ESSAYS ON USING INFORMATION SYSTEMS FOR SOCIAL PROGRESS: AGENT-BASED MODELS FOR A BETTER WORLD

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- I am the sole author of this thesis and that I have fully acknowledged and documented in my thesis all sources of ideas and words, including digital resources, which have been produced or published by another person or institution;
- this thesis contains no material that has been submitted or accepted for a degree or diploma in any other educational institution;
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ABSTRACT

Essays on Using Information Systems for Social Progress:

Agent-Based Models for a Better World

Poverty and inequality continue to be a cause of suffering in global scale, hampering inclusive growth. In this dissertation, we present two essays, which utilises agent-based modelling, to examine two different methods for alleviation of poverty and inequality, namely giving and lending. First essay builds a simple economy model in which only transaction is money transfer between agents, in a macro level approach. It simulates compulsory giving, taxation, and voluntary giving, almsgiving (zakat), both separately and simultaneously, to measure their effectiveness in inequality reduction. Results of experiments with different rates and recipient groups demonstrate that they are both effective at decreasing nonuniformity in wealth distribution, and can substitute each other. Giving a portion of wealth (zakat) reduces inequality in random selection of recipients as well. In specific conditions, if share of wealth given as alms exceeds some critical values, inequality is observed to raise again. Second essay focuses on lending with a micro level approach and models automated relending mechanism in peer-to-peer (P2P) microlending platforms. It aims to find the selection criteria of projects to loan, that enables relatively better resource utilisation. Results show that in conditions of loan default or full funding of projects, criterion of previous experience of entrepreneurs provides better resource utilisation, whereas in equal but partial funding of projects with no loan default, criteria of less additional fund needed or shorter time to expiration of the campaign achieve better utilisation.

ÖZET

Sosyal İlerleme için Bilgi Sistemlerinin Kullanımı Üzerine Makaleler: Daha İyi Bir Dünya İçin Ajan-Bazlı Modeller

Yoksulluk ve eşitsizlik küresel ölçekte bir acı sebebi olmaya devam etmekte ve kapsayıcı büyümeyi engellemektedir. Bu tezde, yoksulluk ve eşitsizliğin azaltımına yönelik iki farklı yöntemi, hibe ve krediyi incelemek için ajan-bazlı modellemeyi kullanan iki makale sunmaktayız. İlk makale, makro düzeyde bir yaklaşımla, tek işlemin ajanlar arasında para transferi olduğu basit bir ekonomi modeli oluşturur. Eşitsizliği azaltmadaki etkinliklerini ölçmek için zorunlu verme, vergilendirme, ve gönüllü verme, maddi yardım (zekat), hem ayrı ayrı hem de eş zamanlı olarak simüle edilir. Farklı oranlar ve alıcı gruplarıyla yapılan deneylerin sonuçları, her ikisinin de servet dağılımındaki eşitsizliği azaltmada etkili olduğunu ve birbirlerinin yerine geçebileceğini göstermektedir. Servetin bir kısmının verilmesi (zekat), alıcıların rastgele seçiminde de eşitsizliği azaltmaktadır. Belirli koşullarda, servetin verilen kısmının oranlarının bazı kritik değerleri aşması halinde eşitsizliğin yeniden arttığı gözlemlenmiştir. İkinci makale, mikro düzeyde bir yaklaşımla kredi vermeye odaklanır ve eşler arası (P2P) mikro kredi platformlarında otomatik yeniden kredi verme mekanizmasını modeller. Kredi verilecek projelerin seçimi için nispeten daha iyi kaynak kullanımını sağlayan kriterleri bulmayı amaçlamaktadır. Sonuçlar, kredi temerrüdü veya projelerin tam fonlanması koşullarında, girişimcilerin önceki deneyimi kriterinin; kredi temerrüdü olmadan projelerin eşit ancak kısmi fonlanması halinde ise, daha az ek fon ihtiyacı veya kampanyanın sona ermesine daha kısa süre kalması kriterlerinin daha iyi kaynak kullanımı sağladığını göstermektedir.

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to my mother,

to my father,

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to my country, Türkiye, its founder, and everybody who helped it to develop,

to everybody who helped me in my life journey,

to everybody and everything I caused suffering, however slight it is, as a form of apology,

to all the best people in the world who love to work for greater good,

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to everything and everybody who suffer, and to everything and everybody who alleviate their suffering,

to goodness and wellbeing of everybody and everything,

to love, and happiness induced by it,

to faith, and everybody who helped it grow stronger and spread to hearts,

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CHAPTER 1

INTRODUCTION

"It was the best of times, it was the worst of times…" Charles Dickens wrote in famous opening sentence of his novel, *A Tale of Two Cities*. Although it is probably not the worst of times thanks to developments in public health and agriculture, this expression might help us metaphorically describe the stark contrast between poorer and wealthier regions of the planet Earth. On one side, great advancements in renewable energy, genetic engineering and artificial intelligence apparently draw a brighter picture for the future. On the other side, it is estimated that a child dies in around 13 seconds due to hunger related causes (Action Against Hunger, 2023; the period is 10 seconds according to World Food Program USA, 2022; for a calculation for a person, please see Hartnett, 2022). As of 2023, 9 million people die of hunger-related causes annually, most of them children younger than five (Concern USA, 2023). Hence, it is not very difficult to observe that, since beginning of COVID-19 pandemic, there has been more deaths due to hunger and related causes cumulatively in the world than deaths caused by COVID-19, even when excess deaths are included and upper bound of estimates are taken into account (The Economist, 2023 - processed by Our World in Data). Global inequality might be a major driving force behind this picture and Prof. James Davies, one of the authors of Credit Suisse Global Wealth Reports informed in his email that “We think that the useful thing to know is that the bottom half almost certainly have less than 1% of the world’s wealth” (Matthews, 2019). Income situation is similar, as in 2019, 47% of global population lived below 6.85 dollars poverty line (Schoch, Baah, Lakner, & Friedman, 2024). Whichever method to observe and measure is used, it would

probably unanimously be accepted that hunger, poverty, inequality, and in general suffering in our world is real. This dissertation does not claim to offer a panacea, or even a working solution to the grim situation in the poorer regions and ages-old problem of inequality. Yet, it humbly analyses, models, simulates and discusses several methods to alleviate the suffering caused by poverty and inequality, with a hope that it may be useful for future efforts in that direction. Less hunger, less poverty, less damage caused by inequality, and less suffering in general... What would be a truer definition of "A Better World"?

How can we help a person physically in need? Whether it is food, water, medical care, a roof to their house which protects from rain or the money that enables obtaining these, regardless of being in exchange for work or other goods and services or not, to the best of our knowledge, there are only two ways to help. We may transfer the ownership of these needed resources either permanently (i.e. giving), or temporarily (i.e. lending). In this dissertation, we attempt at case-based and partial discussion of these two methods via modelling and simulation in two separate essays. However different in scope, and specific in analysing particular forms of aid, the two essays constituting this thesis focuses on subjects or cases directly related to giving (first essay) or lending (second essay). First essay tries to examine and simulate giving behaviour in its both compulsory (taxation) and voluntary (almsgiving) forms and adopts a macro level perspective whereas second essay concentrates on a specific topic in lending activity, automation of relending available funds, and attempts at contributing its optimisation with a micro level approach. Nevertheless, both of the essays are in common for the aim they are hoped to be of help, social progress, as well as for the analysis technique they employ, agent-based modelling and simulation.

Agent-based modelling and simulation is a relatively new methodology in analysis and examination of phenomena, in which meaningful units comprising a system is modelled and simulated in order to observe and understand the behaviour of the whole system. Modelling cars' movements to examine traffic congestion (Thorne, Bailey & Peirce, 2007) or taking cells as agents to study biological tissue patterning (Hofer, Jäger & Füllsack, 2018) might be examples for how this method is used. In agent-based modelling, behaviour of, and interaction among agents are important, and because social progress, as well as economy as a whole, stems from actions and interactions of individuals, selection of individuals as agents in our models should be meaningful. Likewise, since experimentation on these agents in economic systems might be costly as well as unethical, agent-based modelling enables us to harness information systems to simulate social phenomena.

First essay constructs a basic agent-based model of homogeneous agents with one type of transaction or trade among them, as suggested in econophysics literature. Every agent begins with a uniformly distributed random wealth. In every time step of the model's simulation, every agent transfers the same amount of money to a random other agent, in order to simulate transactions of trade. Nonuniformity arising in wealth distribution of agents is observed in this model. Then taxation and almsgiving as redistribution mechanisms are added to the model and their effectiveness in alleviating inequality is investigated. Effect of taxation and almsgiving on inequality is examined individually first, and then their synergistic effect is observed, via examining them simultaneously. Our study tries to contribute econophysics literature via suggesting a change in what is already revealed: can natural, physics-based inequality in exponential monetary distribution in society be altered and reduced via giving, which may be thought of as being nearly as old as human history.

Econophysics literature is apparently lacking in modelling giving behaviour, and we humbly attempt at improving it in this area. Furthermore, we try to contribute to the non-profit sector and philanthropy literature as well, via focusing on ways to optimise social assistance and giving behaviour via agent-based models.

Second essay focuses on a resource allocation problem that needs decision making in real life as well. In P2P microlending platforms such as Kiva.org or Zidisha.org, there are systems for automated relending of available funds to entrepreneurs according to lender-selected criteria. Second essay attempts at finding relatively effective criteria in this selection decision in order to achieve better utilisation of scarce resources. In second essay, we firstly construct a model in which available funds are distributed to selected entrepreneur projects so as to fund them either fully or partially but equally, and gathered back from those completed or failed to be funded, in every time step. The specific selection criteria that first model of second essay, namely Basic Model, examines are the amount of additional fund needed for a project, time to expiration of its campaign, and previous experience of associated entrepreneur. Second model, which is called Improved Model, extends these criteria with percentage of a project loan that is needed additionally and develops first model with the addition of partial funding, loan default and growth of borrower base with referral system for entrepreneurs, which may help us draw closer to real-life conditions. Second essay may assist in future decision-making in project selection to fund for lenders, as well as in effective utilisation of funds for P2P microlending platforms.

Our study and thesis might not appear as mainly built upon concepts of Management Information Systems (MIS) field. However, first essay, while examining effect of giving behaviour in the forms of tax and alms on inequality, may

aid in future plans of decision makers about rate of taxation of transactions or that of philanthropists about the share of their wealth to donate. This might effectively make associated simulation study a decision support system, if needed. Second essay examines P2P microlending platforms and possible optimisation of their automation, which might be accepted as an MIS application to increase the effectiveness of the system.

First essay is organised as follows: first, we present global and historical inequality situation with its proposed causes, and review relevant main themes in econophysics literature (Chapter 2). Building on these themes and related findings, we present and explain our agent-based simple economy model. We introduce and construct hypotheses about taxation policies and almsgiving (particularly Islamic practice of zakat) as candidate solutions for apparent uneven distribution of money wealth in the model (Chapter 3). Then we test our hypotheses and examine the individual effectiveness of taxation and almsgiving to reduce inequality (Chapter 4). In the second phase of the study, we examine simultaneous effect of almsgiving and taxation, and to achieve this, we build and explain a model that includes both (Chapter 5). Then we present this model's results and investigate the substitutability of tax and alms (Chapter 6). Lastly, we present results of our experiments, discuss their significance and propose future work in this research area (Chapter 7).

Second essay is structured as follows: First, we present a literature review for microcredit and P2P microlending (peer-to-peer microcredit distribution) (Chapter 8). Second, explain our basic agent-based model for automated relending mechanism for P2P microcredit platforms (Base Model) (Chapter 9) and demonstrate its simulation results as the first phase of this essay (Chapter 10). Third, we describe our Improved Model built on Basic Model of automated relending (Chapter 11) and

present Improved Model's experimental design and results, emphasising its novel concepts over Basic Model (Chapter 12). Last, we discuss the findings of the second essay and conclude the study (Chapter 13).

General conclusion chapter is aimed to summarise first and second essays' results, present their findings in a concise form and point out the direction further work may take (Chapter 14).

CHAPTER 2

BACKGROUND INFORMATION FOR THE FIRST ESSAY: TOWARDS SOCIAL JUSTICE VIA GIVING – AGENT-BASED ECONOPHYSICS MODELS OF TAXATION AND ZAKAT

As the background information for first essay, we first attempt at understanding and explaining inequality via observing current situation, giving a historical perspective, and examining taxation and almsgiving as possible methods for inequality reduction. Then we describe agent-based modelling as our method of study and econophysics as the research area we build our model benefitting from.

2.1 Inequality and its possible causes: A historical perspective

In 2018, according to the prestigious international charity Oxfam's calculations, 42 people held the same wealth as the poorer half of the world's population: 3.7 billion people (Pimentel, Aymar, & Lawson, 2018). Billionaires' wealth has climbed 13% a year throughout the decade 2006-2015 and in 2017, 82% of global wealth created was shared by the top 1% of the world whereas the bottom 50% of the world's population saw no increase in their wealth (Elliott, 2018). Not only is this wealth distribution difficult to argue to be fair, but resulting global inequality comes with added potential disasters such as pandemic disease risk, social unrest and civil war (Kuhn & Weidmann, 2015).

Beginning from ancient civilizations, wealth inequality and social injustice have been a major burden on peace and welfare of societies, as well as an important subject matter of philosophers and their seminal work from *Republic* of Plato (Plato, 2021/370 B. C. E.) to *A Discourse Upon the Origin and Foundation of the Inequality*

Among Mankind of Jean-Jacques Rousseau (1761). Likewise, the preamble of International Labour Organization's (ILO) constitution openly states, "universal and lasting peace can be established only if it is based upon social justice" (ILO, 1919). Social justice, therefore, should be one of the principal aims of any democratic modern society, not only on moral grounds but additionally if sustainable peace is preferable to chaos and social unrest. This aim involves fairer redistribution of wealth and income as well.

Oxford English dictionary defines social justice as "justice in terms of the distribution of wealth, opportunities, and privileges within a society" (Oxford University Press, n.d.). In this study we are basically interested in the wealth distribution aspect of this definition, while social justice is a much broader concept that covers gender equality, minority rights and more. Whether value judgments and an ethical notion such as social justice have any place in a scientific work is another point of discussion and here we adopt a positive attitude towards this argument, at least for the subject matter of this study. We share the point of view of Keynes, who wrote in his letter to Roy Harrod "that economics is essentially a moral science and not a natural science" (Keynes, John Maynard Keynes: Letter to Roy Harrod, July 4, 1938: 2014). This morality might be argued to imply that reduction of inequality is important as well as distributive, economic, hence social justice. Contemporary capitalist economies, however, find a rather unchangeable equilibrium on an apparent unequal distribution of wealth among citizens.

Wealth distribution in the UK, as an example from Europe, follows a Boltzmann-Gibbs distribution for 97% of the population who owns %84 of total wealth (employees or commoners) and Pareto distribution for top 3 per cent of the population who owns %16 of the total wealth (employers or bourgeoisie), according

to a study by Dragulescu (2003) using the information obtained from Inland Revenue, the UK. The US left Europe behind in terms of income inequality after World War I, and especially after the 1980s, the income inequality gap widened in both the US and Europe. Especially in the post-1980 US, income inequality has risen to levels not seen in history since World War I, with the share of top income decile in total pre-tax income approaching 50% (Piketty, 2015). Growth of income after the 1980s has been shared very unevenly. The top 1% earners increased their income the most, and the bottom 50% earners increased their income with half of the top 1% earners' growth rate. Furthermore, in the same period, using *2018 World Inequality Report*'s terms, the global middle class (between top 1% and bottom 50%), which covers the poorest 90% of the US' and Western Europe's population has been "squeezed" (Alvaredo, Chancel, Piketty, Saez, & Zucman, 2018). According to the same report, governments are not as successful in solving the issue of inequality after the 1980s, as great wealth transfers from public to private ownership led to little, no or even negative public wealth in developed countries. Global wealth distribution picture is not exempt from inequality either, with the top wealth decile holding more than half of total net wealth constantly since the 1870s and a deviation to higher inequality in terms of wealth owned that can be tracked after the 1980s (Piketty & Saez, 2014). Atkinson, Piketty, and Saez (2011) give a comprehensive and detailed treatise on historical development of inequality in 22 countries and their data demonstrate that global wealth distribution issues are not new or transient, raising questions about their root causes.

Historically, inequality and its causes has been a major concern for prominent thinkers. David Ricardo focused on the problem of political economy as being the analysis of distribution of output between classes of workers, capitalists, and land

owners in a growing economy (Ricardo, 1821) whereas Karl Marx examined capitalism as a system in depth, and diagnosed it to be intrinsically predisposed to inequality and crises in his magnum opus, *Das Kapital* (Marx, 1873). After Marx, several major reasons have been proposed to explain wealth concentration and inequality dynamics. Entrepreneurship and high rate of income from enterprises (Gentry & Hubbard, 2004; De Nardi, Doctor, & Krane, 2007), very high (and increasing) compensation and rewards for the top managers (CEOs) resulting in skewness of income (Atkinson, Piketty, & Saez, 2011; Lee, 2019) intergenerational wealth transmission, i.e. inheritance of large amount of wealth at the richest families leading to increasing accumulation of wealth (Gale & Scholz, 1994) and these families' high saving (Dynan, Skinner, & Zeldes, 2004) are among these reasons.

After the global recession of 2008, Marx's ideas saw a surge of interest and found support by new analyses, benefitting from high quality data and utilizing now available processing power of computers. Most successful and influential one of these analyses has been that of Thomas Piketty for his book *Capital in the 21st Century* (Piketty, 2014). For this work, he and co-researchers examined almost all industrial age wealth distribution data beginning from the 19th century for various countries and found that except for periods of war, any modern capitalist economy sinks deeper and deeper into inequality by itself. He pointed out the relation $r > g$, rate of return on capital (r) being greater than rate of growth (g) in an economy, as an important cause of this tendency to rising inequality. Although relationship and interaction between r and g has been questioned (Jones, 2015), De Nardi, Fella, and Yang (2015) utilised aforementioned better computing power, simulated a model of his theories and confirmed his insights. Then, if inequality and its harms are intrinsic to the capitalist system, what would be the solution? Here Piketty and his co-

author(s) propose an inheritance tax as high as 50%-60% (Piketty & Saez, 2013), as well as progressive income tax and internationally coordinated wealth tax to prevent evasion (Piketty, Saez, & Zucman, 2013).

2.2 Taxation as a method of inequality reduction

That taxation is negatively related to inequality is supported in the literature. A study based on OECD data points out an inverse relationship between tax rate and Gini index (a measure of inequality of distribution) of income distribution of countries. Taxation's relationship with betterment of distribution and its potential as a means to social justice can be tracked in Figure 1, in which Caballero and López (2012) demonstrate the relationship between Gini coefficient of income distribution and tax-rate-to-GDP-ratio of countries. We may additionally observe the impact of taxation on societal development and fairness of resources' distribution in countries implementing progressive policies. Governments of these countries are among those having policies for the highest taxation rate in the world. Important examples might be found among Scandinavian and Western European countries with substantially high tax-to-GDP ratio values such as France (48.0% of GDP) and Belgium (45.6% of GDP) and Norway (43.6% of GDP) for 2022 (Eurostat, 2024). Progressive policies apparently lead to treat taxation as an effective method for societal development in these countries since all of them belong to Tier 1 (highest social progress) in 2022 Social Progress Index (Social Progress Imperative, n.d.).

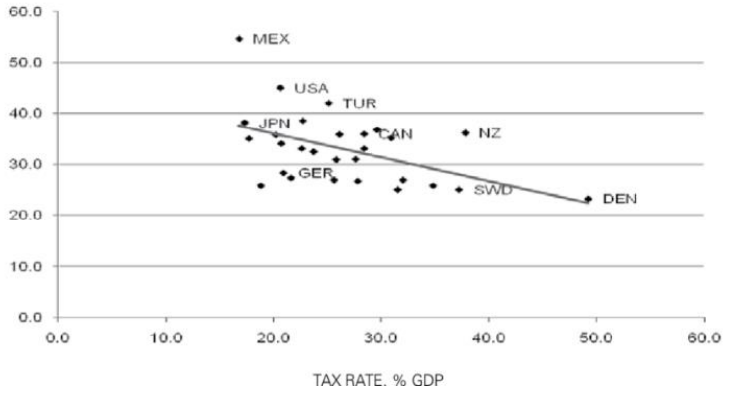


Figure 1. Relationship between Gini coefficient of income distribution (y axis) and tax-rate-to-GDP ratio (x axis) of countries
Source: Caballero and López (2012)

Taxation, therefore, is one of the most widely employed precautions against inequality and adversities associated with it. Thus, in this study, we attempt to investigate and measure the effectiveness of taxation on promoting social justice in a simulated simple economy. We select tax levied on transactions as the widely implemented representative example of taxation. Tax rate (as a percentage of transaction) and destination of redistribution (e.g. to middle wealth group and lower or only the poorest group) will be examined as parameters of taxation policy which possibly affect the monetary wealth distribution outcome.

Before taxation's invention as a government apparatus, communities of people had a method to avoid harms of inequality and to reach solidarity. This method is the giving behaviour (charity) of human beings and next section will try to examine the giving behaviour (almsgiving) as a possible means of ameliorating inequality.

2.3 Almsgiving as a method of inequality reduction

Giving behaviour might be one of the oldest methods for alleviating inequality as it has been inherited from generation to generation throughout human history, and it

would not be easy to point out a portion of history in which almsgiving (charity) is non-existent. On the contrary, it has been exalted as a virtue, generosity. It has found its place in different environments, cultures, traditions and belief systems, albeit with different names: daan in Hinduism (Krishnan, 2005), tzedakah in Judaism (Taitz, 2007) or tithing in Christianity (Pink, 2011). Although prevalence and veneration of charity (almsgiving) imply that it is useful for a society to approach social justice, like taxation, we propose that its effectuality to bring about equality should be investigated and validated as well. This examination may additionally lead to assessment of effectiveness of varying quantities of almsgiving. Hence, in the second model of first essay we introduce almsgiving to our simulated simple economy. We select Islamic practice of zakat as the representative procedure for almsgiving and we measure the efficacy of it in our model, since it has a fairly settled pattern and rules for the amount to be given. Although it has different (and higher) percentages for various assets, its widely applied rate is 2.5% (1/40) of one's savings and any taxable goods in Islamic jurisprudence (Powell, 2009). That is, contrary to taxation of transactions, zakat is given as a percentage of wealth, rather than expenditure or income. It is obligatory in Islamic tradition and is stated to be a way of purification (Quran, 9:103) and a right of the poor to the wealth of the rich (Hassan & Khan, 2007).

Taxation (obligatory giving) as well as almsgiving (voluntary giving) are therefore widely implemented possible solutions to inequality. Hence, in this study both taxation and zakat are investigated for effectiveness as measures to reduce inequality in an artificial economy. We utilise tax rate as well as zakat ratio (as percentage of wealth) as two core factors effecting wealth inequality in our model. As the third core factor for effectiveness of inequality reduction, we employ a metric

of relative poverty of the recipients of taxes and alms. It defines a group of relative poverty in a population, such as tenth wealth decile (bottom 10%) or bottom half of population in terms of monetary wealth. We call this metric destination group ratio.

Our third core factor of destination group ratio is observed to be important in real life conditions. There is claimed to be a general tendency to aid disadvantaged groups rather than the advantaged ones, perhaps to overcome or relieve perceived severe inequality. Paolacci and Yalcin (2020) call this tendency benevolent partiality in their study and demonstrate that people choose to help socioeconomically disadvantaged groups more, even though that makes their help less efficient (e.g. saving less lives). This observed tendency to opt for aiding the more disadvantaged groups is included in our study as the destination group ratio, which determines the relative poverty level of the population who potentially receives social assistance through taxation or almsgiving. This core factor represents the seemingly-powerful natural desire to reach and help needy and disadvantaged groups and it enables us to analyse the situation if people manage to focus their aid to poorer (or even poorest) groups. We analyse whether this more focused aid achieves a better efficiency for inequality reduction or not.

