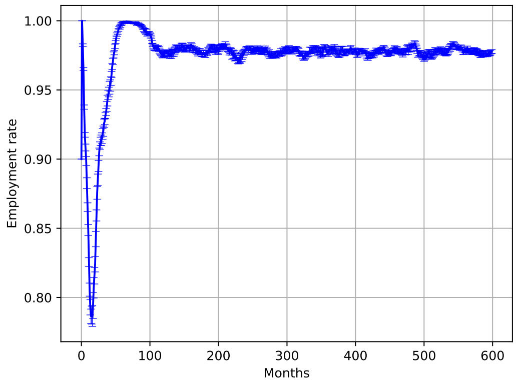

Figure 8.5: Representative government. Household employment rate.

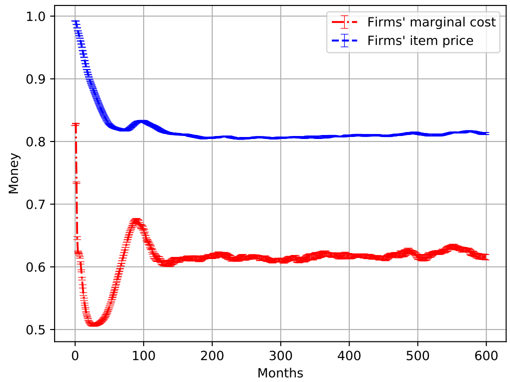

Figure 8.7: Representative government. Item price and marginal cost.

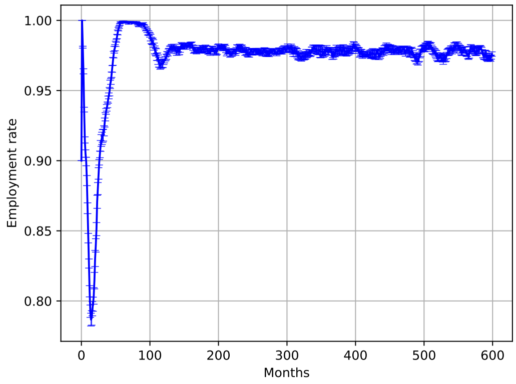

Figure 8.6: Direct government. Household employment rate.

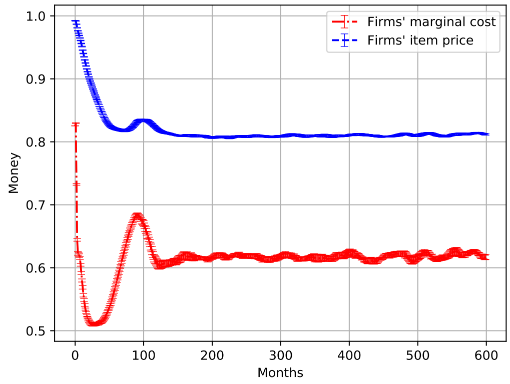

Figure 8.8: Direct government. Item price and marginal cost.