An observed want of people for inequality reduction, demonstrated in the literature, constitutes a major support for including these three core factors in our study. Individuals are reported in several studies to be universally averse to inequality, both in forms of unequal pay as well as unequal wealth distribution. Kiatpongsan and Norton (2014) show that on average, people believe that CEOs are paid 30 times the unskilled workers whereas the actual ratio is 354-to-1. Their ideal ratio is 7-to-1, even more equitable than their perceived less-than-real salary inequality. Norton and Ariely (2011) demonstrate a very similar case for wealth

distribution. People assume more uniform wealth distribution than actual one, and they do not deem their more-equitable-than-real distribution satisfactory, preferring an even more equitable distribution as ideal.

2.4 Agent-based modelling and simulation

In our investigation attempt at efficiency of inequality reduction, we opt for an "agent-based" (i.e. targeting individuals) approach. Here, agent-based modelling and simulation, is a convenient methodology because interactions of individuals as agents of economy are the roots or essence of any economic activity. Asymmetry in these interactions should be tracked in order to understand internal dynamics of, and assuage harmful effects of wealth inequality.

Agent-based modelling and simulation (ABMS) is a field of computational modelling that includes the simulation of actions and interactions of autonomous agents (or individuals) in an environment, in order to observe their impact on the system as a whole. For a definition of ABMS, Macal (2016) uses a gradual approach and in its more comprehensive definition ABMS includes heterogeneous, dynamic agents that interact with themselves and with the environment, and may learn and change while doing so. ABMS method has been employed to gain insight about various phenomena and produced new research questions in many diverse disciplines from land-use (Matthews et al., 2007), to electricity markets (Zhou, Chan, & Chow, 2007), from innovation diffusion (Kiesling, Günther, Stummer, & Wakolbinger, 2012), to public health (Tracy, Cerdá, & Keyes, 2018). In economics literature, ABMS approach has been employed for analysis of wealth distribution in various models. Long term evolution of a model including customers, state, banks and labour market (Romanov, Yakovlev, & Lelchuk, 2010), a simulated environment

for approaching actual, observed wealth distribution in the US (Vallejos, Nutaro, & Perumalla, 2018) and wealth, asset and capital distribution on stock markets (Moiseev & Akhmadeev, 2017) have been studied using ABMS approach. In general, agent-based models in literature quite successfully probe into nonuniformity arising in wealth distribution and simulate dynamics behind it. However, we could not find an extensive body of research in modelling the dynamics and methods in society to overcome inequality. That is, we are able to rebuild the inequality and irregularities in wealth distribution in a simulated environment, but seemingly unable to use this experience to simulate and optimise practices to reach a fairer distribution. This is why in this study we examine two of these practices, namely taxation and almsgiving. We select these two widely practised methods in order to cover both mandatory (taxation) and voluntary (almsgiving) approaches for reduction of inequality.

In order to build an agent-based model to understand how and why inequality arises in an economy and to examine the alleviating effects of taxation and almsgiving on inequality, we utilise theories of the emerging field of econophysics. Econophysics, which is the application of statistical physics laws to economics, offers some novel insights about underlying dynamics of inequality. Econophysics literature, especially studies related to income and wealth distribution will be reviewed in the next section.

2.5 Review of econophysics literature

Econophysics is a relatively new area of research, which was first introduced by prominent physicist Eugene Stanley in 1995 (Săvoiu & Iorga-Simăn, 2008). A large definition proposed for the term econophysics, after the field reached maturity,

describes it as a new area developed by the cooperation among physicists, economists and mathematicians, which uses and applies ideas, methods and models in statistical physics and complexity to analyse data from economic phenomena (Wang, Wu, & Di, 2004).

Econophysics, application of statistical physics laws to economics, utilises analysis of molecular interactions for explanation of money distribution in a closed economic system. When energy is conserved, Boltzmann-Gibbs law states, in a closed system, probability distribution of energy ε is $P(\varepsilon) = C \exp(-\varepsilon/T)$, where T is the temperature, and C is a normalising constant. This is a natural outcome of energy conservation and thus, it could be generalised that "any conserved quantity in a big statistical system should have an exponential probability distribution in equilibrium" (Dragulescu & Yakovenko, 2000). Money distribution in a closed economy is an unusual application area of this principle and one of the important focus points for econophysics literature.

If, in a closed economic system, every agent begins with same amount of money, and every agent i transfers a fixed amount of money α to a random other agent j in every step, in equilibrium state of the system money distribution goes to Gibbs' distribution of statistical mechanics: $P(m) = (1/T) \exp(-m/T)$ where $T = M/N$, the average money per agent in the market (M is the total money of N agents in the market) (Chakraborti & Chakrabarti, 2000). This equilibrium is dynamically robust, with a massive number of agents with minuscule amounts of money and several rich people. Same equilibrium holds with or without the concept of debt involved, as seen in Figure 2 (Dragulescu & Yakovenko, 2000). This might be seen as an unintuitive and surprising result, especially because every agent begins with exactly the same amount of money.

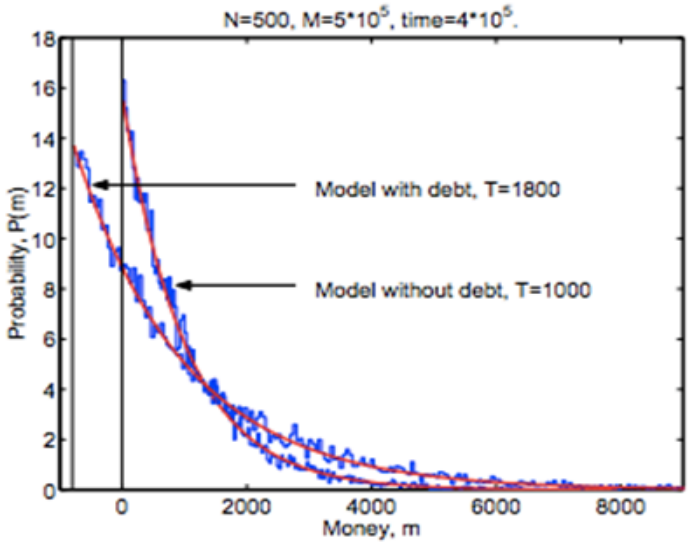


Figure 2. Distribution of money in a simple economy with fixed amount of money transfer with or without debt
Source: Dragulescu and Yakovenko (2000)

The simulation of a simple economy with a fixed money transfer, likened to a thermal system, enables one to think of T, average money of an agent in the system, as the system's "temperature" and to build an imaginary thermal machine in which heat transfer occurs between systems with temperature differences. Empirical evidence by Drăgulescu and Yakovenko (2001) shows that in 1998, the income temperature of the US was 1.9 times higher than that of the UK. This could explain global trade in the world economy as well, by imagining it as money (heat) transfer from high income-high price (hot) countries to low income-low price (cold) countries. Mimkes and Aruka (2005) even build a formal Carnot cycle (an idealised reversible heat engine cycle with maximum efficiency) for international trade.

Chakraborti and Chakrabarti (2000) examine the effect of savings propensity on this type of closed economic system. Savings propensity means agents' choice of keeping a portion of their monetary wealth unspent. Higher values of savings

propensity factor λ (e.g. λ=0.9) transform Gibbs' distribution of money to a still natural but arguably fairer one: normal distribution. This behaviour of a closed simple economy can be tracked in Figure 3. This means, in an imaginary economy, in which every agent opts for saving ninety per cent of their monetary wealth, this saving behaviour leads to social justice.

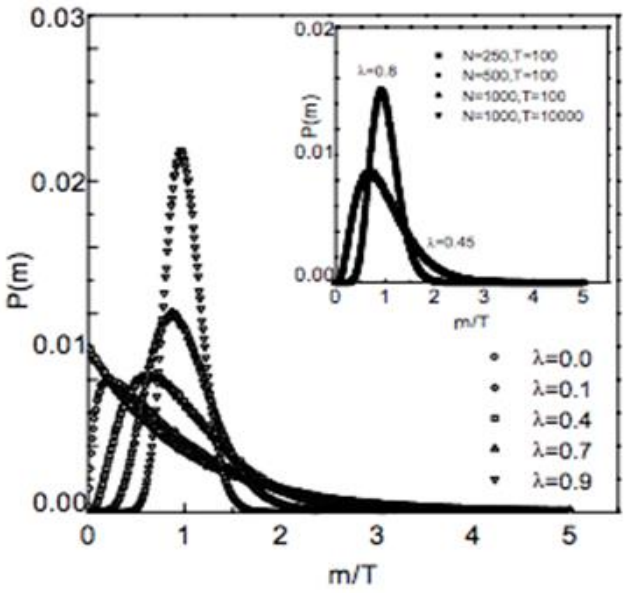


Figure 3. Stationary money distribution for different saving propensity and different N and T values
Source: Chakraborti and Chakrabarti (2000)

Building on econophysics literature and statistical mechanics approach, some recent studies examine different facets of the economy. Scharfenaker and Semieniuk (2017) study the statistical equilibrium approach for profit rates, and Schneider and Scharfenaker (2020) give a well-presented review of finite mixture models for the distribution of income and study the statistical properties of the U.S. income distribution. Cogliano, Veneziani, and Yoshihara (2019) study different redistributive tax schemes using a computational framework and show that taxation schemes may

eliminate exploitation as well as income and wealth disparities, although not in the presence of heterogeneous skills.

This study, utilising econophysics ideas and findings described, investigates two other proposed methods of social justice in different contexts, namely taxation and alms. For these methods, we encounter a lack of studies in the econophysics literature. Taxation has been examined by Dragulescu and Yakovenko (2000), and Guala (2009) in a specific set of conditions, in which income from taxes is redistributed equally to the population. In these conditions Guala (2009) calculates the optimised tax rate to be 32.5%. He analyses another model in which taxes are redistributed to the poorest 20% of the population and states that it leads to a significant majority of the population having average wealth (Guala, 2009). However, to the best of our knowledge, there had been no ABMS study comparing different recipient groups for tax income redistribution, until an article was published out of this dissertation (Taşan & Badur, 2023). After it was published, the study of Iglesias, Cardoso and Gonçalves (2023) has been observed to investigate similar issues, as an example work on tax and inequality. We hope more research will be conducted in this area, clarifying taxation's role in reduction of inequality.

We realise even a deeper research gap in effects of almsgiving on economy and wealth distribution, especially for those that build upon econophysics literature. Important exceptions are notable work by Jaffer (2020), and Younas, Hussain, Anam, and Jaffry (2021) in which zakat is examined in ABMS setting but with no special focus on relative poverty of its recipients. In another exploratory but pioneering study by Sabzian, Aliahmadi, Azar, and Mirzaee (2018), they examine another form of Islamic charity, sadaqah and find it effective for reduction of inequality. To the extent of our knowledge, our research is the first attempt to extend

a prevalent econophysics model to investigate the impact of almsgiving as a portion of wealth, in particular zakat, on nonuniformity of wealth distribution. Hence, main points of contribution to the literature by this study are extending the research on effect of redistribution of taxation as well as almsgiving on inequality by including different recipient groups, and using econophysics approach in an agent-based model.

CHAPTER 3

MODEL INFORMATION FOR FIRST PHASE OF THE FIRST ESSAY

3.1 Problem description

First phase of our study examines the impact of taxation and almsgiving on money wealth distribution separately and investigates whether these mechanisms are actually effective for reducing nonuniformity of money wealth distribution. To achieve this goal, we initially build a very basic economy model called the Base Model. In this Base Model (Model 0), every agent (individual) starts with a uniformly distributed random amount of money. Then we begin to iterate the model with the only economic activity as the fixed money transfer of every agent to a random other agent. We use the resulting distribution of money wealth as the benchmark for subsequent Taxation and Almsgiving models.

In order to estimate inequality level of different wealth distributions, this study opts for using comparison of different wealth deciles of the population and their share in overall wealth distribution. In an ideal economy with perfect equality in terms of wealth distribution, total wealth of every wealth decile would be the same. However, in the presence of nonuniformity in wealth distribution, this equality of wealth deciles no longer holds, and the proportion of these deciles' total wealth becomes a measurement metric for inequality. In this study, for comparison purposes, we select the proportion of total wealth of the top wealth decile (the richest ten per cent of the group) to total wealth of the bottom five wealth deciles (poorer half of the group) as this measurement metric and denote this metric as P (proportion value).

After getting the Base Model's results, we extend the model to include taxation, which is implemented as redistribution of a share of fixed money transfer between two agents to a third agent from a poor class of the population. The second extension of the Base Model examines almsgiving, implemented according to the rules of Islamic practice of zakat, as the transfer of a percentage of every agent`s money wealth to a random other agent. Two models of compulsory and voluntary giving analyse the effect of taxation and almsgiving on the wealth distribution separately. When the effect of taxation is investigated (Model 1) there is no almsgiving behaviour, whereas when almsgiving (zakat) is examined (Model 2), taxation is excluded. These two models, namely Taxation Model (Model 1) and Almsgiving Model (Model 2) will be described in detail.

In the Taxation Model, we try to understand if the instrument of taxation is really effective as a means for a fairer money distribution. In the model's implementation, revenue from taxation of every transaction goes to a random agent from lower classes of the population. That is, we only cover a tax on transactions (expenditure tax) and assume that taxes are only used for social assistance to the poor. Compared to the Base Model, which includes a fixed amount of money transfer, taxation on transactions should lead to a lower percentage of money wealth for the top ten per cent population and a higher share for the bottom fifty percent population. Therefore, we expect a lower value for P. Using this value as the indicator, we hypothesize that taxation should reduce nonuniformity in the distribution (Hypothesis 1 - H1).

Null hypothesis for Hypothesis 1 ($H_0 1$): Compared to the Base Model, proportion of total wealth of the top decile of the population to that of the bottom

five deciles of the population (P value) stays the same, if a tax is levied on transactions.

Alternative hypothesis for Hypothesis 1 ($H_1$1): Compared to the Base Model, proportion of total wealth of the top decile of the population to that of the bottom five deciles of the population (P value) decreases, if a tax is levied on transactions.

Islamic practice of alms (zakat) can be defined as giving one-fortieth or more of one's wealth to the poor or the needy, at least annually. It is considerably difficult to assess zakat's actual impact on inequality. This is because the exact number of people practising it is impossible to measure as in some cases it is given in private. Therefore, in order to precisely assess its efficacy, we analyse the case of universal practice and demonstrate the results when every member of a group practises it. Because recipients of alms are selected by the giver in real-life conditions with no forced regulation, besides helping individuals from poorer classes, we additionally cover the case of totally random distribution of alms in our model. Therefore, we hypothesise that if a certain portion of every agent's monetary wealth is given to another agent, the wealth distribution should approach uniformity (Hypothesis 2 - H2).

Null hypothesis for Hypothesis 2 ($H_0$2): Compared to the Base Model, proportion of total wealth of the top decile of the population to that of bottom five deciles of the population (P value) stays the same, if a portion of every agent's wealth is given to another agent.

Alternative hypothesis for Hypothesis 2 ($H_1$2): Compared to the Base Model, proportion of total wealth of the top decile of the population to that of bottom five deciles of the population (P value) decreases, if a portion of every agent's wealth is given to another agent.

3.2 Model description

This study follows Overview, Design concepts, Details Document (ODD) protocol (Grimm et al., 2006; Grimm et al., 2010; Müller et al., 2013; Railsback & Grimm, 2019) as the formalism for agent-based model specification. This section describes our models utilising this protocol, which includes three main categories, namely Overview, Design concepts and Details.

3.2.1 Overview

Overview subsection presents a brief and general description of the model, consisting of three elements, namely, Purpose, Entities, state variables and scales, Process overview and scheduling.

3.2.1.1 Purpose

The purpose of Model 1 is to examine, assess and control the effect of taxation. In an abstract simulated simple economy in which the only economic activity is a fixed-amount of money transfer between agents, taxation is levied on transactions to observe if it helps to build a more socially fair wealth distribution. The central idea in the model is that taxation of trade might decrease the relative poverty of subordinate classes in a society, if a portion of revenue (i.e. tax) from transactions is redistributed to the needy.

Like Model 1, the purpose of Model 2 is to examine and assess the effect of almsgiving. To operationalise almsgiving, we implement the Islamic practice of zakat, which requires an individual to give 1/40 or more of their wealth. As ethically almsgiving's aim is social justice, transfer of a certain percentage of wealth to

another agent in an economy is expected to lead to a fairer wealth distribution. This premise is what, observing the output distribution, Model 2 tries to test and throughout this way, we attempt at assessing the effectiveness of almsgiving.

3.2.1.2 Entities, state variables, and scales

Both Model 1 and Model 2 include only one type of entity: individuals. As the main economic agents, they are characterised by one state variable: wealth (monetary wealth). Every individual's wealth defines the amount of money they have at a certain point in time, represented in dollars. Minimum value of wealth is zero but there is no upper bound. One time step of the model represents the time in which all individuals have randomly chosen another individual and possibly interacted with it via transfer of money. Same agent can be selected multiple times to receive money transfers. Simulations run until the overall wealth distribution becomes stationary.

3.2.1.3 Process overview and scheduling

In both models in each time step every individual chooses randomly one other individual to interact with, and transfers a fixed amount of dollars to them as the transaction of simple trade. Sender`s (buyer) wealth is decreased by that fixed value, whereas receiver`s (seller) is increased by the same amount. The updating process of state variables of agents is thus asynchronous (one by one).

In Model 1, after a transaction is complete (from buyer to seller), seller's revenue is taxed by the government by a fixed tax rate. The government immediately passes this money to lower classes of the population as transfer income. Being of lower classes are defined by belonging to bottom wealth deciles of the population.

An agent is selected randomly from these lower classes after every transaction and associated tax is given to this agent as social assistance.

In Model 2, after a transaction is complete, the buyer gives a specified portion of their wealth to a different second receiver as alms (zakat). The buyer chooses this receiver randomly and freely from either lower classes or all of the population.

3.2.2 Design concepts

Design concepts category, as a single element, includes ten items. Our model covers the items of Basic principles, Interaction, Stochasticity and Observation. Emergence, Adaptation, Objectives, Learning, Prediction, Sensing and Collectives are excluded, as they are not appropriate for, or applicable to our model.

3.2.2.1 Basic principles

Our Base Model extends an earlier simple economy model of Wilensky and Rand (2015; Dragulescu & Yakovenko, 2000) in which a fixed money transfer between agents results in an exponential (Boltzmann) wealth distribution. Their model begins with an equal initial wealth for agents whereas in our model agents get a uniformly distributed random amount of initial wealth. Model 1 examines taxation of trade via transfer of a certain ratio of income to lower wealth deciles of population. Model 2, on the other hand, examines transfer of a certain proportion of wealth personally to a random needy recipient, as an act of almsgiving.

3.2.2.2 Interaction

Pairs of individuals interact for money transfer for trade, tax collection-redistribution (Model 1) and almsgiving (Model 2).

3.2.2.3 Stochasticity

The interaction between individuals is a stochastic process because interaction partners are chosen randomly. In each transaction every agent selects a random other agent for fixed money transfer. Recipients of redistribution of taxes and alms are selected randomly as well (either from lower wealth deciles or from all of the population).

3.2.2.4 Observation

Two plots are used for observation, the histogram of wealth distribution and wealth of top 10% and bottom 50% population. Resulting wealth distribution pattern of the population is assessed for normality (by performing Shapiro-Wilk test) and proportion of highest ten per cent level wealth to lowest fifty per cent level wealth.

Other elements of the Design concepts category of ODD, Adaptation, Objectives, Learning, Prediction, Sensing and Collectives are excluded in this description, since they are not applicable in any of our models.

3.2.3 Details

Details category presents the characteristics of the model, in terms of the elements of Initialisation, Input data and Submodels.

3.2.3.1 Initialisation

Simulations are run with 500 individuals, each beginning with a random amount of wealth uniformly distributed between 0 and 200 dollars (therefore both poor and wealthy individuals exist initially). This results on the average 50000 dollars of total wealth for initialisation of each replication of each experiment.

3.2.3.2 Input data

None of the models includes any input from the user or external data sources.

3.2.3.3 Submodels

For Model 1, there are two parameters, namely T, taxation rate of transactions, and N, the proportion of population with bottom level wealth for whom taxes are spent or redistributed. For Model 2, parameters are Z, the proportion of wealth given to a random other individual as alms (zakat) and S, proportion of population from whom recipient of alms is selected. Explanations of parameters for the Model 1 and Model 2 are given in Table 1.

In the Base Model of simple economy, in both Model 1 and Model 2, after initialisation, simulations run with trade process in each time step. In Model 1, taxation process follows every trade (trade with taxation). In Model 2, almsgiving process follows every trade (trade with alms).

Table 1. Parameters for Model 1 and Model 2

Parameter	Explanation
R	Range for uniformly distributed initial wealth of agents
M	Money transfer for trade
T	Taxation rate
N	Proportion of population that gets the taxes
S	Proportion of population that recipient of alms is selected
Z	Proportion of wealth given as alms

Trade process: This process represents an instance of trade (or transaction) between two individuals in a simple economy. In the models, we are only interested in money transfer resulting from the trade (transaction amount, which is 10 dollars) and we exclude goods or services provided in return. Trade process is exercised according to the pseudocode supplied in Figure 4.

```
For every time step t {
    for every individual i1 {
        Select a random individual i2
        Decrease i1`s wealth by transaction amount for trade(ten dollars): W1=W1–M
        Increase i2`s wealth by transaction amount: W2=W2+M }  }
```

Figure 4. Pseudocode for trade process

Trade with taxation: In Model 1, we assume that taxation income is wholly redistributed to subordinate classes of the society as social assistance. Associated procedure is as shown in Figure 5.

```
For every time step t {
    for every individual i1 {
        Select a random individual i2
        Decrease i1`s wealth by transaction amount: W1=W1–M
        Increase i2`s wealth by transaction amount minus tax: W2=W2 + M*(1-T)
        Select a random individual i3 from poorest N percent of the population
        Increase i3`s wealth by amount of tax: W3=W3+T }  }
```

Figure 5. Pseudocode for trade with taxation

Trade with alms: This algorithm introduces Islamic practise of almsgiving (zakat). Because it is a free, personal and often undisclosed process in which an almsgiver could choose any person they like, in this algorithm we assume a random selection process for the recipient from either lower wealth deciles or all of the population. Associated trade with almsgiving procedure is demonstrated in Figure 6.

```
For every time step t {
    for every individual i1 {
        Select a random individual i2
        Decrease i1`s wealth by transaction amount: W1=W1–M
        Increase i2`s wealth by transaction amount: W2=W2+M
        Select a random individual i3 from S percent of the population
        Decrease i1`s wealth by proportion of Z: W1=W1*(1-Z)
        Increase i3`s wealth by the same amount: W3 = W3 + W1*Z } }
```

Figure 6. Pseudocode for trade with alms

3.3 Model assumptions and potential limitations

After describing our models and before presenting experiment results and associated discussion, in order to achieve scientific objectivity, we want to state various contrasting points of view to our approach and related different ideas briefly. First, because trade is not motivational in our models, and utility, production, banking, saving propensity and other economic phenomena are not included, our models might be argued to be econophysical models, and not economic models, at least in the standard economy theoretical sense. Second, although we adopt the point of view

that encourages reduction of inequality, there is an argument suggesting that unequal distributions are natural and efficient, and interventions to alter the wealth distribution make the wealthy worse off, therefore such efforts should be avoided. Third, although our models are not based on utility maximisation, there is an argument that opposes interpersonal comparison of utility based on ordinality of utility. Fourth, although we try to examine and grasp the nature of giving in both peer-to-peer almsgiving and taxation-based social transfer forms, our work does not, by no means, claim to be or attempt at putting an end to the scientific inquiry of how reduction of poverty and inequality might best be achieved. Any potential policy change for these aims should be thoroughly and cautiously investigated against possible unforeseen outcomes on other economic phenomena such as inflation, labour supply, productivity and so forth. Our work should only be seen as intending to be a humble contribution to the efforts for a more inclusive and better functioning economy, without harming what current economic order has already achieved.

CHAPTER 4

SIMULATION AND RESULTS FOR FIRST PHASE OF THE FIRST ESSAY

This chapter presents the outcome of the first phase of our study, beginning with implantation and parameterisation details and continuing with actual results of the models involved. After an overall presentation of outputs, model results are given in the order of Base Model (Model 0), Taxation Model (Model 1) and Almsgiving Model (Model 2).

4.1 Implementation of simulation and overall results

Initial parameters of Base Model, Taxation Model and Almsgiving Model as well as their values are given in Table 2. For simulation of Taxation Model, tax rate parameter (T) is assigned the values of 10%, 20%, and 30%, which are realistic as in majority of countries sales tax rate is between 10% and 30% (Trading Economics, 2022). Values for proportion of wealth given as alms (Z) are 1/100, 1/40 and 1/10, and this set of values is determined to include the most commonly practised ratio for zakat in Islamic jurisprudence, 1/40 (2.5%). Experiments examine cases in which taxes and alms are transferred to bottom wealth decile (10%), and lower half of the population (50%), as poorer individuals are thought to be more likely to benefit from social assistance. Simulation of Almsgiving Model includes the case of totally random selection of recipients from the whole population (100%) as well, in order to test the effectiveness of almsgiving out of wealth (zakat), even if alms are not given to the poor and the needy.

Models are implemented in Netlogo 6.0 simulation software (Wilensky, 1999), with Netlogo programming language. Associated basic program code is

shared in ComSES Net / OpenABM portal (Taşan, 2018). For every model, every parameter value is set at each simulation experiment and each of these experiments are run for 20 replications. Wealth distribution pattern of the population is obtained and associated data are gathered after the simulation ends. Data for proportion of

Table 2. Values Assigned to Model Parameters

Parameter	Value
R: Range for uniformly distributed initial wealth of agents	0 (lower bound) to 200 (upper bound) dollars
M: Money transfer for trade	10 dollars
T: Taxation rate	10%, 20%, 30%
N: Proportion of population that gets the taxes	Bottom 10%, Bottom 50%
S: Proportion of population that gets the alms	Bottom 10%, Bottom 50%, Anyone
Z: Proportion of wealth given as alms	1/100, 1/40, 1/10

the top decile`s wealth to the sum of bottom five deciles` wealth of the population is calculated (P value) after the distribution pattern becomes relatively stationary. Distribution pattern is accepted to be stationary when the wealth proportion chart is observed to be stable for at least 100 time steps. Specific proportion P values for every replication of the experiments are calculated as the main indicator for uniformity in wealth distribution. Average and standard deviation of these P values are obtained for the set of 20 replications. Each set of 20 replications is treated as a group and the Shapiro-Wilk test of normality is conducted. When it is observed that normality assumption cannot be rejected, Welch’s t-test for unequal variances is

calculated between the Base Model and each different experiment for proportion P values. If the Shapiro-Wilk test rejects normality assumption, we rank the data and conduct Welch's t-test on ranked data again, as suggested by Zimmerman and Zumbo (1993). We follow this process in order to test our hypotheses H1 and H2 and reject previously described null hypotheses H01 and H02, at the significance level of 0.05 (associated p-values of Welch's t-test are given in Table 3). That is, we reject the hypothesis that when a tax is levied on transactions, or a portion of wealth is given to another agent (zakat), the proportion of the top decile of population in terms of wealth to that of bottom five deciles (P) stays the same. Therefore, we might conclude that taxation and almsgiving are effective in reshaping wealth distribution.

Results of the Base Model (Model 0) of the simple economy, Taxation Model (Model 1) and Almsgiving Model (Model 2) are summarized in Table 3. Then the Base Model is explained, concepts of taxation and almsgiving are discussed about their impact on wealth distribution.

Table 3. Proportion of Total Wealth of Top Wealth Decile to That of Bottom Five Wealth Deciles of Population (P), Shapiro-Wilk Test for Normality of P Values in Replications, and Their Welch's T-Test Results Compared to Base Model

	Proportion P		Shapiro-Wilk test for normality of P values		Welch's t-test, compared to base run	
	Average	St. Dev.	p-value	Result	p-value	Result
Only trade with ten dollars (base run)	1.681529	0.080	0.821	can't reject normality		
1/10 taxation to bottom 50%	0.614217	0.031	0.617	can't reject normality	< 0.000001	Reject $H_0$1
2/10 taxation to bottom 50%	0.355904	0.008	0.238	can't reject normality	< 0.000001	Reject $H_0$1
3/10 taxation to bottom 50%	0.284264	0.003	0.256	can't reject normality	< 0.000001	Reject $H_0$1
1/10 taxation to bottom 10%	0.565335	0.029	0.007	reject normality - we rank the data	< 0.000001	Reject $H_0$1
2/10 taxation to bottom 10%	0.331340	0.006	0.858	can't reject normality	< 0.000001	Reject $H_0$1
3/10 taxation to bottom 10%	0.269235	0.003	0.252	can't reject normality	< 0.000001	Reject $H_0$1
1/100 zakat to bottom 10%	0.503016	0.023	0.469	can't reject normality	< 0.000001	Reject $H_0$2
1/40 zakat to bottom 10%	0.329505	0.008	0.586	can't reject normality	< 0.000001	Reject $H_0$2
1/10 zakat to bottom 10%	0.257422	0.003	0.593	can't reject normality	< 0.000001	Reject $H_0$2
1/100 zakat to bottom 50%	0.531119	0.022	0.015	reject normality- we rank the data	< 0.000001	Reject $H_0$2
1/40 zakat to bottom 50%	0.350793	0.011	0.805	can't reject normality	< 0.000001	Reject $H_0$2
1/10 zakat to bottom 50%	0.275142	0.003	0.413	can't reject normality	< 0.000001	Reject $H_0$2
1/100 zakat to any person	0.808023	0.023	0.344	can't reject normality	< 0.000001	Reject $H_0$2
1/40 zakat to any person	0.561916	0.014	0.135	can't reject normality	< 0.000001	Reject $H_0$2
1/10 zakat to any person	0.425688	0.004	0.250	can't reject normality	< 0.000001	Reject $H_0$2

4.2 Base Model

For comparison with Taxation and Almsgiving models, the resulting wealth distribution pattern of the Base Model simulation including only trade with a fixed amount of money transfer transactions (ten dollars) is given in Figure 7 (this figure and subsequent wealth distribution figures are adapted from Netlogo software output (Wilensky, 1999)). Other two concepts (taxation and almsgiving) are built upon this model. This enables us to compare their effects to the Base Model, since underlying

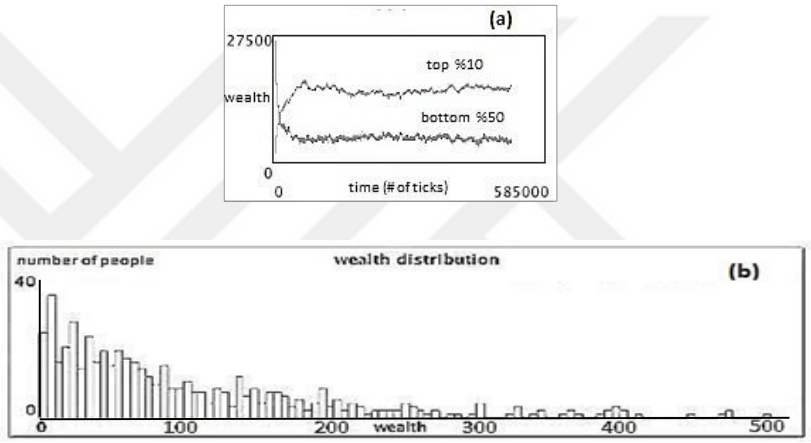


Figure 7. (a) Evolution of total wealth of top decile and bottom half of population as a function of interactions, (b) resulting wealth distribution in the Base Model, with only trade and money transfer of ten dollars between random agent pairs, after more than 400000 time steps

economic activity is the same in every experiment. As can be tracked in Figure 7b, trade-only experiment produces an exponential distribution of wealth in the long run (more than 400000 time steps), which is in parallel with the econophysics literature (see Chakraborti (2007) for example). This result is corroborated by Figure 7a, which shows that resulting total wealth of top wealth decile is greater than that of bottom half of the population. When distribution of wealth is analysed in these settings via chi-squared goodness-of-fit test, we fail to reject that the distribution is exponential,

since $\chi 2 = 5.091488$ with 12 degrees of freedom, $p > 0.9$. Additionally, we present time series evolution of our main output variable for inequality, P value (proportion of top decile's wealth to that of bottom half of population) in Figure 8. Data points are obtained in every ten time steps, and the average P values of 20 replications as well as 3 standard deviations above and below of these average values are presented. It shows that P value stabilises around 1.6 - 1.7 and performing more iterations does not seem to alter this result.

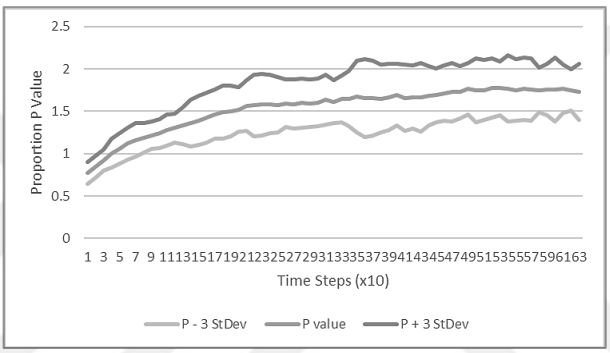


Figure 8. Evolution of P value through time in the Base Model

4.3 Effect of taxation

Table 4 summarizes the effect of taxation on inequality in the artificial simple economy, presenting the proportion P values for different sets of tax rate (T) and redistribution groups (N). Compared to the Base Model of simple economy, introduction of taxation to transactions of trade reduces inequality (P value), supporting first hypotheses (H1). This proportion equals 1.682 on average for the Base Model without taxation and drops

Table 4. Average Values of Proportion P for 20 Replications of Experiments of Taxation Model

Results of taxation experiment (P=1.681529 for Base Model)		Taxation Rate (T)		
		1/10	2/10	3/10
Proportion of population that gets the taxes (N)	Bottom 50%	0.614217	0.355904	0.284264
	Bottom 10%	0.565335	0.331340	0.269235

dramatically to 0.614217, 0.355904 and 0.284264 for 10%, 20% and 30% tax rates, respectively, when the bottom half of the population receives the tax collected. Furthermore, as the tax rate increases (the parameter T), money transfer to the poor population increases as well. This triggers a fairer distribution of wealth among individuals and generates observable social justice. This can be tracked in Figure 9 for tax rates of 10%, 20% and 30%. All simulations in these figures assume the government's redistribution of tax income to the bottom half (fifty per cent) of population in terms of wealth.

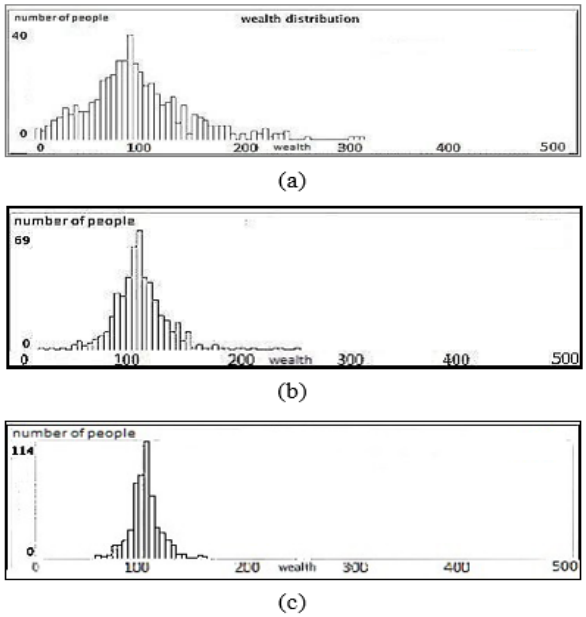


Figure 9. Wealth distribution in trade with (a) 10% tax rate, (b) 20% tax rate, (c) 30% tax rate, and taxes redistributed to individuals of bottom half of the population in terms of wealth

Target of the taxes redistributed is influential on inequality outcome as well. Parameter N denotes the proportion of the population that receives the redistribution of taxes by the state. This could be the poorest ten per cent (in terms of wealth) or the poorest fifty per cent of the population. This parameter especially affects the lowest class, the neediest people in the Taxation Model. If only the bottom decile receives social assistance (tax redistribution) rather than the poorer half of the population, ultimate poverty is eradicated – people with no wealth do not exist in the resulting situation. This is observable in Figure 10 when the tax rates are 10%, 20%, and 30% respectively. In all experiments in this figure government redistributes tax income to the bottom decile (the poorest ten per cent) of population in terms of wealth.

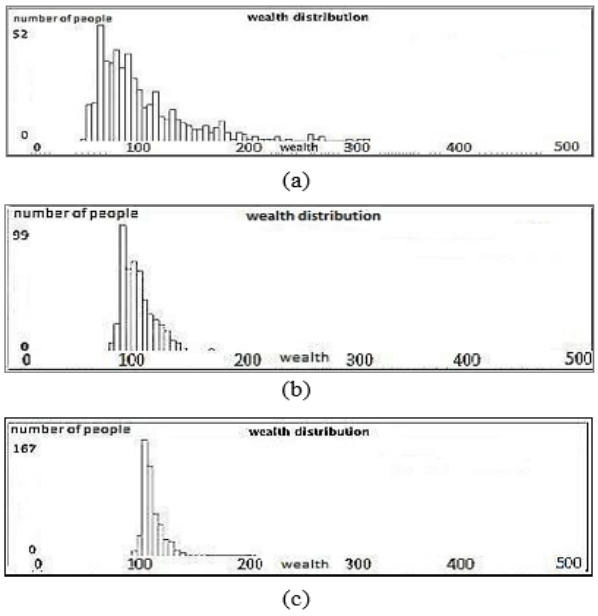


Figure 10. Wealth distribution in trade with (a) 10% tax rate, (b) 20% tax rate, (c) 30% tax rate and taxes redistributed to individuals of bottom %10 (poorest ten per cent) of the population in terms of wealth

In both taxation and alms experiments, we assess the stability of resulting P values and we conduct global and local sensitivity analyses. Average values of P as well as 3 standard deviations above and below mean based on 20 replications are

monitored to ensure stability of the variable throughout the simulation when tax rate is 30% and taxes are redistributed to poorer half of the population, which is presented in Figure 11. Figure 11 demonstrates that P value dramatically drops in the initial steps and stabilises after 70 - 80 time steps. After this initial phase, P value becomes considerably stable and standard deviation values remain substantially low.

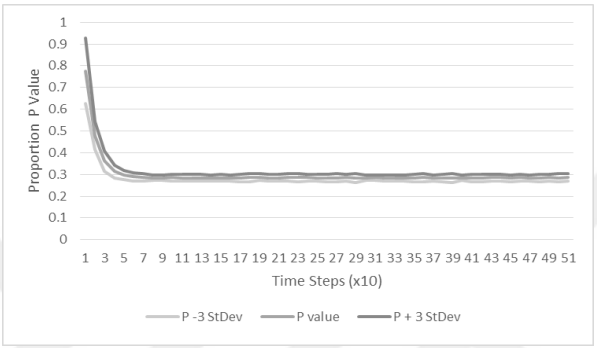


Figure 11. Progress of P value through time and its three upper and lower standard deviations in taxation experiment when tax rate is 30% and taxes are redistributed to bottom 50% of population

We perform global sensitivity analysis on the P variable by varying T and N parameters. In global sensitivity analysis, we re-conduct the experiment many times with minor increments in parameters and observe the effect of every different combination of inputs on the outcome. For taxation experiment, we increase tax rate (parameter T) from 0.000 to 0.400 via 0.003 increments and change ratio of destination group for taxes (parameter N) from 0.000 to 1.000 via increments of 0.050. Each combination of parameter values is replicated only once. For different T and N parameters, we draw a contour plot for demonstrating resulting proportion P values, which can be tracked in Figure 12. As seen in the figure, although taxation seems to have a diminishing marginal effectiveness for higher tax rates (parameter T - x-axis), it is still quite effective at ameliorating inequality. Of particular interest

here is the influence of destination group ratio (parameter N – y-axis), which considerably changes inequality outcome. This is especially true for N values less than 0.6 or 0.5, and this shows that taxes should really be redistributed to

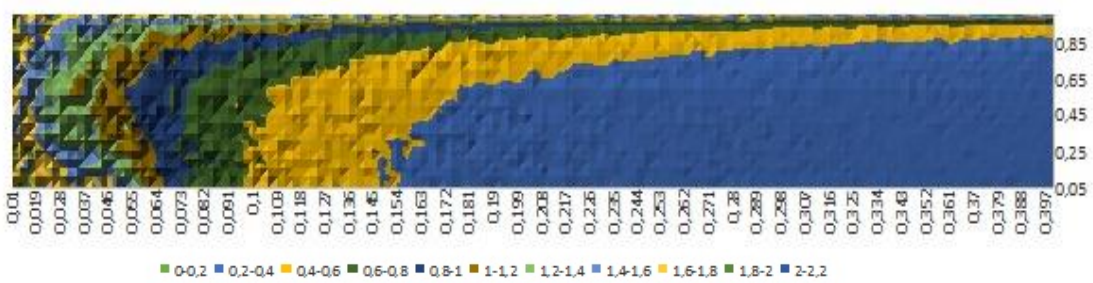


Figure 12. Contour plot for P value for different combinations of tax rate T (x-axis) and ratio of destination group for redistribution of taxes N (y-axis)

poorer classes in order to be effective. In addition, there seems to be an optimum value for N around 0.5, for smaller rates of tax (less than 0.1 or 10%). N values less than 0.5, although means more specific selection of poorer people, seem to produce a more unequal outcome. This is an interesting and counter intuitive finding as well, which could be examined in further studies.

As the last part of the global sensitivity analysis of taxation, we attempt at building a regression model that predicts inequality level (P value) from the proportion of wealth given as tax rate (T) and the proportion of population that taxes are redistributed to (N). In order to do this, we conduct a linear regression analysis using data generated via global sensitivity analysis. P value is the dependent variable in this model while T, N, their powers, combination of their powers up to the degree of eight (T^2,T^3,…T^8,N^2,N^3,…N^8,TN,T^2N,TN^2,…T^4N^4) are taken as independent variables affecting the outcome. Stepwise regression process with bidirectional elimination with SPSS software (model fitting information given in Table 5) produces Equation 1 as the final regression equation.

$$P = 1.938 - 2.15T + 12.378N^8 + 1.011T^2 - 0.179T^3 + 13.758N^7 - 0.294TN^3 - 0.725T^2N^3 + 0.002T^5 + 1.928TN^4 + 0.126T^2N^2 + 1.430N^4 - 0.008T^4N \quad (1)$$

Table 5. Model Fitting Information for Linear Regression Analysis of Taxation Experiment

Model	R value	R^2 Value	Adjusted R^2 Value	Std. Error of the Estimate
Model 1: Taxation	0.980	0.960	0.960	0.881169698

As local sensitivity analysis of taxation experiment, we observe the effect of incrementally rising rates of taxation on inequality outcome of the population. As shown in Figure 13, increasing tax rate reduces proportion P value when redistributed to poorer half of the population, so that P value asymptotically approaches to 0.2. This is the theoretical value of complete equality in wealth distribution. P value cannot be less than 0.2 because if wealth were distributed uniformly, proportion of top decile`s wealth to that of bottom half of population would be 0.2. Additionally, we fit a polynomial equation to the resulting data points, and it is supplied in the figure as well.

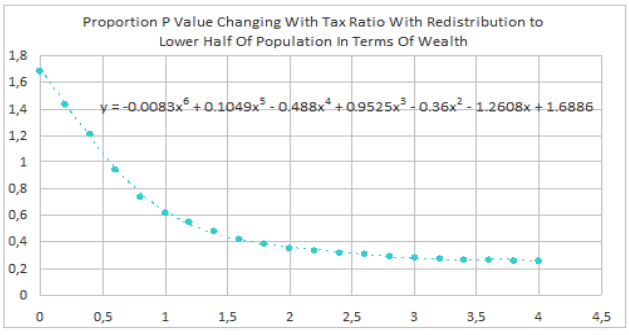


Figure 13. P value changing with tax rate with redistribution to lower half of population in terms of wealth and polynomial fitting equation (local sensitivity analysis of tax rate)

4.4 Effect of almsgiving

Almsgiving as a portion of wealth (in our example, zakat) seems clearly influential for reshaping the wealth distribution for the benefit of the lower class population. Table 6 demonstrates this effect via giving the proportion P values for different portions of wealth given as alms (Z) and for different target groups who receive the alms (S).

Table 6. Average Values of Proportion P for 20 Replications of Experiments of Almsgiving Model

Results of almsgiving experiment (P=1.681529 for Base Model)		Proportion of wealth given as alms (Z)		
		1/100	1/40	1/10
Proportion of population that gets the alms (S)	Anyone	0.808023	0.561916	0.425688
	Bottom 50%	0.531119	0.350793	0.275142
	Bottom 10%	0.503016	0.329505	0.257422

Compared to the Base Model of simple economy, introduction of almsgiving through giving a specified share of wealth by every individual decreases the proportion of top decile's wealth to bottom five deciles` wealth (P), supporting second hypotheses (H2). Furthermore, when the share of wealth given is increased, the poor and needy population is better off. To test this claim, we conduct nine distinct experiments in which zakat (almsgiving behaviour) is simulated. In these experiments, both zakat ratio and destination group ratio take three different values as shown in Table 3.

Since the main aim of almsgiving is aiding the poor and the needy and this principle is emphasised for zakat as well (Quran, 9:60), we first simulate the case in which recipients of zakat are people in the most severe conditions of poverty: bottom 10% of the population in terms of wealth. When almsgiving as a portion of wealth is sent to the neediest members of the society, it might be observed to effectively create

a social safety net as seen in Figure 14a when 1/100 of wealth is given as zakat ratio, in Figure 14b for 1/40 zakat ratio and Figure 14c for 1/10 zakat ratio, respectively. Proportion P values (total wealth of top decile divided by that of bottom half of population) for 1/100 zakat is 0.503016, for 1/40 zakat it is 0.329505 and for 1/10 zakat it is 0.257422, showing increasing equality with more almsgiving. Zakat ratio is found to be inversely related to inequality, as seen from the decrease of the proportion P values as zakat ratio increases.

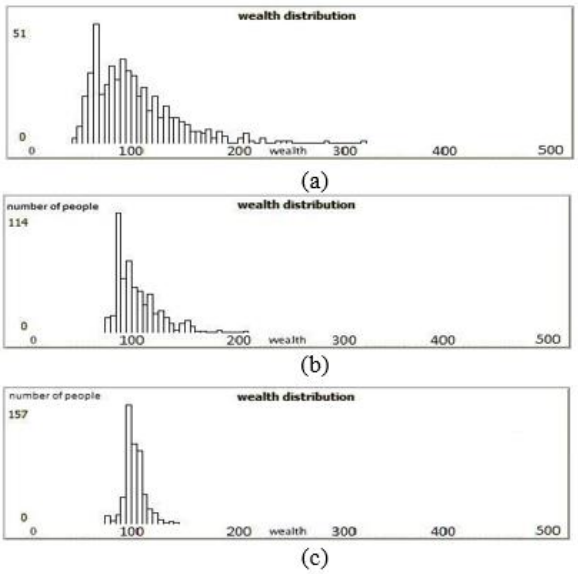


Figure 14. Wealth distribution in trade with almsgiving of (a) 1% (1/100) of wealth, (b) 2.5% (1/40) of wealth, (c) 10% (1/10) of wealth (zakat) given to poorest 10% of the population

In our second set of experiments with zakat, we simulate its effect when there is a larger recipient population. Only relatively poor people, lower half of the population in terms of wealth, obtain the alms given. In these settings zakat seems to be effective again in altering wealth distribution and alleviating inequality. Proportion P values are observed to decrease as the portion of wealth given increases, demonstrating that higher zakat ratios lead to more uniformity in wealth distribution. In these experiments, P values for zakat ratio 1/100 is 0.531119 (Figure

15a), for 1/40 zakat ratio it is 0.350793 (Figure 15b), and for 1/10 zakat ratio it is 0.275142 (Figure 15c).

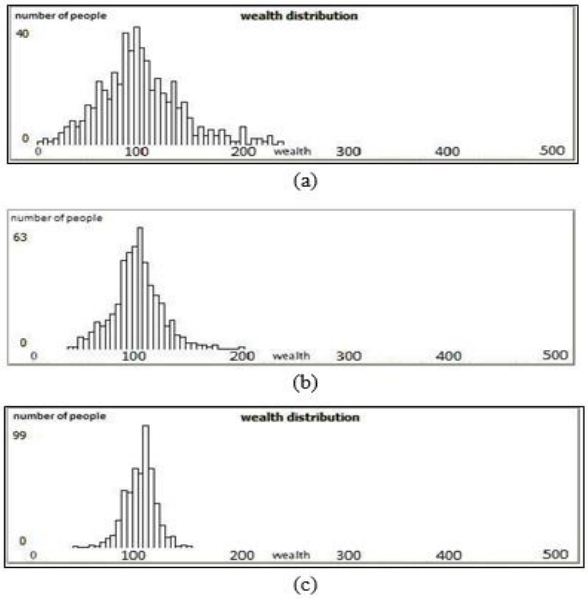


Figure 15. Wealth distribution in trade with almsgiving of (a) 1% (1/100) of wealth, (b) 2.5% (1/40) of wealth, (c) 10% (1/10) of wealth (zakat) given to poorer half of the population

In our third set of experiments with almsgiving out of wealth, we examine the inequality reduction capability of practise of zakat in more extreme conditions. We completely eliminate recipient selection restrictions and prefer random transfers of zakat. This means a rich person is equally likely to obtain a certain amount of zakat as a severely poor person. In these last set of experiments, the proportion of top decile to bottom five deciles value (proportion P value) for 1/100 zakat ratio is 0.808023, for 1/40 zakat ratio it is 0.561916 and for 1/10 zakat ratio it is 0.425688. This important influence of almsgiving on wealth distribution is shown in Figure 16a, Figure 16b and Figure 16c for zakat ratios of 1/100, 1/40 and 1/10, respectively. This result is especially interesting because even if almsgiving of wealth (e.g. zakat) is given to a totally random other agent, it still helps with approaching social justice.

Although not so commonly observed in real societies, in these settings, zakat givers do not select poor or needy as recipients for zakat and they give it to random other agents they reach conveniently. We deliberately include this scenario, as we want to exclude inequality-mitigating effects of selection of zakat recipients. The fact that almsgiving as a percentage of wealth (zakat) is apparently still effective in relieving inequality, might be an indicator that it is indeed a powerful means for the quest of social justice.

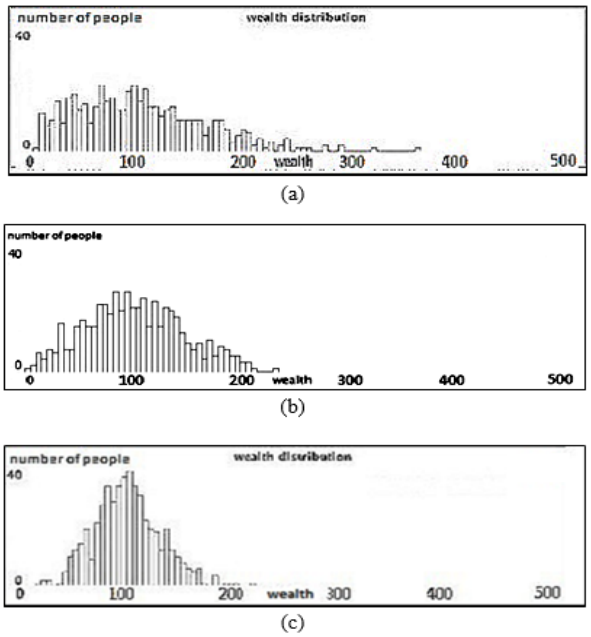


Figure 16. Wealth distribution in trade with almsgiving of (a) 1% (1/100) of wealth, (b) 2.5% (1/40) of wealth, (c) 10% (1/10) of wealth (zakat) given to a random recipient

As in the taxation experiments, we perform stability and sensitivity analyses for the almsgiving experiments as well. Stability analysis of the output variable, proportion P value is conducted. Progress of P value over course of the simulation is tracked at Figure 17 with average P value and three standard deviations (upper - lower bounds) for 20 replications when zakat ratio is 1/40 and destination group ratio

is bottom 50%. As seen from Figure 17, in the initial steps the P value dramatically drops and stabilises after around the 80th time step.

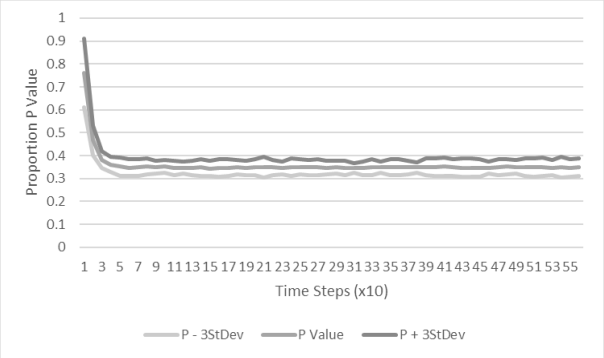


Figure 17. Progress of P value through time and its three upper and lower standard deviations in almsgiving (zakat) experiment when 1/40 of wealth is given to poorer 50% of population

In global sensitivity analysis, we re-conduct the experiment many times with minor increments in parameters (from 0.000 to 0.250 for zakat ratio parameter with 0.020 increments and from 0.000 to 1.000 for destination group ratio parameter with 0.050 increments) replicating each combination once. As seen in Figure 18, zakat ratio is substantially effective on P value, as the primary outcome of the experiment. Zakat ratio quickly reduces proportion P value while it is still close to zero (left hand side of the figure) and for larger values it makes P approach to its theoretical minimum value of 0.2 (perfect equality). An interesting finding is that the zakat ratio seems to have an optimum value for different destination group ratio values, with which P value reaches its minimum point (minimum inequality). For instance, for the destination group ratio of approximately 0.75, if we draw an imaginary horizontal

line in the graph, we observe that between zakat ratio values of 7.5%-10%, P value approaches around 0.3, and for higher and lower zakat ratio values, P value

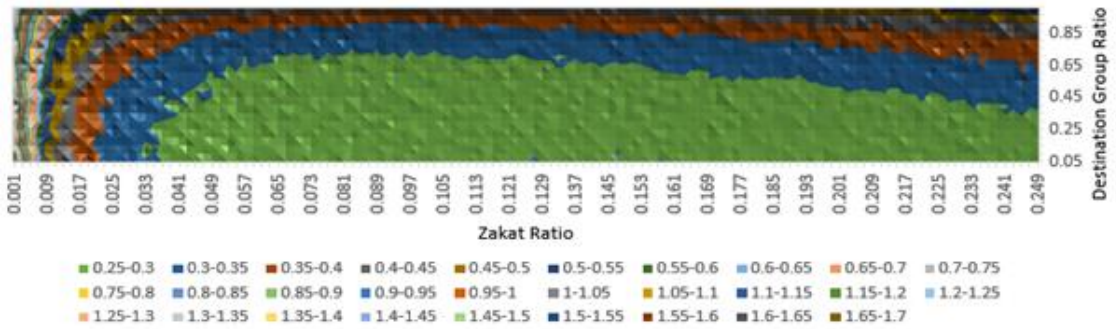


Figure 18. Contour plot for P values for different combinations of zakat ratio (parameter Z, x-axis) and ratio of destination group for giving of alms (parameter S, y-axis)

increases, signifying higher inequality. This finding is important because for equality maximisation, giving one's whole wealth, although the most altruistic case, is not the most effective way. With different optimal values to be discovered for different targets in terms of equality level, giving seems to have its own rules.

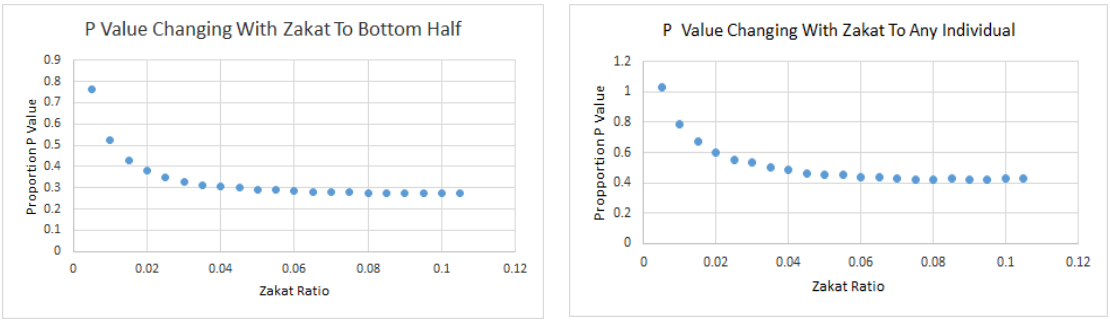
As a complement to visual global analysis of almsgiving, we attempt at building a regression equation that calculates inequality level (P value) from proportion of wealth given as alms (Z) and proportion of population that recipient of alms is selected (S). We conduct a linear regression analysis using data generated via global sensitivity analysis. Here, P value is the dependent variable while Z, S, and their powers, combination of their powers up to the degree of eight in total (Z^2,Z^3,…Z^8,S^2,S^3,…S^8,ZS,Z^2S, ZS^2,…Z^4S^4) are taken as independent variables affecting the outcome. Stepwise regression process with bidirectional elimination with SPSS software produces Equation 2 as the resulting final regression equation (associated model fitting information is given in Table 7).

$$P = 0.826 + 0.272S^4 - 20.913Z + 232.937Z^2 - 867.249Z^3 + 3803.977Z^5 + 30.348Z^4S + 0.783S^8 - 0.873S^7 \quad (2)$$

Table 7. Model Fitting Information for Linear Regression Analysis of Almsgiving (Zakat) Experiment

Model	R value	R^2 Value	Adjusted R^2 Value	Std. Error of the Estimate
Model 2: Almsgiving (Zakat)	0.864	0.746	0.745	0.073603207

For local sensitivity analysis of the zakat ratio parameter, we conduct two different sets of experiments, (when S=50% and S=100%), for incremental values of this parameter. When zakat is given to the poorer half of the population, P value approaches to its theoretical minimum of 0.2 (Figure 19a). A more intriguing finding is the confirmation of previous observation that when practised by every member of the society, zakat helps with social justice even in the absence of proper selection of recipients. As can be tracked in Figure 19b, for increasing amounts of zakat, P value can be dropped to around 0.4, which is considerably lower when compared to Base Model value of 1.681 (approximate value, see Table 3 and Table 6). Zakat, or any other system with almsgiving as a portion of wealth, seems to be substantially effective for reducing inequality, without the need for an arduous selection process of poorest individuals to give. This statement seems to hold true even in the case of totally random selection of recipients.



(a) (b)

Figure 19. P value changing with zakat ratio with alms given to (a) poorer half of population or (b) anybody randomly (local sensitivity analysis of zakat ratio)

CHAPTER 5

MODEL INFORMATION FOR SECOND PHASE OF THE FIRST ESSAY

5.1 Problem description

In first phase of our study we investigated the act of giving in two forms, compulsory giving (taxation) and voluntary giving (almsgiving, particularly zakat) and their level of efficacy to decrease wealth inequality in a group of individuals. However, we conducted this investigation with simulation of two distinct models for two forms of giving and observed their isolated effects. We did not cover the case in which both forms of giving operate simultaneously and possibly even synergistically. This second phase of the study will try to explore this particular condition of simultaneous execution of both compulsory and voluntary forms of giving, and their effectiveness for reduction of inequality while working together.

Taxation and charitable giving are fundamentally related and it is not illogical for them to be substitutable. Their substitutability is observable in policy of tax deductibility of donations implemented in most countries. According to Charities Aid Foundation's (2016) research of 26 countries spanning six continents and responsible for 77% of world GDP, 24 of these 26 countries have some form of tax incentives for charitable giving. Excluding Saudi Arabia, which has no income tax, and Nigeria, which has no tax incentives, their study shows that their sample of countries implemented tax deductibility of donations to some extent. When 10000 dollars are donated to some cause, the tax incentive of the countries, i.e. the amount that can be deduced from taxes to be paid, is given in Figure 20, which is obtained from aforementioned study. Since these wide range of countries utilise tax incentives to encourage charitable giving, there should be an underlying presupposition that is

widely held by their policy makers. This presupposition should be in parallel with the main idea of this study: Both charitable giving (including almsgiving) and taxation serve the same purposes, which are social progress and social justice, and they are substitutable.

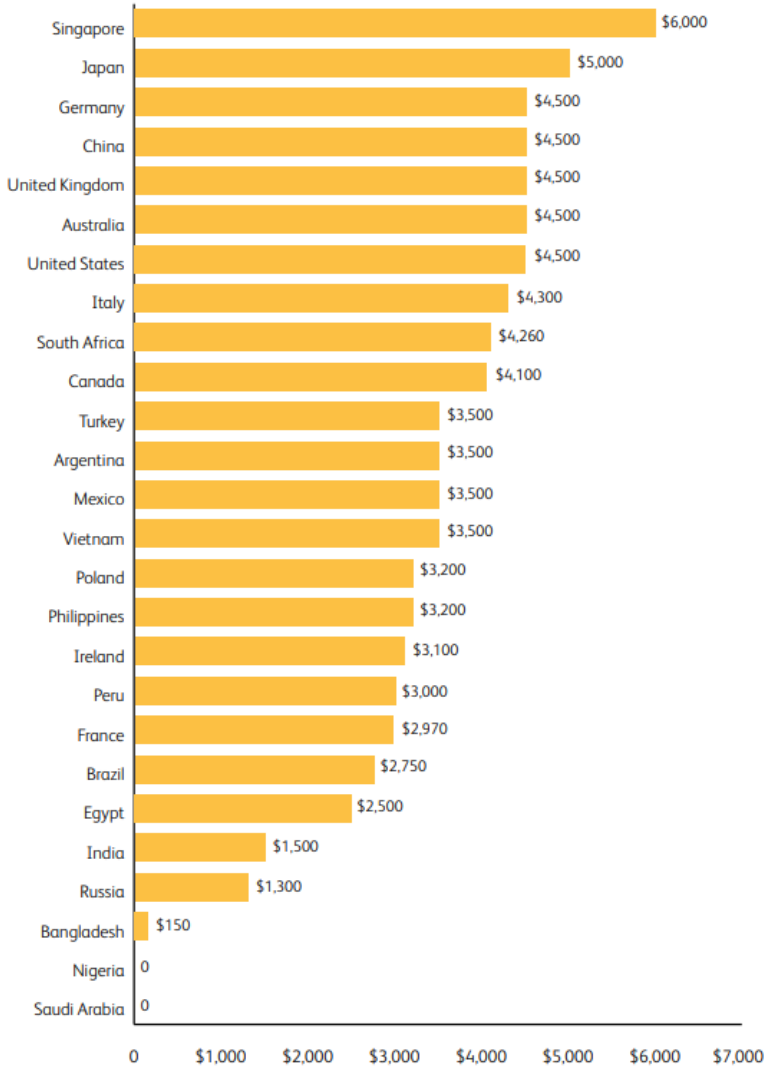


Figure 20. Incentive value on a US $10000 donation for a wealthy donor
Source: Charities Aid Foundation (2016)

There seems to be another way charitable giving (almsgiving) may synergistically increase total amount of taxes paid. This incremental effect can be thought to stem from the surprising result reached by Brooks (2007), which suggests

charitable giving actually is related to an "increase" of income. He demonstrates that 1 dollar donated is related to a 3.75 dollars increase in earnings for the households analysed. In order to clarify the relationship between donations and income and to assess the effect of giving on earnings and not vice versa, this study uses the volunteering as the instrument variable, which is shown to be correlated to charitable giving but not to income level. At the time of donation, charitable giving certainly leads to an amount of drop in one's money or assets, but in the long run, it seems to be related to higher earnings, according to this study's unintuitive and, maybe even mystical, result. Hence, as the businesses' earnings increase, taxes paid for these earnings are expected to be more. This might be another form of hypothetical synergy between taxation and almsgiving.

This second analysis examines the fusion of taxation and almsgiving and extends previous study by using both voluntary and compulsory giving in the same model. Impact of taxation and almsgiving together on money wealth distribution is the primary focus of this chapter and this extended model examines whether almsgiving and taxation synergistically work together for a better wealth distribution in the society. We investigate if they build a fusion to increase the effectiveness of each other and if they could substitute each other against inequality. If we can demonstrate that almsgiving may substitute taxation for reduction of inequality, we can analyse the simultaneous effect of compulsory and voluntary giving and this may lead to social policy recommendations. Government might be able to adjust taxation rate according to level of almsgiving in the population. This study may even culminate in an actual formula of uniformity of wealth distribution in a community, which calculates level of equality/inequality for given rates of almsgiving and taxation.

Hence, in this second phase of agent-based study of inequality and giving as a possible solution, combination of both voluntary giving (almsgiving - zakat) and compulsory giving (taxation) in the same model enabled to acquire insight about two main points:

1. Could these two giving methods substitute each other and if so, how can this substitutability effect be expressed?

2. Could inequality in a population be calculated using rates of these methods, that is, could tax rate and zakat ratio be employed to reach proportion of wealth of top decile and bottom half (P value)?

To answer these questions while not losing our connection to the first phase of the study and findings reached thereof, we preserve our very basic economy model. We begin our simulation with this Base Model's initial conditions, in which every agent (individual) begins with random amount of money, uniformly distributed in a range. We keep the iteration of our Base Model as well, with the only economic activity as a fixed money transfer of every agent to a random other agent. We use the outcome distribution of money wealth as the basic state for comparison purposes. That is, Base Model results are compared with the results obtained when almsgiving and taxation are added simultaneously.

In order to facilitate comparison of inequality levels with the first phase of the study, we utilise the same metric for measurement of it: P value. It has been defined previously as the proportion of wealth of top decile (the richest ten per cent of the group) to that of bottom five deciles (poorer half of the group). For second phase of the study, we extend the Base Model conditions to cover taxation and almsgiving simultaneously. Like the first phase, taxation is operationalised as redistribution of a portion of transaction between two agents to a third agent whereas almsgiving is

implemented according to the rules of Islamic practice of zakat, i.e. giving a portion of every agent`s money wealth to a random other agent. This new model, which we call Fusion Model, including both taxation and almsgiving, will be explained in next section.

5.2 Model description

Like the first phase of the study, which examined almsgiving and taxation separately, we present our Fusion Model description according to ODD (Overview, Design concepts, Details Document) protocol, in order for easier comparison between analyses in the two phases of the study.

5.2.1 Overview

Overview category of ODD protocol provides a brief and general explanation of the model, via presenting three elements, namely, Purpose, Entities, state variables and scales, Process overview and scheduling.

5.2.1.1 Purpose

The purpose of the Fusion Model is to investigate, assess, control the impact of taxation and almsgiving together on inequality. In this very simple economy simulation, the only economic activity is a fixed amount of money transfer between agents to represent trade. For every transaction both voluntary and mandatory forms of giving are simulated as well. For mandatory giving, tax is imposed on transactions which is simulated as redistribution of a percentage of transaction to a random or poorer agent. For voluntary giving, every agent sends a portion of wealth to another agent (to simulate zakat), selected randomly or among the needy. These two forms of

giving are modelled and simulated together to observe whether they strengthen each other and help to build a more socially just distribution of wealth. Additionally, two forms of giving are examined simultaneously to reveal if there is substitutability between each other, i.e. whether almsgiving may reduce the need for taxation or vice versa. Thus, our main purpose in this model is to measure effectiveness of, and synergy between voluntary giving (almsgiving / zakat) and mandatory giving (taxation) for decreasing nonuniformity in wealth distribution and through this way to understand if they are useful against possible harms caused by inequality.

5.2.1.2 Entities, state variables, and scales

Like models of the first phase, simulation of Fusion Model consists of interactions among only one type of entity: individuals (members of the society). Their main state variable is wealth (monetary wealth), which enables them for economic activities, Wealth is a discrete variable that defines how much money an agent has at a particular time and it is represented in dollars. The minimum value of it is zero, while it has no upper limit. However, because there is only internal economic activity, total wealth of agents is constant. A time step in the model is defined to be the interval in which all individuals randomly select another individual and possibly interact with them, if there is adequate wealth. Simulations are run until the wealth distribution is observed to become stationary.

5.2.1.3 Process overview and scheduling

In Fusion Model at each time step, each agent (individual) randomly selects another agent for a single type of trade and transfers a fixed amount of money to them to represent the transaction between them. The sender's (buyer) wealth is dropped by

the fixed value, while the recipient's (seller) is increased by the same amount. Thus, updating state variables for agents is asynchronous (one by one).

In the same time step, for every transaction, in order to simulate taxation a specified portion of taxation is transferred to a person who owns a relatively less wealth in the population (as if government redistributes taxes as transfer income). Therefore, seller (recipient) receives less than how much the buyer (giver) actually sends. After taxation process is complete, buyer (giver) gives their alms out of the wealth they already have. This procedure roughly implements Islamic practise of zakat, albeit more flexible in terms of percentage (various values for different experiments) and selection of recipient (needy or random). After every agent's transfer of money (trade), redistribution of a portion of transaction (taxation) and sending a portion of wealth (almsgiving) complete, time step concludes.

5.2.2 Design concepts

Design concepts category of ODD is a single element covering ten items. Our model includes the items of Basic principles, Interaction, Stochasticity and Observation. The other items of Emergence, Adaptation, Objectives, Learning, Prediction, Sensing and Collectives are excluded, as they are not appropriate for, or applicable to our model.

5.2.2.1 Basic principles

Base Model is the same with that of first phase of the study, which itself originates from an earlier simple economy model of Wilensky and Rand (2015; Dragulescu & Yakovenko, 2000) in which a fixed money transfer between agents leads to an exponential (Boltzmann) wealth distribution. Their model begins with an equal initial wealth for agents whereas in our model agents start with random (uniformly

distributed in a range) amount of initial wealth. Fusion Model extends Base Model to include both compulsory and voluntary forms of giving simultaneously. The former is taxation of trade, which is via transfer of a certain ratio of income to lower wealth deciles of population. The latter is almsgiving, which is implemented as transfer of a certain proportion of wealth personally to a random or needy recipient.

5.2.2.2 Interaction

Three types of interactions occur: (1) Pairs of individuals interact for money transfer for trade, (2) tax redistribution and (3) almsgiving. Interactions between the same pair may happen more than once throughout the simulation.

5.2.2.3 Stochasticity

As each interaction partner is chosen (pseudo)randomly for every time step, the interaction between individuals is a stochastic process. In each transaction every agent is paired with a random other agent for fixed money transfer. Recipients of redistribution of taxes and giving of alms are chosen randomly as well (either from lower wealth deciles or all of the population). Agents can be selected multiple times as recipients of fixed money transfer, tax redistribution or almsgiving.

5.2.2.4 Observation

Main values of observation are total wealth of top 10% and bottom 50% of population. Resulting wealth distribution pattern of the population is assessed via using proportion of these two values, which is previously named as P value.

Adaptation, objectives, learning, prediction, sensing and collectives are excluded in this description, since they are not effective in any of our models.

5.2.3 Details

Details category of ODD protocol describes the characteristics of the model, covering the elements of Initialisation, Input data and Submodels.

5.2.3.1 Initialisation

In parallel with the models of the first phase, simulations are run with 500 individuals, each beginning with a random amount of wealth uniformly distributed between 0 and 200 dollars. This results in approximately 50000 dollars of total wealth for initialisation of each replication of each experiment.

5.2.3.2 Input data

None of the models includes any input of external data.

5.2.3.3 Submodels

For Fusion Model, there are three important parameters, namely T_F, taxation rate of transactions, Z_F, the proportion of wealth given to another individual as alms (zakat) and D_F, proportion of population from which recipients of alms given and taxes redistributed are selected. Therefore, in our Fusion Model, destination group for both almsgiving and taxation are the same for each simulation. This may assist in creating a fusion between these two forms of giving as they affect the same group of the

population to reduce poverty and alleviate inequality. These parameters and others in our Fusion Model are shown in Table 8.

Table 8. Fusion Model Parameters for Second Phase of the Study

Parameter	Explanation
R_F	Range for uniformly distributed range of agents
M_F	Money transfer for trade
T_F	Proportion of transaction redistributed as tax (taxation rate)
Z_F	Proportion of wealth given as alms (zakat ratio)
D_F	Proportion of population that recipients of alms and taxes are selected (destination group ratio)

In the Base Model, after initialisation simulations are run with trade process in each time step, and this process is identical to its counterpart in Taxation Model and Almsgiving Model. In Fusion Model, procedures of taxation and almsgiving follows every trade, creating trade with giving process.

Trade process: This process represents an instance of trade (or transaction) between two individuals in a simple economy. In the models, we are only interested in money transfer resulting from the trade (transaction amount, which is ten dollars) and we exclude goods or services provided in return. Trade process is exercised according to pseudocode in Figure 21.

```
For every time step t {
    For every individual i1 {
    Select a random individual i2
    Decrease i1`s wealth by transaction amount for trade (ten dollars): W_F1 = W_F1 – M_F
    Increase i2`s wealth by transaction amount: W_F2 = W_F2 + M_F  } }
```

Figure 21. Pseudocode for trade process in Fusion Model

Trade with giving: In our Fusion Model, both taxation and almsgiving are forms of social assistance, which involves flow of monetary wealth to different and possibly needy members of the society. Trade with giving process includes both of these forms of social assistance, therefore, in this model, both forms of compulsory and voluntary giving immediately follows transaction of trade, and associated procedure is as shown in Figure 22.

```
For every time step t {
        For every individual i1 {
                Select a random individual i2
                Decrease i1`s wealth by transaction amount: W_F1 = W_F1 – M_F
                Increase i2`s wealth by transaction amount minus tax: W_F2 = W_F2 + M_F*(1-T_F)
                Select a random individual i3 from poorest D_F per cent of the population
                Increase i3`s wealth by amount of tax: W_F3 = W_F3 + T_F
                Select another random individual i4 from poorest D_F per cent of the population
                Decrease i1`s wealth by proportion of  Z_F : W_F1 = W_F1*(1-Z_F)
                Increase i4`s wealth by the same amount: W_F4 = W_F4 + W_F4*Z_F  }}
```

Figure 22. Pseudocode for trade with giving process in Fusion Model

CHAPTER 6

SIMULATION AND RESULTS FOR SECOND PHASE OF THE FIRST ESSAY

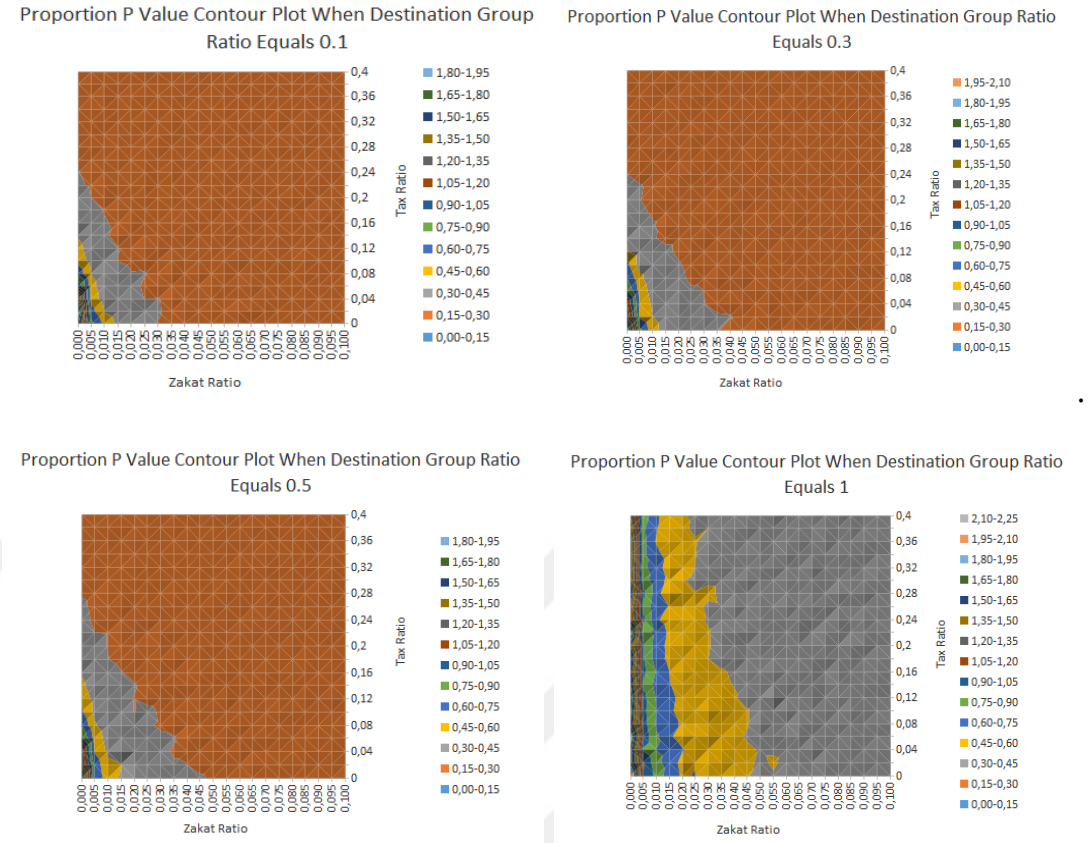
In the first phase of our study, we ran the simulations with several different values for input parameters (tax rate and ratio of wealth give as almsgiving / zakat ratio) for determining if these two types of giving bring about meaningful change in inequality levels of the population. Examining them individually for different destination group ratios (group of population to give alms and taxes) and finding a significant positive effect on inequality measure P value has been enough to show this. However, as we have three distinct independent variables in this Fusion Model, namely tax rate, zakat ratio and destination group ratio and as we are interested in relationship and synergy among them, examining their effect individually would not be adequate. In order to reveal underlying relationship between inequality and balancing forces of compulsory and voluntary giving to various segments of population, we design a study which cover many distinct value combinations for these three independent variables.

We design an experiment with Netlogo software (Wilensky, 1999) consisting of 1761 different parameter value combinations with minor equal increments for both tax rate and zakat ratio. For tax rate, between 0 (no tax – covered as a case) and 0.4 (forty per cent tax – covered as a case) 21 different values with equal increments (an increment of 0.02 – two per cent tax) are chosen to use in the experiments. Same selection process is conducted for zakat ratio between 0 (no zakat – covered as a case) and 0.1 (ten per cent of wealth as zakat – covered as a case) 21 different values with equal increments (an increment of 0.005 – half a per cent zakat). For both tax and zakat, destination group ratio determines the target population that receives the

gathered money (zakat and tax) and it equals 0.1 (only bottom ten per cent of the total population may receive the sum), 0.3 (only bottom thirty per cent of the population), 0.5 (only bottom half of the population) and 1 (all of the population may receive the sum, if selected). Then these two set of values are multiplied (Cartesian product) for four different recipient groups to reach aforementioned 1761 ([21x21x4] - 3 [excluding duplicates when tax and zakat ratio are both zero]) different parameter value combinations. These experiments lead to specific inequality levels for every distinct case, specific proportions of wealth among segments in the population and this is tracked in the resulting P values. Contour plots of the resulting P proportion value (ratio of top decile's wealth to the wealth of bottom half of population) is demonstrated in Figure 23.

As seen in the first three figures when destination group ratio (D_F) equals 0.1, 0.3 or 0.5 (only relatively poorer groups receives tax and zakat gathered) we obtain a similar pattern with most of the area is covered by colour orange, which represents the range 0.15-0.30, and this range includes theoretically minimum value of proportion P value, 0.2 (perfect wealth equality in the population). This may be interpreted as high effectiveness of focused targeting of centre of poverty in redistribution of resources to alleviate the harms of inequality. When poorest strata of the society are focused and aided, it seems actions against adverse effects of inequality could be more successful. Additionally, in these three figures an inverse relationship is observed between tax rate and zakat ratio i.e. when zakat ratio is higher a lower tax rate is needed to achieve the same level of equality. For instance, for D_F=0.3, proportion P value of 0.30 is reached by tax rate of 24 per cent (T_F=0.24) in the absence of almsgiving as a portion of wealth (zakat ratio Z_F=0), whereas with

a. b.



c. d.

Figure 23. Contour plots for P (measure of inequality) when D_F (proportion of population from which receiver is selected) equals 0.1(a), 0.3(b), 0.5(c) and 1(d)

Z_F=0.025 (two point one per cent or one fortieth of wealth is given as alms in the population) less than 8% tax is adequate for reaching the same value of P.

When every individual is a potential receiver for sum of money gathered as tax or zakat (D_F=1, Figure 23d), first observation of interest might be that P value still changes according to different input values, which means giving (especially out of wealth like zakat) is still effective in reshaping wealth distribution even if poverty is not targeted and recipients are randomly selected. It seems act of giving has a kind of intrinsic value in itself, nearly regardless of the recipient.

Another interesting point in Figure 23 is that minimum inequality area changes to cover the range of P=0.30-0.45, and higher proportion P value means less

effectiveness for inequality reduction of both types of giving (tax and zakat). This figure demonstrates a clearer, albeit non-calculable relationship between tax rate and zakat ratio. As seen in Figure 23d, this inverse relationship follows a nonlinear, seemingly exponential equation. If we compare values for higher and lower rates of tax, slope of edges between different ranges of P seems to change, implying a higher order relationship. However, nature of this relationship cannot be extracted from observation of a contour graph only, thus, we build regression analyses to discover the equations that govern them.

We employ regression models for analysis of experiments' data to attempt at extraction of underlying equation for relationship between tax rate and zakat ratio for four different destination group values (D_F=0.1, 0.3, 0.5, 1). The method we follow, using SPSS software, includes creating independent variables by calculating powers of tax rate and zakat ratio values until the power of eight (for tax rate: T_F, T_F^2, T_F^3, T_F^4, T_F^5, T_F^6, T_F^7, T_F^8, for zakat ratio: Z_F, Z_F^2, Z_F^3, Z_F^4, Z_F^5, Z_F^6, Z_F^7, Z_F^8) and multiplication of these new variables to until sum of the powers reaches eight (Z_FT_F, $Z_FT_F^2$, $Z_FT_F^3$, $Z_FT_F^4$, $Z_F^2T_F$, $Z_F^2T_F^2$, $Z_F^2T_F^3$, $Z_F^2T_F^4$, $Z_F^3T_F$, $Z_F^3T_F^2$, $Z_F^3T_F^3$, $Z_F^3T_F^4$, $Z_F^4T_F$, $Z_F^4T_F^2$, $Z_F^4T_F^3$, $Z_F^4T_F^4$). This allows us to catch synergistic effects of zakat ratio and tax rate (i.e. stemming from their interaction) on inequality as well. Hence the equation that includes all candidate variables for regression analysis with stepwise method might be expressed as in Equation 3.

When stepwise method by SPSS Software is applied, a group of output sets are generated by regression analysis. First, a model summary is supplied which presents which of the independent variables are kept as predictors in the resulting equation (here TZ2 actually means $T_FZ_F^2$ and power of variables are given after them). Additionally, R squared or coefficient of determination value of the

$$
\begin{aligned}
\boldsymbol{bP} \;=\; & a_1 + a_2 T_F + a_3 T_F^2 + a_4 T_F^3 + a_5 T_F^4 + a_6 T_F^5 + a_7 T_F^6 + a_8 T_F^7 \\
& + a_9 T_F^8 + a_{10} Z_F + a_{11} Z_F^2 + a_{12} Z_F^3 + a_{13} Z_F^4 \\
& + a_{14} Z_F^5 + a_{15} Z_F^6 + a_{16} Z_F^7 + a_{17} Z_F^8 + a_{18} T_F Z_F \\
& + a_{19} T_F^2 Z_F + a_{20} T_F^3 Z_F + a_{21} T_F^4 Z_F + a_{22} T_F Z_F^2 + a_{23} T_F^2 Z_F^2 \\
& + a_{24} T_F^3 Z_F^2 + a_{25} T_F^4 Z_F^2 + a_{26} T_F Z_F^3 + a_{27} T_F^2 Z_F^3 \\
& + a_{28} T_F^3 Z_F^3 + a_{29} T_F^4 Z_F^3 + a_{30} T_F Z_F^4 + a_{31} T_F^2 Z_F^4 + a_{32} T_F^3 Z_F^4 \\
& + a_{33} T_F^4 Z_F^4
\end{aligned}
\tag{3}
$$

Equation 3 Equation for relationship between tax rate and zakat ratio, which is used for regression analysis

resulting equation is given, stating how much of the variance of dependent variable P is explained by independent variables jointly. This is a goodness-of-fit measure and may roughly be interpreted as strength of relationship between the linear model and the dependent variable P. Then constant value in the equation and resulting coefficients for independent variables are presented with accompanying significance values.

Like contour graphs presented in Figure 23, when $D_F = 0.1$, $D_F=0.3$ and $D_F=0.5$ relatively similar regression analysis results are obtained. This phenomenon's underlying idea can be thought of as if redistribution of taxes and alms of wealth is redistributed to poorer groups of society, resulting wealth distribution is more uniform and similar. When individuals belonging to bottom wealth decile ($D_F=0.1$, Table 9), bottom thirty per cent group in terms of wealth ($D_F=0.3$, Table 10) and poorer half of the population ($D_F=0.5$, Table 11) receive sums of money gathered as zakat and tax regression analysis produces the output given in the associated table.

Table 9. Regression Analysis Results When Destination Group Ratio $D_F = 0.1$

a.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
	,890p	,792	,785	,063984137387229	,025	50,452	1	426	,000	,366

Predictors: (Constant), Z, T, ZT, Z2, TZ2, Z3, TZ3, Z5, T2, ZT2, Z4T4, Z3T3, T3Z4, T3
Dependent Variable: Proportion P Value

b.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	1,359	,030		45,460	,000
	Z	-73,854	2,764	-16,229	-26,722	,000
	T	-8,849	,420	-7,778	-21,078	,000
	ZT	391,126	18,714	26,445	20,900	,000
	Z2	1632,922	82,132	37,167	19,882	,000
	TZ2	-5630,642	336,821	-34,407	-16,717	,000
	Z3	-12637,719	801,056	-27,844	-15,776	,000
	TZ3	28532,017	2240,711	16,105	12,733	,000
	Z5	252557,413	23932,003	5,142	10,553	,000
	T2	23,067	1,906	8,400	12,099	,000
	ZT2	-467,432	30,341	-11,425	-15,406	,000
	Z4T4	-1204393,499	245002,791	-2,748	-4,916	,000
	Z3T3	233460,379	19344,847	15,786	12,068	,000
	T3Z4	-1224066,953	156824,963	-7,617	-7,805	,000
	T3	-19,973	2,812	-2,816	-7,103	,000

Table 10. Regression Analysis Results When Destination Group Ratio $D_F = 0.3$

a.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
	,904	,818	,812	,054959713636331	,002	5,409	1	425	,021	,393

Predictors: (Constant), Z, T, ZT, Z2, TZ2, Z3, TZ3, T2, ZT2, Z5, Z4T4, Z3T3, T3Z4, T3, T5
Dependent Variable: Proportion P Value

b.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	1,293	,026		49,209	,000
	Z	-67,335	2,378	-16,119	-28,310	,000
	T	-8,792	,452	-8,418	-19,440	,000
	ZT	357,465	16,161	26,328	22,120	,000
	Z2	1475,806	70,606	36,592	20,902	,000
	TZ2	-5086,980	289,770	-33,862	-17,555	,000
	Z3	-11371,031	688,296	-27,291	-16,521	,000
	TZ3	25434,278	1924,772	15,639	13,214	,000
	T2	27,780	3,223	11,021	8,620	,000
	ZT2	-430,778	26,271	-11,470	-16,397	,000
	Z5	227530,808	20561,703	5,046	11,066	,000
	Z4T4	-1188624,490	217135,965	-2,954	-5,474	,000
	Z3T3	214248,780	16722,596	15,781	12,812	,000
	T3Z4	-1081218,994	135125,344	-7,329	-8,002	,000
	T3	-37,757	8,561	-5,800	-4,410	,000
	T5	43,641	18,765	,991	2,326	,021

Table 11. Regression Analysis Results When Destination Group Ratio D_F = 0.5

a.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
14	,911	,830	,824	,051631894774729	,013	31,737	1	426	,000	,335

Predictors: (Constant), Z, T, TZ2, Z2, ZT, Z3, TZ4, T2, ZT2, Z2T2, T3Z4, Z3T3, T3, Z5
Dependent Variable: Proportion P Value

b.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	1,240	,024		51,873	,000
	Z	-59,699	2,064	-14,694	-28,917	,000
	T	-7,601	,343	-7,483	-22,140	,000
	TZ2	-3930,387	255,378	-26,901	-15,390	,000
	Z2	1179,881	57,083	30,080	20,669	,000
	ZT	331,296	17,056	25,089	19,424	,000
	Z3	-7883,589	550,193	-19,455	-14,329	,000
	TZ4	145014,346	10912,352	8,601	13,289	,000
	T2	18,961	1,594	7,734	11,893	,000
	ZT2	-501,365	37,282	-13,726	-13,448	,000
	Z2T2	3029,711	545,544	7,119	5,554	,000
	T3Z4	-1341657,896	132902,260	-9,351	-10,095	,000
	Z3T3	146386,306	15422,857	11,087	9,492	,000
	T3	-14,347	2,465	-2,266	-5,821	,000
	Z5	102660,264	18223,021	2,341	5,634	,000

As seen in the figures above R squared value is 0.792 for D_F=0.1 (Table 9a), 0.818 for D_F=0.3 (Table 10a), and 0.830 for D_F=0.5 (Table 11a) implying a considerable portion of variance in inequality measure P is explained by zakat ratio and tax rate jointly. Increasing precision of models (higher R squared values) for greater D_F values might be because of proportion P value's closeness to its theoretical minimum of 0.2 for large portion of experiments with small D_F, with more targeted redistribution. This is observable in the contour graphs presented in Figure 23 as well. When coefficients of resulting independent variables are examined, we observe that both tax rate (T_F) and zakat ratio (Z_F) are kept in the equation, which means both are at least partially effective in reducing inequality. In addition, their powers and perhaps more importantly, combinations of these are included in the equation as well, which means interactions between them are effective on the resulting equality level as well. Coefficients are rather large for some variables, especially with ones with greater power values, and this is understandable as T_F and Z_F values are already

less than 1 and their powers and combinations are increasingly smaller, needing a greater multiplier (coefficient) to be effective on the output (independent variable).

Next, we examine the case when any individual in the population may get the alms and taxes with equal chance (destination group ratio D_F =1). Table 12 describes resulting equation and variable coefficients in this situation.

Here (D=1, Table 12), we observe even a stronger linear relationship between a simpler regression model and the dependent variable P, as can be tracked in model summary table: R squared value is fairly high, 0.912, with only seven predictor variables (Z_F, Z_F^2, Z_F^3, Z_F^5, T_F, Z_FT_F, $Z_F^2T_F$). More importantly, we discover the dominance of zakat ratio effect: first four predictor variables are derived from only Z_F. This finding might be interpreted as relative strength of effect of giving as a portion of wealth, instead of a portion of transaction (tax), in the absence of poverty targeting for redistribution. We might speculate here that since without efficient social policies (unless the poor are sought after and helped) the act of giving as a portion of wealth seems to be more effective, its voluntary practice should be encouraged, while at least partial inclusion of it in taxation policy might be also considerably useful.

For investigating the substitutability of taxation and almsgiving at constant values of destination group ratio, total derivative of P value with respect to tax rate and zakat ratio is computed, and then on the level curves where P value is constant, total derivative is set to zero. When there is a miniscule change in zakat ratio, the compensatory change in tax rate so as to keep P value constant, is equal to the negative of ratio of partial derivatives of P value with respect to tax rate (T_F) and zakat ratio (Z_F). The relation between P value and tax rate / zakat ratio is obtained

Table 12. Regression Analysis Results When Destination Group Ratio $D_F = 1$

a.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
7	,955	,912	,910	,085702019600113	,002	9,667	1	433	,002	,335

Predictors: (Constant), Z, Z2, Z3, Z5, T, ZT, TZ2
Dependent Variable: Proportion P Value

b.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	1,611	,024		67,044	,000
	Z	-88,389	2,210	-9,357	-39,988	,000
	Z2	2236,135	75,016	24,520	29,809	,000
	Z3	-19855,967	835,318	-21,076	-23,771	,000
	Z5	521517,464	29040,119	5,115	17,959	,000
	T	-,739	,092	-,313	-8,012	,000
	ZT	18,409	4,272	,600	4,309	,000
	TZ2	-128,227	41,242	-,377	-3,109	,002

from special forms of full linear regression equation, Equation 3, where only significant derived features are included. Resulting output values are presented in Table 13 for $D_F = 0.1$, Table 14 for $D_F = 0.3$, Table 15 for $D_F = 0.5$, Table 16 for $D_F=1$.

Table 13. Substitutability of Taxation and Almsgiving When $D_F = 0.1$

$D_F = 0.1$		Zakat Ratio		
		0.01	0.025	0.1
Tax Rate	0.1	-9.5475	-19.643	-43.6741
	0.2	18.34292	-1.08874	-16.2597
	0.3	-0.39401	-0.31239	-7.19199

Table 14. Substitutability of Taxation and Almsgiving When $D_F = 0.3$

$D_F = 0.3$		Zakat Ratio		
		0.01	0.025	0.1
Tax Rate	0.1	-11.0368	28.30086	-18.6205
	0.2	5.098411	-0.58047	-7.86874
	0.3	-0.17549	-0.14349	-3.47703

Table 15. Substitutability of Taxation and Almsgiving When $D_F = 0.5$

$D_F = 0.5$		Zakat Ratio		
		0.01	0.025	0.1
Tax Rate	0.1	-7.75876	-9.74907	-7.59821
	0.2	-7.48718	-10.1491	-104.803
	0.3	33.84705	12.30527	31.38036

Table 16. Substitutability of Taxation and Almsgiving When $D_F = 1$

$D_F = 1$		Zakat Ratio		
		0.01	0.025	0.1
Tax Rate	0.1	-82.615	-26.2922	15.89187
	0.2	-79.8858	-23.5596	15.39712
	0.3	-77.1566	-20.8271	14.90237

As can be observed in the tables, most of the substitutability values are negative, indicating that for these conditions, for reaching the same P value (metric for the level of inequality in the simulation), if almsgiving decrease, tax rate should increase. This implies that there is substitutability in our settings for taxation and almsgiving in associated case conditions. Positive values demonstrated in the tables may be caused by model, metric and linear regression imperfections or too much giving, that is, after a threshold, giving might actually increase inequality. This is especially observable in Table 16 for zakat ratio of %10, a result which can be thought to be in parallel with Figure 18.

After examining how for different values of D_F acts of taxation and almsgiving interact and function together to reduce inequality, we try to look at the bigger picture with a more generalised model, via including destination group value (D_F) as an independent variable as well. We build potential independent variables by taking every power of D_F, Z_F and T_F until four (e.g. D_F^3 and T_F^4), as well as including possible combinations (multiplications) of these variables (e.g. $D_F^3 T_F^4$ or

$Z_F^2 D_F^4 T_F$). Then regression analysis constructs the model (equation) using stepwise method.

In the last regression analysis, which covers all three different independent variables, their powers and associated combinations, we observe that destination group ratio is an effective factor in determining resulting inequality level as well. As seen in Table 17, both itself (D) and its various combinations with other variables (e.g. $T_F D_F^2 Z_F^4$) are retained in the resulting equation. This last experiment clearly demonstrates the importance of social policies that target the poorest groups of the society, since it seems the more focused poverty is targeted at, the better it could be combatted against.

Table 17. Regression Analysis Results When Destination Group Ratio (D_F) Is Included in the Model

a.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
33	,947	,898	,896	,067848943844953	,000	7,407	1	1734	,007	,493

Predictors: (Constant), ZD3, Z2D3, Z3D3, T, Z, ZT, D2Z4, D2Z3, D3, DZ2, Z2, DZ4, TZ2, D, T2, ZT2, T2Z3, Z3, TZ3, T3Z4, Z2T3, TD3, ZTD4, TZ2D4, TD2Z4, D2T4, ZD2T4, Z3D3T4, D3T4

Dependent Variable: Proportion P Value

b.

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
33	(Constant)	1,186	,018		65,481	,000
	ZD3	-64,809	2,398	-7,921	-27,027	,000
	Z2D3	2225,351	73,148	22,439	30,423	,000
	Z3D3	-17312,037	740,783	-15,447	-23,370	,000
	T	-6,312	,180	-3,636	-35,029	,000
	Z	-50,923	1,323	-7,333	-38,484	,000
	ZT	309,428	11,507	13,709	26,890	,000
	D2Z4	187357,791	7585,069	15,396	24,701	,000
	D2Z3	-17584,891	778,195	-15,705	-22,597	,000
	D3	,813	,037	1,599	22,167	,000
	DZ2	272,961	23,533	2,792	11,599	,000
	Z2	815,331	31,066	12,161	26,245	,000
	DZ4	-26961,522	3061,448	-2,359	-8,807	,000
	TZ2	-4034,795	191,877	-16,156	-21,028	,000
	D	-,173	,031	-,275	-5,658	,000
	T2	10,381	,442	2,477	23,493	,000
	ZT2	-404,102	22,035	-6,472	-18,339	,000
	T2Z3	37494,239	2844,530	4,653	13,181	,000
	Z3	-4051,478	216,235	-5,849	-18,736	,000
	TZ3	14877,060	1105,060	5,503	13,463	,000
	T3Z4	-573736,867	55299,147	-2,339	-10,375	,000
	Z2T3	4412,823	460,596	2,191	9,581	,000
	TD3	2,495	,160	1,220	15,572	,000
	ZTD4	-107,318	8,185	-3,217	-13,112	,000
	TZ2D4	1125,990	106,408	2,739	10,582	,000
	TD2Z4	-31114,976	5158,446	-,612	-6,032	,000
	D2T4	-40,937	6,653	-,861	-6,153	,000
	ZD2T4	646,173	71,890	,813	8,988	,000
	Z3D3T4	-42830,874	7028,931	-,373	-6,094	,000
	D3T4	15,188	5,581	,318	2,722	,007

CHAPTER 7

DISCUSSION OF THE RESULTS OF THE FIRST ESSAY

7.1 Main findings and contribution to the literature

Main findings of first phase of our study, which covers distinct effects of compulsory and voluntary giving, may be summarised as follows: We reached a largely non-uniform wealth distribution in Base Model with fixed money transfer among agents as indicated in econophysics literature. We measure inequality in wealth distribution with our novel metric of proportion P value. Then in Taxation Model we introduced taxation of transactions as a compulsory form of giving and showed that it is effective on reducing inequality. The third model was Almsgiving Model and it included zakat as a voluntary form of giving out of one's wealth. This model not only did demonstrate this form of giving is effective at approaching more equitable distribution of wealth, but also it showed that this inequality reduction effect is valid in totally random conditions, not necessitating targeting the poorest as recipients.

In the second phase of our study, which covers voluntary and compulsory giving simultaneously, we examined the synergistic effect of taxation and almsgiving on reduction of inequality in the model we named as Fusion Model. Associated experiment design that includes different parameter values for these two forms of giving in the same simulation supplied results that support substitutability of voluntary and compulsory giving. The same level of wealth equality has been demonstrated to be achievable via different value combinations of tax rate and portions of wealth given as alms. We then built regression equations to analyse this relation of substitutability. This inspection of relationship between compulsory and voluntary giving may provide insight to future initiatives to alleviate inequality.

Almsgiving seems to be able to made a tool for inequality reduction which may become as valuable as taxation.

We contributed to the literature with our analysis of the recipients of social assistance in an econophysics model setting. Although studies by Jaffer (2020), and Younas, Hussain, Anam, and Jaffry (2021) examine the effect of zakat on inequality reduction, they do not build their model on econophysics literature and they do not analyse the cases in which distinct recipient groups of different relative poverty. Our metric of destination group ratio assesses the relative poverty of recipients of taxes and alms. We examined the trade-off of higher rates of taxation and almsgiving and that of higher poverty of target groups of social assistance. We showed in our econophysics-based model that in general, the more focused giving efforts to the poorest groups the higher the effectiveness of assistance.

As a possible drawback of our study, we focused on achieving inequality reduction implicitly assuming that equality is an important goal for social justice of society. This is a normative point of view and there are rival theories in economics literature, which assert that efforts to achieve equality may not be beneficial to overall economy (e.g. Lucas (2004)). Additionally, although we selected zakat as a starting point for investigation of giving a portion of wealth on inequality, and tried different portions of wealth as almsgiving rate, zakat is a faith-based ritual and valuable as it is, on religious and cultural grounds.

7.2 Research implications and further study

This study examined the impact of legally enforced giving (taxation) and voluntary giving (alms) on wealth distribution. For this purpose, the agent-based modelling and simulation approach is used for constructing an artificial economy model. This

model employed the simple trade (money transfer) idea of econophysics literature and it was extended to cover taxation of transactions and almsgiving out of wealth. Equality-inducing effects of these mechanisms have been observed that led to a healthier wealth distribution in this artificial representative economy, especially for the agents with little or no wealth. Therefore, effective implementation of taxation and almsgiving should not be overlooked for any future campaign or collective effort for social justice. This finding may be deemed as a contribution to econophysics literature as well, since, to our knowledge, it does not include a study on effect of both compulsory and voluntary giving on wealth inequality arising from fixed money transfer among agents. Efficacy of taxation and zakat is observed to rise with higher rates of taxation and almsgiving. In addition, focusing on needier groups for recipient selection (targeting lower classes of population) further increases their efficacy. Almsgiving as a portion of wealth (in our study, zakat) is important in another perspective, as it is demonstrated to be effective in alleviating wealth inequality even if recipient people are randomly selected irrespective of their wealth. That is, almsgiving as a portion of wealth (and possibly every form of doing good) seems to be beneficial to society unconditionally, not necessitating to target the poorest members of it. Therefore, almsgiving as a portion of wealth (besides taxation) should be encouraged and attempted to be spread in any society aiming for social justice. Additionally, if given after every transaction by every individual, around 7.5% - 10% of wealth given as charity is observed to be an effective value for giving to random recipients from around bottom 75% of population, as it apparently leads to equality maximisation and in these conditions giving more seems to raise inequality again. This finding is among main contributions of this study to the literature of non-profit sector and philanthropy research. It may help future philanthropists who try to

achieve the best possible social good with their wealth through donations. It may be of particular service to philanthropy movements such as The Giving Pledge and Effective Altruism communities for optimising the way they give for maximum social benefit.

Future work may examine an open system rather than a closed one like ours or analyse and compare different forms of compulsory and voluntary giving in terms of bringing society closer to social justice. Total wealth of agents is fixed in our model and in further models it might increase (or decrease) throughout simulation, via including a form of production process. Other types of taxation and almsgiving might extend and enhance our models as well. As future possible extension to our taxation experiment could be addition of other types of taxation such as income tax, wealth tax and different implementations of taxation such as progressive, regressive and flat taxes. Our analysis of voluntary giving examines only giving out of wealth (zakat), other forms of which could be included in future studies as an improvement of investigation of better forms of giving. Almsgiving practises in other belief systems (e.g. daily almsround / pindabat in Theravada Buddhism or tithing in Judaism and Christianity) might be examined for effectiveness and compared to each other. This pursuit might lead to a fusion method for better giving (in addition to religious obligations) as a remedy of suffering and inequality. The ideal of a fairer world has existed throughout human history and it will never die, just like the research for better means to achieve it.

CHAPTER 8

BACKGROUND INFORMATION FOR THE SECOND ESSAY: TOWARDS SOCIAL JUSTICE VIA LENDING – AGENT-BASED MODELS OF AUTOMATED RELENDING OF MICROCREDIT

Second essay of this dissertation focuses on agent-based modelling and simulation of automated relending systems, which are used by online peer-to-peer (P2P) microcredit platforms. In this essay, we develop two models to try to understand, examine and if possible, optimise this algorithm-controlled microcredit distribution system. To this end, this background information chapter first tries to briefly analyse the phenomenon of microcredit, its history, its effectiveness, and philanthropic implementation of microcredit concept in the P2P microlending platforms of Kiva and Zidisha. Then we present a literature review for P2P microlending.

8.1 Microcredit, from its modern history to a form of online charity: A brief overview

Microcredit might be defined as a form of microfinance in which small-sized loans are lent to poor groups, often with the aim of social progress of the population. This aim of social progress may be said to differentiate it from other financial systems focusing on such values as training (e.g. entrepreneurship training in group settings) or financial strengthening of vulnerable members of society (e.g. targeting women). Compared to traditional banking systems, microcredit organisations usually opt for group lending, in which group members share the responsibility for repayment of the loans. Group lending enables internal monitoring of group members by other members, resulting in reduction of transaction cost of microcredit while improving

repayment rate. It might enable in-group learning on successful entrepreneurship as well. Additionally, there is a tendency for lending to females by microcredit organisations, as female entrepreneurs are deemed to be more reliable borrowers and to tend to spend more on basic needs. Academic research supports this idea and demonstrates that women are indeed better borrowers of microcredit (D'espallier, Guérin & Mersland, 2011; Zainuddin & Yasin, 2020). Women are more frequently chosen as lenders than men, and in microcredit industry proportion of female loan recipients are given as 73% (D'espallier, Guérin & Mersland, 2011) and 64.9% (Cull, Demirgüç-Kunt & Morduch, 2007) in two different studies. These strategies of targeting poor and disadvantaged groups seem to work for microcredit industry, with microloan repayment rate is shown to reach up to 95% in 2017, as portfolio at risk after 90 days is 4.7% (MIX Market, 2019). This is a growing business as well, with both non-profit and for-profit players' total microcredits reaching up to 112 billion US dollars in financial year 2017, distributed to 120 million active borrowers (MIX Market, 2019). There is apparently still a large potential for growth as well, since, for 2012, median market penetration, which is calculated as ratio of microcredit borrowers to working age population below national poverty line, was found to be 0.69% for all countries, and 2.96% when high income countries are excluded (Gutiérrez & Krauss, 2015).

Modern microcredit financing originated from foundation of Grameen Bank by Prof. Muhammad Yunus in 1983 in Bangladesh (Yunus, 2004). Prof. Yunus came up with the idea that built modern form of microcredit when in the village of Jobra, near his university campus, he met people living in extreme poverty. He realised that many problems arose from lack of the initial capital to build economic ties and he calculated the amount needed for 42 poor women to be surprisingly low: only 27

dollars. When he lent 27 US dollars problems disappeared, women were able to make and sell stools, and in the end he obtained his money back (Yunus, 1998). What he understood and demonstrated was that the poorest of the poor, although often neglected by traditional banking systems, were reliable borrowers as well, and financing them could be an economically viable activity. Furthermore, allocating financial resources to them might help not only the immediate borrower of the loan, but also other economic partners, spurring economic growth with only a small amount of capital. Resulting Grameen Bank (meaning village bank in Bengali) led to a story of astonishing success, cumulative loans amounting 24 billion US dollars as of 2021. As of January, 2021, its member count reaches 9.38 million, 97 percent of whom are women (Grameen Bank, 2021). Grameen Bank borrowers own 76% of the bank, while %24 is owned by the Bangladeshi government (Grameen Bank, n.d. -b). These social development effects of the project as well as empowerment of the poor and disadvantaged groups were a critically acclaimed success as well, earning Prof. Yunus Nobel Peace Prize award in 2006, "for their efforts to create economic and social development from below" (Nobel Prize Outreach AB 2021, n.d.).

Critics of microcredit point out the change of attitude and structure of creditor organisations for a more profit focused approach. Indeed, after Prof. Yunus' and other organisations' early work proved that very poor people are reliable borrowers who pay their loans back at a very high rate, many for-profit organisations have been founded in the microcredit sector. According to MIX Market report (2019), only around 32% of total number of microcredit loans outstanding have been provided by non-profit NGOs. There are arguments and anecdotal stories that microcredit financing resulted in "debt trap", leading to suffering of a portion of the borrowers (Melik, 2010; Uddin & Uddin, 2021). That is, being unable to "graduate" from "more

credit for repayment of credit" cycle, they are argued to become worse off after borrowing microcredit. Osmani (2017) calculates the proportion of debt trap cases as 4.5% of microcredit borrowers. This study tries to stay at the charitable side of microcredit environment, and therefore focuses on online peer-to-peer microlending based on donations, facilitated by non-profit services such as Kiva and Zidisha. These services will be described later in this chapter.

Proponents of microcredit focus on the ability of very poor and disadvantaged populations to reach financial services via microcredit. Many borrowers of microcredit are illiterate (for instance Paul (2014) reports the rate of illiterate borrowers as 39% in a case study), therefore unable to prepare documents required to access traditional banking systems. In addition, formal banking systems frequently require physical collateral for credit whereas microcredit organisations typically do not (e.g. Grameen Bank (n.d. -b)) states this openly in their webpage). Thus, it is reasonable to argue that microcredit supplies poor and unbanked populations with previously unavailable financing services. Community orientation in group lending (e.g. 16 decisions for community improvement are encouraged by Grameen Bank (n.d. -a)) and, as stated before, lending to females constitute a substantial portion of total microcredits given, thus it may be argued that there are social development and gender equality targets for loan allocation most of the time. Female empowerment is a relatively consistent finding in microfinance literature and microcredit seems to be generally effective at empowerment of female borrowers (Weber & Ahmad, 2014; Haile, Bock & Folmer, 2012) There are other impacts of microcredit financing that were pointed out in the literature. Health related behaviour such as an increase in contraceptive use (Amin et al., 2001; Mainthia et al., 2013), improvements in sleep and social support (Rao, Vanguri, & Premchander, 2011),

health knowledge (Strobach & Zaumseil, 2007) and better child nutrition (Friesen, 2012; Ojha et al., 2017) are among these. However, these results may be more related to education given along with microcredit programs, rather than the effects of loans given.

Overall picture appears to be more complex. Studies that review existing literature point out a lack of rigorous evidence (Gichuru et al., 2019; O'Malley & Burke, 2017; Duvendack et al., 2011), mixed (both positive and negative) results (Van Rooyen, Stewart, & De Wet, 2012), and even a lack of meaningful benefit (Yang & Stanley, 2012) of microcredit programs. Although there appears an income increase effect in Yang and Stanley's (2012) meta-analysis (average correlation coefficient of 0.052 in random effects model, $p<0.001$), it might be deemed as practically negligible and prone to publication bias. Perhaps, situation is not as bright as seen at the beginning of the story of microcredit. Yet there are apparently positive effects as well, therefore probably best conclusion would be that of systematic review of 32 systematic reviews about financial inclusion by Duvendack and Mader (2020): "...impacts are more likely to be positive than negative, but the effects vary, and appear not to be transformative in scope or scale..."

After microcredit as a concept gained considerable growth and popularity, and the world wide web (the Internet) became an essential part of life globally, online platforms for peer-to-peer microfinance services eventually appeared. In 2018 global online alternative finance industry (covers microfinance as well as financial services to micro, small and medium enterprises (Voss, 2017)) reached 304.5 billion US dollars in transaction volume (Ziegler et al., 2021). When online microfinance services are considered, these platforms enable entrepreneurs from poor regions to explain themselves, their projects, plans and amount of credit they need. Potential

lenders among wealthier people examine their profiles, if they decide that they have enough resources and the project is worthy of being funded, they lend to the entrepreneur to cover project expenses partially or fully. If a project gets completely (in some services, partially) funded via this way, the entrepreneur withdraws and spends money available on their project, reaps its benefit, and pays it back, often with an interest.

Described human-led mechanism of online peer-to-peer microlending platforms is the main and traditional model for borrower selection of microcredits. However, the need of the lender to frequently check the state of their loans and to relend those repaid is inconvenient for the lender, and it is an inefficient method for utilisation of the fund. This method might lead to a considerable portion of available funds to stay idle, or even forgotten. This problem is solved by online peer-to-peer microlending platforms by an effective and clever idea: automated relending mechanism. This might be an important financial technology innovation as Jansen, Nguyen and Shams (2024) found that algorithmic underwriting outperforms human underwriting process, lowering default rate by 6.8% in their randomised experiment in auto lending.

Automated relending is computerisation of the process for allocation of and selection of recipients for available funds. According to a certain algorithm and previously determined criteria, microcredit that returned is redistributed to other entrepreneurs without need for human intervention. Details of different algorithms are specific to every implementation. Prioritisation of borrowers and optimisation of allocation of resources are dependent on decisions made in these algorithms. This process of automated relending of microcredit is in active use by online microlending

platforms. Therefore, there is current and actual necessity for determining method or methods that nearly or fully optimise automated relending mechanism.

We might exemplify a lender's need to decide on how to allocate their funds in two real-life implementations of automated relending mechanism: Kiva.org and Zidisha.org. These philanthropic peer-to-peer microlending platforms are mostly the reason why this second essay has been thought of, planned and written in the first place.

8.1.1 Two examples of non-profit microlending platforms: Kiva and Zidisha

Kiva.org is one of the biggest and most established one among philanthropic microlending platforms. Its total loan amount, distributed and repaid as microcredit, reached 1.4 billion dollars so far, in 77 counties. Its lending preferences are socially progressive, with 83% of recipients are women and a sizable number of education, farming and clean energy projects have been supported. More than one million borrowers are from least developed countries while more than two hundred thousand borrowers are in conflict zones (data obtained from Kiva.org website, "Impact" page [Kiva, n.d.-a]). Kiva.org mostly works with local partner organisations (named as Field Partners) in its service areas for reaching poor populations. While this method is truly useful to increase geographical coverage and operational effectiveness, these local partner organisations' lending practices are very rarely interest-free. As a measure for interest rate borrowers are subject to, Kiva.org publishes average portfolio yield of Field Partners, which is calculated to be approximately %36 for December 2018 and 2019 (Abbott, Stringham, & Lynch, 2020). This fact is not very easy to argue for being in parallel with the aim of empowering the poor, since there

might be difficulties in repayment, and the threat of debt trap (Moodie, 2013). This is where Zidisha.org brings a novel idea and attempts at a solution.

Zidisha.org's founder Julia Kurnia worked for Kiva.org for some time, and her personal field experience encouraged her to find a method to ameliorate the ills of heavy interest. She tried to obviate excessive operational expenses and trim. The interest rate via providing a direct link between borrowers and lenders, without any intermediaries. Zidisha.org project became successful in building this direct microcredit link from wealthier borrowers of mostly Western countries to entrepreneurs of some of the poorest countries of the world such as Uganda and Ghana. Still, as of March 30, 2024, “a contribution of between 10 and 23% is reserved when [a] project is disbursed” (Zidisha, n.d.-a) to cover the cost transferring the project and to compensate for possible loan defaults. Therefore, the ideal of zero-cost microcredit for poor borrowers seems to be still ahead. Kiva.org and Zidisha.org are nevertheless major milestones on the road to this ideal.

Both Kiva.org (Niemira, n.d.) and Zidisha.org (Zidisha, n.d.-a) have automated relending mechanisms implemented and operational, but users have the ability to activate or deactivate it. Both systems are flexible, giving the user many options to control the way repaid loans are redistributed.

Kiva.org, with default settings, automatically chooses new borrowers according to previous user directed selections. However, it enables users to determine the amount of money (i.e. loan size) repaid microcredit will be divided into. This amount is then redistributed to every new entrepreneur. In addition, location based relending is possible, so that specific countries' entrepreneurs may be targeted. Gender based selection, lending only to groups or individuals, supporting specific causes (referred to as attributes), and sector targeting are available as well.

Loan terms might be set as another filtering option, which means in the automated relending process Kiva.org enables including time factor. Local partner organisations may be targeted as well, using field partner risk rating, default rate and delinquency rate. This demonstrates that in Kiva.org through automated relending loans may be directed according to previous experience and success in repayment.

In Zidisha.org automated relending options are a bit narrower but they can be said to be more generic. Like Kiva.org's sector preferences, Zidisha.org enables selection of project categories, which includes education, clothing or health. Using its more general settings, repaid loans' funds may be allocated according to lenders' previous reviews, number of comments by borrower, fundraising projects' length of time to expiry, or totally randomly. Lender reviews can be likened to field partner ratings by Kiva.org, since they are mostly based on previous success in repayment by a borrower, and they are mainly utilised to minimise risk. Time factor of a project is important for Zidisha.org as well, as funds might be allocated to projects that are about to expire. This option is useful to prevent projects from expiring unfunded. Number of comments by borrowers and random allocation with equal chance to every one of them, as project prioritisation methods, are unique to Zidisha.org. The former may be used to assess the borrower' allegiance and care for the system whereas the latter is an important basic setup to compare and measure other methods' success.

Both time factor and previous success are taken into consideration in Kiva.org as well as Zidisha.org. Therefore, these two criteria should be examined in a model that simulates and attempts at optimising automated relending mechanism. This brings us to the main subject matter of this study, which is examining and using ideas from current implementations of automated relending in order to understand

internal dynamics of it, model it, simulate it, and attempt at optimising and transforming it. Next section reviews the P2P microlending literature to ground this effort on previous studies and have a broader perspective.

8.2 Literature review for P2P microlending

For the literature review of P2P microlending platforms, we firstly present studies that describe strengths and weaknesses of these platforms, their activities, or microfinance in general. Then we explore, although not exhaustively, articles which examines current dynamics in the area, the analyses that describe the P2P microlending. Lastly, we cover the studies that aims at betterment of the platforms and their efficiency or output. We mainly focus on studies employing agent-based models for investigating methods of improvement.

8.2.1 Strengths and weaknesses

Microfinance is generally praised for enabling the access of financial services by the disadvantaged or poor people and thus for achieving financial inclusion. In this regard, Nguyen (2021) gives a group of studies which supports that microfinance provides greater financial accessibility. Brown, Guin and Kirschenmann (2016) examine an instance of microcredit banks, Procredit, and show that the number of banked individuals is higher where its branches are opened, especially among low-income neighbourhoods. Adeola and Evans (2017) find a significant positive relationship between microfinance and financial inclusion in the long run in Nigeria. P2P microlending platforms, however, take this financial inclusion phenomenon to the global scale, making microcredit globally accessible (Uddin, Vizzari & Bandini, 2015). This function of P2P microlending is described by Kiva.org co-founder

Jessica Jackley Flannery as "creating a global community of people connected through lending" (Flannery, 2008). Building a sense of community seems to be successful, as it is stated in the literature that there is “financial, social and emotional commitment to distant others” by lenders (Schwittay, 2019), driven by the borrower stories, and this is perhaps what spurs the lenders in richer countries into action.

Although charities on average may spend 60-70% of donations for charitable activities (Lee, 2017), non-profit P2P microlending platforms seem to be in a better position to utilise the funds at hand to help the poor. Kiva, for instance, directs 100% of the loan lent to the borrower, without taking a cut (O’Brien, 2008). This is possible partially with a deal with PayPal which enables zero cost transfers (Milliken, 2017).

P2P microlending platforms' information technology usage allows a high level of transparency. In Kiva a high level of transparency is achieved (Marchitti, 2013), and records are kept for every transaction and associated information is available via an application programming interface (API). Kiva even presented a challenge to DataFest 2011 participants extract meaningful insights from these data (Çetinkaya-Rundel & Stangl, 2013).

Use of information technologies help to reduce the human-centric control on distribution of loans to borrowers, enabling auto-lending of funds to different entrepreneurs according to pre-specified criteria (Smith et al., 2023). This point is especially important for this study, since this automated relending mechanism is what we try to achieve betterment of, through experimenting with different borrower selection criteria.

Aside from perceived strengths, there are criticisms and perceived weaknesses of P2P microlending platforms in the literature as well. Some of these

negative characteristics, as listed in Asgary and McNulty's (2017) SWOT analysis, are burdensome interest rates resulting from high operational costs, lack of direct relationship between lender and borrower and field partner default and exchange rate fluctuation risk. Fortunately, P2P microlending sector is a developing area, in which innovations are possible for finding solutions to existing problems. Zidisha.org which was founded in 2009, came up with solution of enabling direct transfers between lenders and borrowers, obviating the need for intermediaries. (Zidisha, n.d.-a). Direct lending to borrower might be seen as ameliorating aforementioned problems, reducing operational cost and risks associated to local intermediaries. Kiva started a similar programme as well, giving direct loans to US-based borrowers, namely Kiva US. Other topics of criticism in literature include issues of surveillance and control of the poor related to participation in online lending activity (Yartey & Birzescu, 2915), sustaining problematic neo-liberal conceptions (McKinnon et al., 2013), and Kiva's recent tendency for more profit orientation (creating an investment fund with interest for companies, higher CEO salaries and less transparency for interest rates of field partners) (Kardas-Nelson, 2023).

8.2.2 Descriptive studies

Everett (2019) presents a historical picture of microfinance and traces it back to friendly societies of 18th century England and even to the fund for loaning poor tradesmen by Jonathan Swift (author of Gulliver's Travels) with his personal resources. He curates a comprehensive list of historically prominent peer-to-peer lending platforms over the internet and includes both Kiva and Zidisha in the list. (Everett, 2019). Van Damme (2013) examines Zidisha descriptively in his thesis and praises its efforts and results in the path of interest rate reduction. Hence, he opines

that this platform is a philanthropically motivated one and its lending activity continues so as well.

Like offline lending through brick-and-mortar microfinance institutions, higher rating of borrower leads to more loans by lenders in P2P microlending platforms and specifically, small homogeneous groups obtain more lending activity and larger loans in them (Paruthi, Frias-Martinez & Frias-Martinez, 2016). Lender preference of borrowers has been examined by Chen and Putterman (2015) Lenders are shown by them to tend to prefer borrowers who belong to same gender or similar ethnic group, emphasising share of characteristics. In addition, although financial return is important in borrower choice, there seems to be a tendency to assist the borrowers in more difficult conditions in their study, where lenders may accept greater risk to help needier borrowers. Allison et al. (2015) corroborate this finding and demonstrate that an opportunity-to-help narrative, rather than a business-oriented narrative, attract faster lending activity, reducing the funding time.

Repayment behaviour by borrowers have been studied by Dorfleitner and Oswald (2016) and some of their findings indicate that loan size and loan term are positively related to default risk of the loan, whereas female borrowers, but not groups, are more likely to repay their loans.

Use of IT in microfinance activities have been analysed and found to have enhancing effect as well. Nguyen (2021) shows that usage of IT leads to better financial results for microfinance institutions while Byers (2011) demonstrates a positive impact of IT on livelihoods of economically disadvantaged people, through the use of P2P microfinance. These findings may be thought to support this study as well, which, if possible, aims to strengthen and optimise this positive effect of IT on P2P microfinance through betterment of automation.

8.2.3 Betterment studies

Aiding microlending platforms via a model or recommendation system are the focus of some studies which aim to improve the existing conditions in the P2P lending ecosystem, Choo et al. (2014) examine the lending group characteristics and preferences in loan selection to fund in such features as geo-location and gender of borrower. Then they build a maximum entropy based model for microlending recommendation. Lee et al. (2014) extend the recommendation concept to include the notion of fairness, in order to be less biased and more inclusive in borrower selection. Their proposed system tries to establish fairness, while also retaining accuracy of recommendation. Zibriczky (2016) lists several other recommendation system studies for microfinance. Austin and Rawal (2023) build a machine learning model of Kiva microlending activities, with an intent to monitor, and possible reduce investment risk. In the model what they try to predict for a project is to be funded, and the most influential predictors are loan amount and loan term. Ai et al. (2016) recommend lending teams for lenders in an effort to strengthen prosocial behaviour in an experimental setting and show its effectiveness for increasing lending activity.

Simulation studies, although hard to argue to be adequate, exist in the literature as well. Lucas (2014) reviews the literature for microfinance simulation examples and lists Microfin, by the Consultative Group to Assist the Poorest (Lunde, 2001) and MIFOS (Micro Finance Open Source Software) (Feuer, 2010) as a project of Grameen Foundation’s Technology Center. Although these two pieces of software have mainly been developed for enhancing and digitizing the management microfinance institution, they have simulation capabilities via statistical extrapolation of the institution's finances. Another listed tool by Lucas (2014) is Symbanc (Hirsch,

2005), system dynamics based simulation software specifically targeted at measuring and predicting financial health of a microfinance institution.

Regarding agent-based modelling and simulation (ABMS) method for analysis of microfinance and/or microlending, it appears that there is considerable scarcity in the literature. Several studies exist, as pointed out by Lucas (2004), yet it is difficult to mention about a large body of publications allowing detailed comparison, contrast and synthesis. Rashid, Yoon and Kashem (2011) build an agent-based model for extensive coverage of general microfinance environment and include trade, loan, production, employment, possible disasters and relative poverty. Their principal aim is to test whether the promise of microfinance for poverty reduction is true and demonstrable. An interesting idea in their work is that for the poor people to be wealthier, they need to sell goods or services to rich people. This is because if there is an internal trade among poorer classes, average wealth of the poor would not be affected. This idea, in our opinion, should be taken into account for future efforts for microfinance regulation and loan direction. Their simulation produces results in which higher interest rate of microloans leads to lower average wealth for the poor, and while not unintuitive, this result is highly relevant for microfinance initiatives. It might be argued that this is the main idea that led to the foundation of Zidisha.

Saqalli et al. (2011) conduct an ABMS study of effect of microcredits on rural dynamics and income, and their model primarily focuses on village characteristics and agricultural activity. They examine two possible methods by which microfinance might help with poverty alleviation, namely buying and using inorganic fertilisers and inventory credit technique. However, they find out that positive effects of microfinance on poverty reduction are not as high as anticipated,

at least in the agricultural model conditions. We observe that their model is carefully constructed to approach real-life conditions, however.

Bourhime and Tkiouat (2018) build an agent-based model of Islamic microfinance, and in their model conditions, Islamic microfinance is operationalised as microlending with no interest for loans and requiring joint liability. They divide loan funds into two, one given as part of Islamic microfinance, the other given as normal microfinance with interest. They demonstrate that in the absence of interest burden, the poverty reduction effect of microfinance is substantially amplified. However, although it is true that interest is prohibited in Islamic jurisdiction, in real-life conditions, there is apparently still a cost to the borrower for loans supplied by Islamic microfinance institutions, which should be taken into account. We can exemplify this in Kiva, in which some loans are tagged as Islamic microfinance, and they include a monetary cost to the borrower. Yet, their work, can be argued to be a well thought-out one in a relatively understudied area. They build a framework for profit-sharing mechanism and Islamic charity of zakat in the context of microfinance as well, although the article about the agent-based model does not include its implementation (Bourhime and Tkiouat, 2021).

Although there is not an abundance of simulation studies for microfinance in the literature, even more scarcity exists for P2P microlending platforms' auto-lending mechanism. An exception to this scarcity, we could find Omarini’s (2018) study, which briefly mentions auto-lending mechanism in his study on business model analysis of P2P lending. He refers to this mechanism as a method for the platform to retain its lenders, even in a lock in situation. To the best of our knowledge, there is seemingly no study in the literature which analyses, models, and simulates automated lending (auto-lending) mechanism in P2P microfinance platforms. Paucity of studies

on auto-lending, even a seemingly absence of simulation of it, might be argued to magnify a need for them in the literature. While this essay, whose experiments for Basic Model and Improved Models will be explained in the next chapter, focuses this area of study, there seems to be a necessity for further work by comprehensive studies.

CHAPTER 9

PROBLEM DEFINITION AND MODEL INFORMATION FOR FIRST PHASE OF THE SECOND ESSAY

In order to build an automated relending mechanism model, we first need to design a microcredit financing environment. In this environment entrepreneurs continuously borrow for their projects and repay whereas a central microcredit organisation gathers these repaid funds and relend them for other projects. These borrowing/lending and repayment/ gathering cycles of microcredit should continue throughout the simulation of the model, just like in a real-life online peer-to-peer microlending platform. Utilisation of scarce resources of monetary funds for betterment of society is primary aim of any philanthropic organisation, thus rather than keeping returned microcredit loans idle, an organisation would relend them as soon as possible, and continuously. This is the basic reason of existence for automated relending mechanism in the first place.

The main problem about continuous relending operation for gathered funds is determining to whom and according to what to lend them. Although location-based and sector-based allocation are possible as well in real-life implementations, for the scope of this study, we examine the following criteria for fund allocation in our model:

- previous success of entrepreneurs,
- funds needed to complete current project,
- time left to complete a funding campaign.

Based on observations of automated relending systems of Kiva and Zidisha, as well as novel proposed methods for optimisation of use of resources, there are

three basic algorithms utilised for prioritisation of projects needing microcredit in the Basic Model of automated microlending. These three prioritisation methods are;

i. We select projects whose entrepreneurs successfully completed most projects previously. Credit history and successful previous projects of entrepreneurs give important information about both competency and honesty of them. These qualifications are deemed of fundamental importance in online microcredit platforms, and they usually publish entrepreneurs' credit history and reviews of them by previous funders. Previous success in repayment is a sign for both reliability and protection against risk of delinquency. We order projects according to the number of previous repaid credits of their entrepreneurs and select from a determined percentage, like top ten per cent. This percentage variable is an input parameter that is subject to change in the simulation.

ii. We select projects according to time left for their funding campaign to end. Funding campaigns are normally given a time interval to complete in online microcredit platforms and when they expire, policy on what to do with gathered funds might differ. If gathered funds are returned to their owners, the entrepreneur needs to begin a whole new process of funding campaign with a new project. Therefore, campaigns that are about to expire may be a good target to use existing funds, since more projects might be saved from going unfunded.

iii. We select projects that need the least additional resources to be fully funded. For instance, financial resources, in order to optimise their usage, are utilised to fund the projects that need only one more dollar to be completely funded. However, we make the selection process based on percentage, i.e. when projects are in increasing order in terms of money needed to be fully funded, we may select from the first ten per cent of the group. This percentage variable is an input parameter.

These three prioritisation methods are experimented with two types of lending to selected projects.

i. We lend a fixed amount to every selected project. In every time step (i.e. tick), for every funding campaign that fits our conditions we give the same amount of money as a loan, regardless of how much is needed. This method might be more appropriate when there is a lack of resources, as more projects will benefit from scarce resources. This method does not guarantee total funding of a project in any time step, but guarantees equal distribution of resources among selected projects.

ii. We lend every selected project all of the resources it needs so that it becomes totally funded. This method requires substantially more resources in every time step but guarantees to supply associated entrepreneurs with adequate loans to begin with their projects.

Because we use three different ways of prioritisation matched with two types of loaning methods, there are six (2 x 3 = 6) different cases in the simulation of Basic Model. Algorithm of Basic Model and its simulation dynamics is presented in the following description.

Agent-based Basic Model and its simulation involve one basic type of agent, entrepreneur, and one central treasury to gather repayments (returning of funds) and to select entrepreneurs to relend them. Flow of simulation is as follows:

- We determine the way of prioritisation (least amount of additional resources - fund needed, time to expiration of project campaign - time to expiration, previous experience - previous number of successful projects), the loaning method (equal but limited funding or full

funding) and the percentage for selection of projects for a specific experiment.

- 500 entrepreneurs are created and initialised. Every entrepreneur has a current project which several attributes:
    - money in their wallet (initialised to zero),
    - current amount of money needed for completion of project (initialised to a uniformly distributed value between 1 – 20),
    - number of completed projects according to previous success (initialised to zero).
    - loan expiration date (initialised to a uniformly distributed value between 1 – 20),
    - repayment date for loan (initialised to a uniformly distributed value between 1 – 20).
- We keep track of time passed through 10000 time steps (tick).
- In every time step (tick),
    i. Central treasury selects a number of entrepreneurs one by one to lend according to the specified way of prioritisation, specified percentage for selection and loans them according to the specified loaning method.
    ii. For those entrepreneurs who completed their projects pay their loans back to the central treasury and become a candidate for taking loans again with a project of greater size.
    iii. For those entrepreneurs who failed to gather needed funds at the campaign expiration time, gives back the amount in their

wallet to the central treasury and become a candidate for taking loans again with a project of similar size.

iv. Total microcredits returned up to this time step and loans distributed and in use at this time step are recorded.

- After a specific time period (in our model 10000 time steps/ticks) simulation ends and simulation results are reported.

The most fundamental objective of this agent-based model is to reach a better decision making for utilisation of funds. Therefore, a measurement metric is required to assess how efficient resources are utilised. In our model, we calculate an output metric Measure for Utilisation of Resources (MUR) in every time step, for this assessment. MUR metric is defined as given in Equation 4. As seen in Equation 4, we divide total amount of microcredit that is given, used and returned until a specific point in time to loans distributed and in use at that time and time passed up to that point (ticks). We add one to denominator in MUR formula in order to avoid division by zero when no loans are in use in a certain time step (tick).

$$MUR = \frac{Total\ microcredits\ returned\ up\ to\ that\ time\ step}{(Loans\ distributed\ and\ in\ use\ at\ that\ time\ \times ticks) + 1} \quad (4)$$

For a higher MUR value, microcredit loans should be used and repaid many times over, with little amount of loans currently in use and in a short period of time. This way, it should represent higher efficiency in utilisation of funds, i.e. using less resources of money (current amount of loans) and time (ticks at a specific point of time).

In order to have sense of possible range of MUR value, we may determine minimum and maximum values it can take. Minimum possible value of it is zero (0), since if every project fails to gather required funds, total returned microcredits would be zero. Maximum possible value of it needs some calculation, which we try to make as follows:

If, in every time step , every entrepreneur agent creates the greatest possible project, beginning from 20 dollars and increasing with 5 dollars for every new project, and if every project gets totally funded, completed in minimum time period possible with and associated funds are returned in 2 ticks (1 tick for campaign, 1 tick for repayment) and if at the last time step there is no more need for any funds since somehow every desired project is funded, then we may try to calculate resulting maximal and ideal (but not so probable) MUR value for base run conditions as:

$$\frac{[(20x500) + (25x500) + (30x500) + \ldots + ((2499x5 + 20)x500)]}{(0\ x\ 5000) + 1}$$

we calculate this value as 7,834,375,000.

As the first phase of our study, results of which are presented in the next section, we utilise MUR metric in our Basic Model for assessment of different strategies for allocation of funds in terms of efficiency.

CHAPTER 10

SIMULATION AND RESULTS FOR FIRST PHASE OF THE SECOND ESSAY

In this chapter, results of Basic Model simulation are presented, in a particular order of experiments. Three selection methods of entrepreneur's previous experience, project's time to expiration, and amount of extra funds needed are given, respectively, for the options of funding projects equally with a limited amount and fully. Associated experiment codes are demonstrated in Table 18.

Table 18. Experiment Codes and Associated Methods for Project Selection and Funding

Experiment Code	Project selection criterion	Funding method
Experiment 1.1	Highest previous number of successful projects	Equal but limited funding
Experiment 1.2	Least amount of time left to expiration	Equal but limited funding
Experiment 1.3	Least amount of additional funding	Equal but limited funding
Experiment 2.1	Highest previous number of successful projects	Full funding
Experiment 2.2	Least amount of time left to expiration	Full funding
Experiment 2.3	Least amount of additional funding	Full funding

20 different percentage values (5%, 10%, ..,100%) of three input parameters, namely the least time to expiration, the highest number of previous successful projects and the least additional funds needed, are specified as initial settings for two different funding methods (i.e. giving a fixed amount of funding to selected projects and fully funding them) and 20 replications are run for every scenario. Therefore 20 x 3 x 2 x 20 = 2400 simulations are run. Experiment results, in terms of average MUR value of replications with two standard deviations for different input parameters and initial setting are demonstrated in the following charts.

As the result of Experiment 1.1, Figure 24 demonstrates partial funding of projects with an equal amount, when entrepreneurs are ordered according to their

number of previous successful projects. This graph shows that although a visible pattern exists, there is not great change in MUR value, which varies around 0.12. This may be viewed as evidence that if a fixed amount will be loaned to selected entrepreneurs, previous success in projects might not be a good candidate to order them. It apparently does not increase overall utilisation of resources to a great extent.

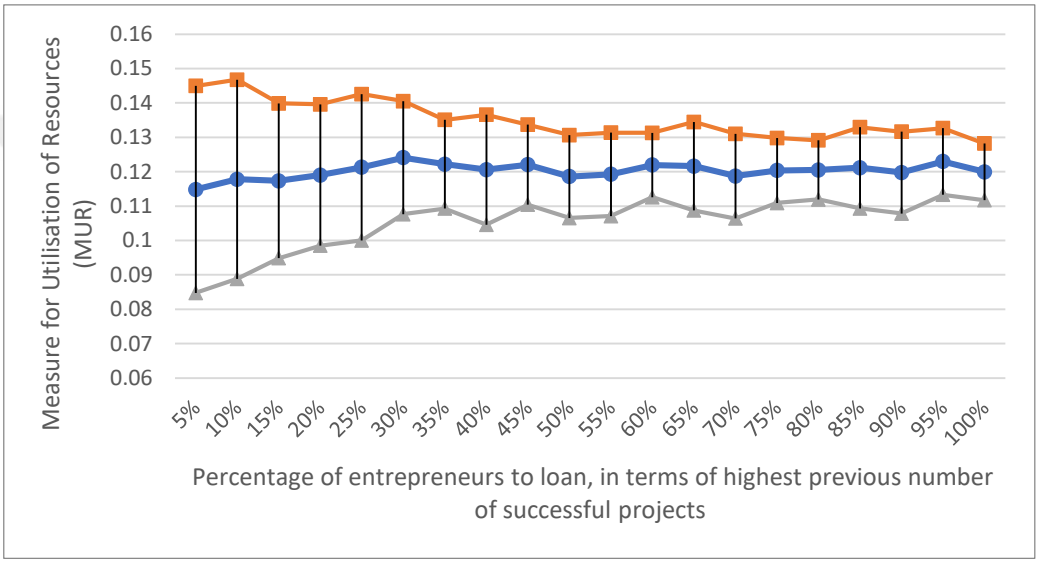


Figure 24. Average MUR value with two standard deviations, according to percentage of entrepreneurs to loan an equal amount to projects, in terms of highest previous number of successful projects

According to the outcome of Experiment 1.2, time left to expiration of project campaigns massively affects utilisation of resources when number of selected entrepreneurs are low, as Figure 25 shows. Up to 15% of campaigns, this selection criterion results in very large MUR values. Probably there is a catch here, however. When a small group of campaigns about to expire are selected, a portion of them will fail to gather the required amount of funds and loans given to them will immediately be returned to the central treasury. There might be cases in which no projects are fully funded and therefore "Loans distributed and in use" variable will be zero. This

makes MUR value equal to "Total microcredits returned up to that time step", which explains large deviations of it for lower percentage of entrepreneurs for this scenario.

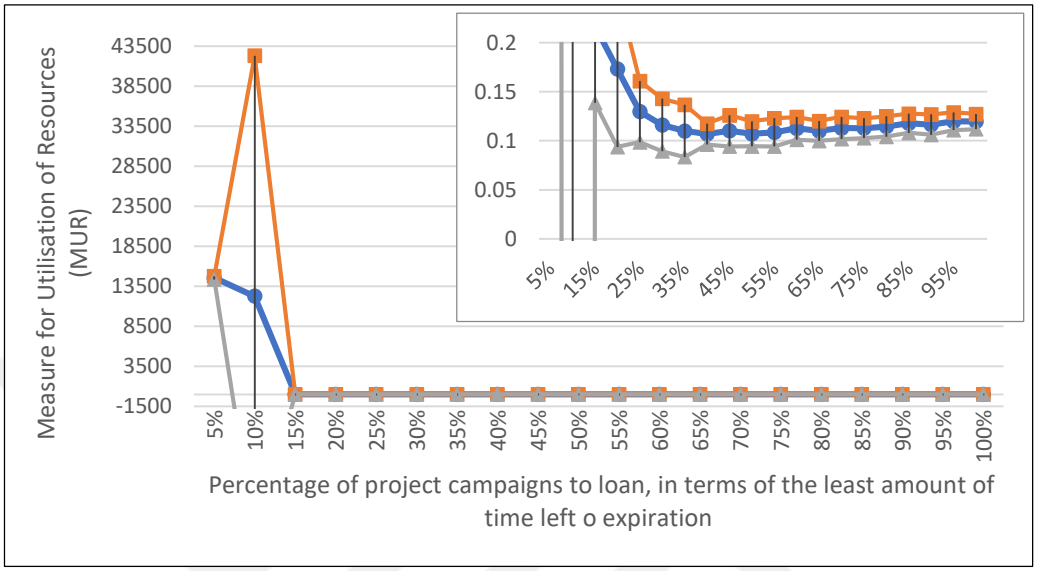


Figure 25. Average MUR value with two standard deviations, according to percentage of entrepreneurs to loan an equal amount to projects, in terms of least amount of time left to expiration (zoom-in chart is given upper right corner to show the change around 15%)

Experiment 1.3 examined the distribution of fixed amount of loans according to the need of additional funds and the less the need the more chance to obtain the loan. In these circumstances, as Figure 26 presents, it is clearly observable that MUR value is dependent on percentage of entrepreneurs and the underlying relationship might be exponential. Thus, provided that resources are scarce and funding projects fully is not feasible, giving fixed amount of loans to the ones that need the least additional funds appear to be a very reasonable idea.

An important observation about equal distribution of fixed amount of loans is that in every experiment MUR value approaches to ~0.12 as the percentage of entrepreneurs selected is close to 100% (no selection, random distribution). This

should be viewed as base value for resource utilisation in this method and selection processes attempt at refining it. Selection of projects that need the least extra funds might be argued to be the best at this refinement.

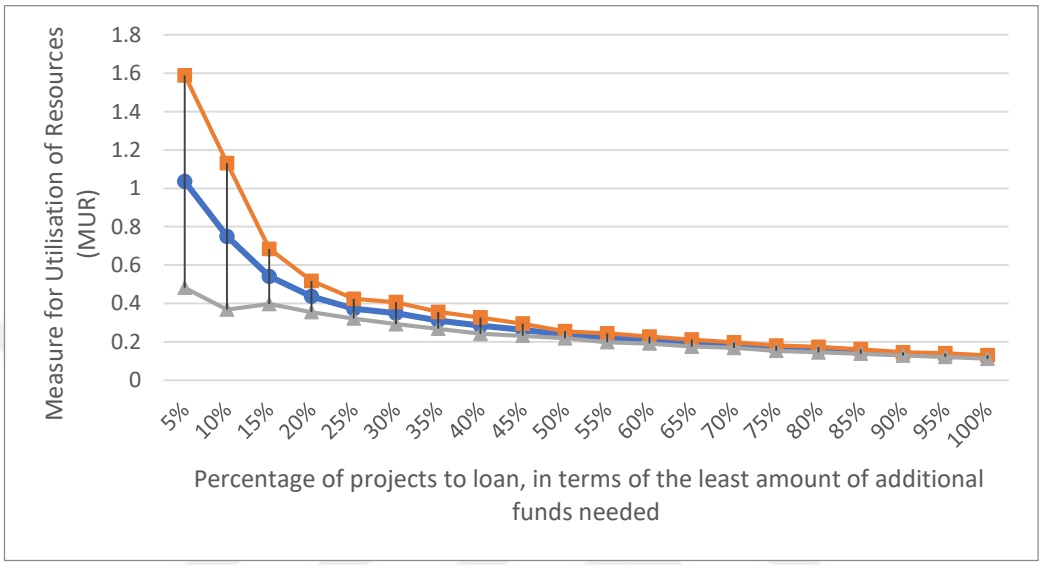


Figure 26. Average MUR value with two standard deviations, according to percentage of entrepreneurs to loan an equal amount to projects, in terms of least amount of additional funding

If there are adequate resources to fund the projects of selected entrepreneurs fully, and if this method is decided upon, effectiveness of selection criteria changes. Experiment 2.1, as the first example, focused on previous success based selection with the method of funding projects fully. In these settings, Figure 27 demonstrates that utilisation of resources (MUR value) increase with more focused selection process, which means for the full funding method this type of selection is an effective way for better utility of scarce resources at hand. Main reason for this phenomenon is probably the growth potential of entrepreneurs' projects. That is, when we choose entrepreneurs with more previous successful projects, their projects will tend to be bigger (as they have already grown over time) and tend to grow even

bigger as well (they will be chosen again and again). This selection of an elite group of entrepreneurs seems to be working well for the full funding method.

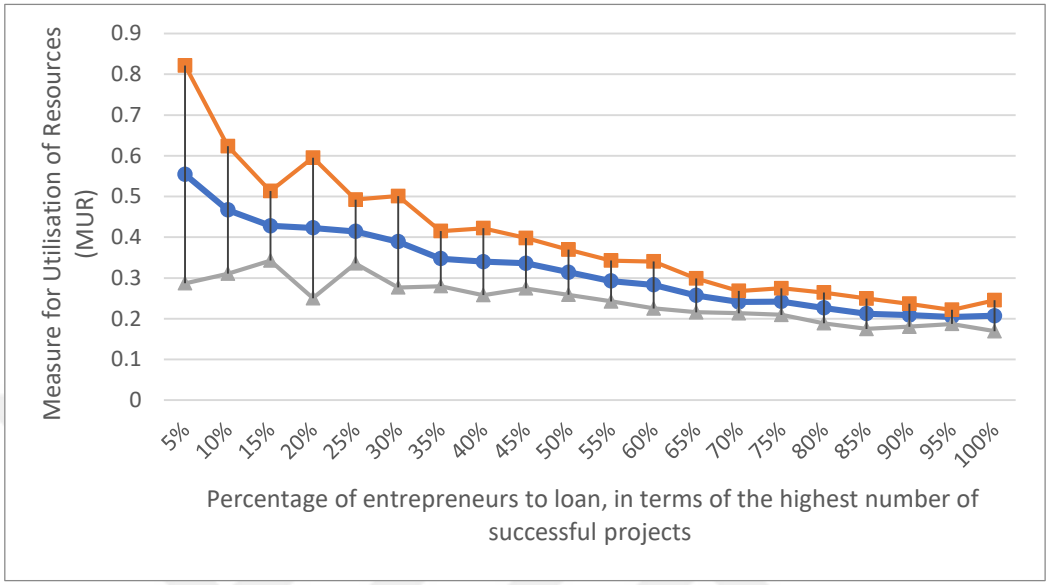


Figure 27. Average MUR value with two standard deviations, according to percentage of entrepreneurs to loan to fully fund projects, in in terms of highest previous number of projects

Experiment 2.2 reveals that selecting projects that are about to expire is not so useful for funding fully, since it fails to achieve better utilisation of resources, as can be tracked in Figure 28. It lowers MUR value for smaller percentages of entrepreneurs, making it an apparently unwise strategy.

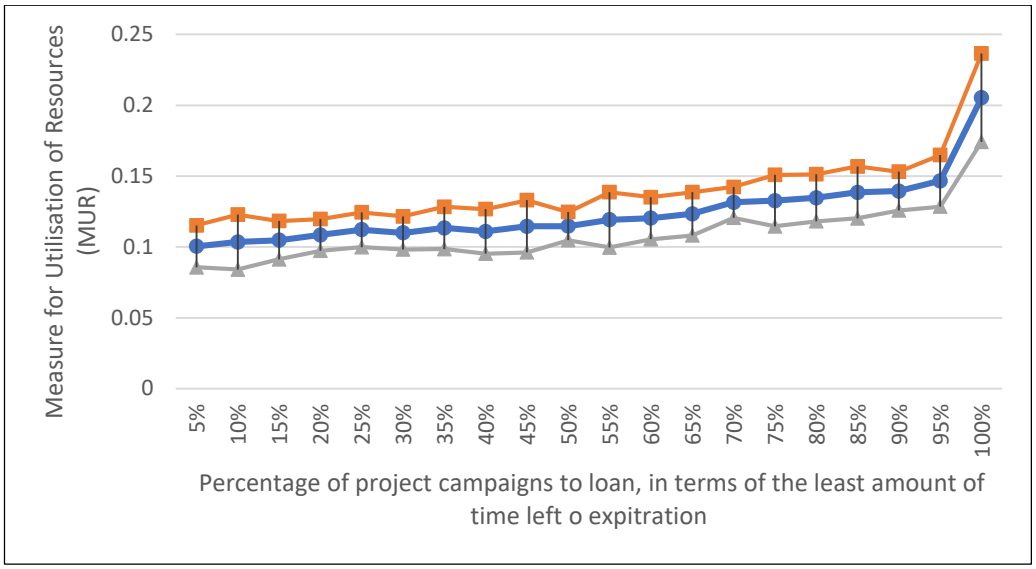


Figure 28. Average MUR value with two standard deviations, according to percentage of entrepreneurs to loan to fully fund projects, in terms of least amount of time left to expiration

Selecting projects needing the least extra resources is another criterion where different funding methods diverge. As the results of Experiment 2.3 clearly shows in Figure 29, selecting projects according to the lowest need for additional funds and funding them fully is not as useful as in equal funding settings: it actually decreases utilisation of resources (if MUR value is used for assessment). This result is not unintuitive since enough resources to cover projects' needs fully means bigger projects can be funded as well. Bigger projects funded at the same time period might mean better utilisation of resources.

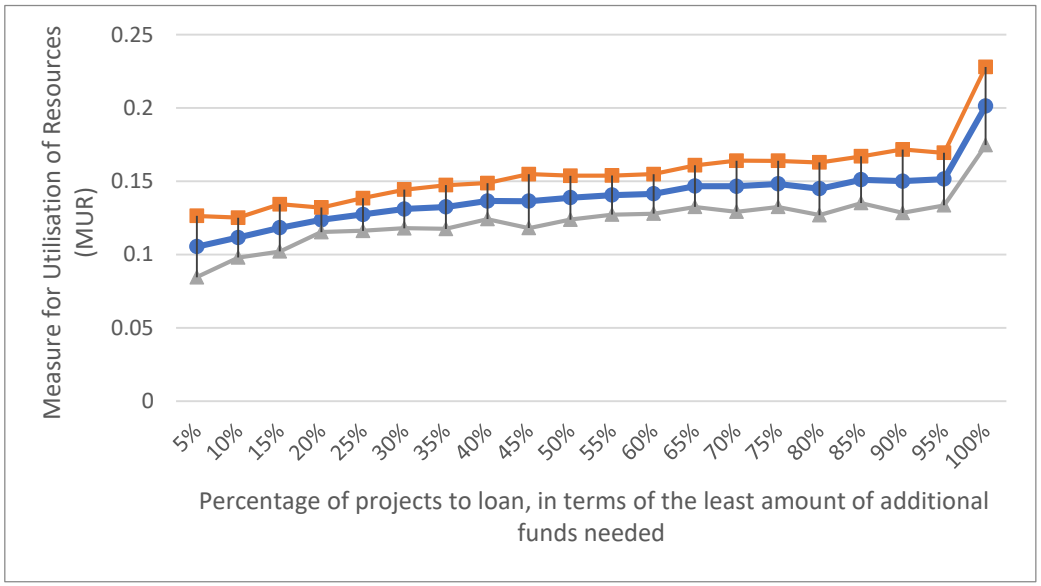


Figure 29. Average MUR value with two standard deviations, according to percentage of entrepreneurs to loan to fully fund projects, in terms of least amount of additional funding

In conclusion, in the Basic Model, for project funding with fixed amount of loans, selection of those that need least additional funds appear to utilise the scarce resources most efficiently. Apparently very high MUR values for selecting projects according to the time left for expiration are probably due to resources staying idle for certain periods of time. For the case of adequate resources to fully fund projects, the best strategy to utilise them appears to involve selection of entrepreneurs with most successful projects completed previously. This strategy probably enables focusing on a select group of successful entrepreneurs and funds them to make their projects grow bigger and bigger. Yet, this focusing might cause inequality in the population via creation of a class of successful entrepreneurs, and this outcome should be properly handled with specific precautions against possible harms of it as well.

Second phase of this essay will focus on advancing the model with changes that aim to better simulate real-life conditions. Evolving the model with such

extensions as default of loans and partial funding may bring about more in depth analysis and more valid results for the problem at hand.

CHAPTER 11

PROBLEM DEFINITION AND MODEL INFORMATION FOR SECOND PHASE OF THE SECOND ESSAY

In the second phase of the automated relending of microcredit essay, we attempt at constructing an improved version of automated re-lending model by making several additions to Basic Model. These additions have been conceived in order to approach real-life conditions and to simulate microcredit platform dynamics better, and resulting model is named as Improved Model. These additions are availability of partial funding, joining of new entrepreneurs via invitation by existing borrowers while simulation is running, possibility of loan default, and using funding percentage as a novel project selection criterion.

11.1 Partial funding

Partial funding means enabling the entrepreneur to obtain the sum of money at the end of funding campaign for their project, regardless of the initial target for funding is achieved. Online non-profit peer-to-peer microcredit platforms we examined offer partial funding as an option in their microlending system. Kiva.org prefers to call partial funding "flexible funding" (as opposed to fixed funding) which does not require the loan to reach its goal, and any amount raised within 30 days (their campaign term is fixed) will be sent to associated field partner (Fisher, 2019). Zidisha.org brought the concept of partial funding as an update to its microcredit mechanism and a novel option for existing borrowers on February 12, 2018[1]. From

1 Information about date of implementation was obtained from https://www.zidisha.org/forum-thread/1403?page=1 but as of January 1, 2024, site seems to be unavailable.

that date on, it has become completely the entrepreneur's decision to take the amount raised as partial funding, or leave it to be "returned to the backers" (Zidisha, n.d.-a). In Improved Model of microcredit re-lending mechanism, partial funding is implemented basically as a change on the algorithm of failed campaigns. In Basic Model, when a project's campaign fails to collect adequate funds, we return the raised amount to the central treasury, requiring the entrepreneur to start over with a new campaign. However, in Improved Model, we give the entrepreneur whatever amount that is raised and adjust their project's size accordingly, in order to make them able to utilise any amount of fund available. This modification that introduces partial funding is expected to increase the efficiency of utilisation of funds in general, since it prevents returning of money collected without being used for projects.

11.2 Joining of new entrepreneurs via referral process

Improved Model introduces the concept of growth to the system via allowing entrance of new entrepreneurs while simulation is running. In the previous model the number of entrepreneurs in the system was fixed and money available in the central treasury was constantly borrowed and returned only by them. We tried to enable new entrepreneurs to come to the system, and it could be appropriate to do this through following an actual implementation: Zidisha.org's method of invitation. In 2013, Zidisha introduced an e-mail tool for existing entrepreneurs to invite potential new members and this enabled them to track referral flows more easily. The idea worked beautifully and although joining via invitation is not a must, it has been observed that entrepreneurs who joined the platform via invitation showed better repayment performance (Kurnia, 2017). When previously unknown people want to get a loan,

they may be said to utilise invitation method as a chain of trust, building upon successful entrepreneurs' reputation. Such a trust factor can be thought of as useful for long term health of the system, and Improved Model employs invitation as the method for new entrepreneurs to join with their projects. In the implementation of invitation method in Improved Model, there are several requirements for referral system. For an existing entrepreneur to be able to invite new potential entrepreneurs, there is a lower limit of previous successful projects whose loans are returned. In addition, number of referrals by a certain entrepreneur is limited. However, once new entrepreneurs who join through invitation meet these requirements, they invite other individuals as well, giving the overall system opportunity to grow (it stabilises over time, as will be described below).

11.3 Loan default

Improved Model extends the Basic Model to cover the possibility of loan default. In real-life conditions, there could be several reasons why a microcredit is not repaid. It may range from trivial daily hassles causing delay to catastrophic events leading to business failure or from simply forgetting to pay the instalment of a loan to self-conscious delinquency. For non-profit online microcredit platforms, the picture of default rate of loans is apparently not very unfavourable. Kiva.org presents repayment rate statistics in "The risks of lending" page and as of January 1, 2024 repayment rate for all loans is given as 96.2% (Kiva, n.d.-b). For Zidisha.org, its founder Julia Kurnia shares a chart of historical on-time repayment rate of first instalments up to March 2015, while explaining the story of Zidisha (Kurnia, 2017). Figure 30 demonstrates that repayment rate of loans gets better over time:

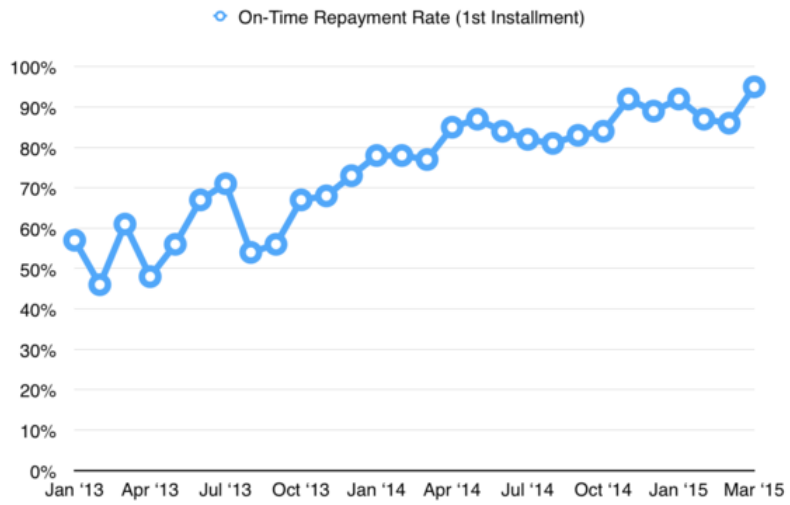


Figure 30. On-time repayment rate of Zidisha borrowers over time (1st instalment)

Although repayment rates are high or getting high, loan default is still a real-life phenomenon. Events of default occur to some of the microcredit loans provided, and although not very frequent, they still pose a considerable risk to both lenders and microcredit platforms. In order to reflect the loan default phenomenon in Improved Model, we add a novel parameter to entrepreneur agent that determines the probability of the loans borrowed by this entrepreneur to default. This default rate parameter is set at the beginning of the simulation for every entrepreneur (for new entrepreneurs who join via invitation, it is set at the initialisation). It is set to a uniformly distributed random variable, and is fixed throughout the simulation. When repayment time for a loan comes, this fixed default rate of the entrepreneur is compared to a random variable generated at that instant and if it is greater than this random variable, the loan defaults. This means in our simulation some entrepreneurs are more predisposed to loan defaults, which may be thought of as related to risk level of their sector, economic conditions of their location, or their characters.

When a loan defaults, from then on, its entrepreneur is completely excluded from the simulation, effectively banning them ("DIE" command of Netlogo

simulation software is used). This leads to a decrease of entrepreneur agents in the simulation, and together with the increase of entrepreneur agents through invitation, system becomes able to stabilise over time. This stabilisation is fundamentally important because it enables us to gather statistical information about simulation result. A metric of efficiency of utilisation of resources, for instance, would be very difficult to measure and compare other experiments' results, if the system is not stable, as it would change over time. Therefore, throughout providing both entrance to and exit from the simulation, it may be thought that a relatively open system is reached, while still not losing stability and still allowing extraction of results.

Default rate of new entrepreneurs' loans may not be equal to that of experienced entrepreneurs who already successfully completed one or more projects. This is because it might be difficult to be sure of purity of intentions of new members in a microcredit platform (For a well-described example, see foundation story of Zidisha by founder Julia Kurnia [2017]). Additionally, after designing, executing and completing successful projects, an entrepreneur may become more resilient to shocks, as their business will probably grow bigger and perhaps financially stronger. This growth and empowerment effect may be another reason for reduction of default rate for the same entrepreneur over time. In our simulation, default rate of an entrepreneur is divided by some constant after every successful loan repayment, gradually approaching zero over very long term. This constant is adjusted and set to such a value that system stabilises over time, reaching to a balance which is suitable for statistical calculations.

11.4 A new criterion for project selection: fund needed wallet ratio

Last improvement on the Basic Model is introduction of a new criterion for selection of projects of entrepreneurs for loan delivery. This novel criterion employs proportion of raised amount to total amount of loan needed as the measurement metric. This percentage of loan amount raised might be of great assistance to better utilisation of funds since our original three criteria did not take project sizes into account. One of our criteria selected projects according to how much more money is needed for its campaign to be completed. However, this may not be enough for maximisation of utilisation of funds. Two projects with sizes 100 dollars and 1000 dollars, for instance, may both lack only 5 dollars more to begin to be executed. Our least additional funds needed (fund needed) criterion would treat these projects equally, whereas selecting the larger project for loan may be a better option for both utilisation of resources and expected social benefit over time. Our novel criterion enables this option and it is named and parameterised as fund needed wallet ratio in our implementation.

11.5 Algorithm of Improved Model

Because Improved Model is mainly a development over Basic Model, presenting its algorithm with additions to that of Basic Model given in Chapter 9 might enable easier comparison. Building on the previously explained extensions, the Improved Model of automated relending of microcredit is implemented according to following algorithm:

- We determine the way of prioritisation (least amount of additional resources – fund needed, time to expiration of project campaign –

time to expiration, previous experience - previous number of successful projects, or highest proportion of money in the wallet to total fund needed for the project - fund needed wallet ratio), the loaning method (equal but limited funding or full funding) and the percentage for selection of projects for a specific experiment.

- 500 entrepreneurs are created and initialised. Every entrepreneur has a current project which several attributes:
    - money in their wallet (initialised to zero),
    - current amount of money needed for completion of project (initialised to a uniformly distributed value between 1 – 20),
    - number of completed projects according to previous success (initialised to zero),
    - loan expiration date (initialised to a uniformly distributed value between 1 – 20),
    - repayment date for loan (initialised to a uniformly distributed value between 1 – 20).
    - default probability (initialised to a uniformly distributed value between 0 and maximum default rate parameter)
    - allowed referral count (initialised to zero).
    - partial funding is accepted (initialised to one/true)
- We keep track of time passed through 10000 time steps (tick).
- In every time step (tick),

i. Central treasury selects a number of entrepreneurs one by one to lend according to the specified way of prioritisation, specified percentage for selection and loans them according to the specified loaning method.

ii. Those entrepreneurs who completed their projects without default (checked by comparing default rate to a temporary variable) pay their loans back to the central treasury and become a candidate for taking loans again with a project of greater size and less default probability; and if conditions are met for allowed referral count and previous number of successful projects needed for referral, a new entrepreneur is included in the simulation. If loan default occurs, associated entrepreneur is removed from simulation.

iii. Those entrepreneurs who failed to gather needed funds at the campaign expiration time, if partial funding is applicable, adjust fund needed for their project according to partial funding available, if it is not, they give back the amount in their wallet to the central treasury and become a candidate for taking loans again with a project of similar size.

iv. Total microcredits returned up to this time step and loans distributed and in use at this time step are recorded.

- After a specific time period (in our model 10000 time steps/ticks) simulation ends and simulation results are reported.

To summarise, for constructing Improved Model, we included one more criterion for project campaign selection: the lowest percentage of additional funds needed (fund needed wallet ratio). Additionally, we covered four novel initial parameters to better represent various characteristics of online microcredit platforms in real-life conditions. These parameters are related to our Improved Model's extension about microcredit processes. We included default of microcredit loans, partial fulfilment of microcredit loan requests, and joining of new entrepreneurs to the system by referral. Associated newly added parameters are previous number of successes needed for referring (how many previous successful projects are needed to be able to invite a new entrepreneur to the system), partial funding ratio (the percentage of a campaign that needs to be completed to obtain associated funds), maximum default rate (upper threshold for probability value for an entrepreneur to default), referral count (how many new entrepreneurs may be invented by one person in the system). Through running the code implementing previously given algorithm with these additions, which is presented in Appendix B, experiments of Improved Model are conducted as second phase of the study and its simulation results are obtained. Next chapter will present the description of simulation of the second phase, and its results.

CHAPTER 12

SIMULATION AND RESULTS FOR SECOND PHASE OF THE SECOND ESSAY

We developed the Improved Model of automated relending of microcredit to better represent and understand online microcredit platforms and associated processes, and we can now explain the experimental design of Improved Model as well as its simulation information. Improved Model simulations are run for 5000 steps except for referral count experiment, which we needed to limit to 600 steps as the system grows too large for two referrals case. The Improved Model's initial parameter values and design are summarised in the Table 19 (these experiments are conducted for loaning methods of both giving an equal but small amount of loan to every project and giving the amount of loan that fully funds the project, like the first phase of the study).

This chapter presents the Improved Model's simulation results in following order: First we demonstrate experiments with equal but limited funding, then full funding for every section. In the first section, for both of the functions, we present average of 20 replications of a specific set of conditions. These conditions are around half of the range of initial parameters given above, and this set of simulations is used as a bench mark of comparison for other sets of simulations. This set of simulations might be named as "Midway Experiment" (please see Table 19 for input values of

Table 19. Design and Initial Parameters of Experiments

Initial Parameters / Experiment name	Partial Funding Ratio	Maximum Default Rate	Prev. Num. of Successes Needed for Referring	Referral Count	Number of Replications
Midway Experiment	0.5 (50% of the campaign must be funded)	8% (default rate can be 8% at most)	3 (3 previous projects with returned microcredits)	1 (1 new entrepreneur might be invited, 600 steps)	20 for every criterion (20 x 4)
Experiment with Base Run Conditions	1 (no partial funding)	0% (no default)	0 (no referral)	0 (no referral)	1 for every criterion (1 x 4)
Upper and Lower Bound Experiments	0.01, 1 (presented with 0.5 midway exp. value)	0%, %16 (presented with 8% midway exp. value)	1, 5 (presented with 3 midway exp. value)	0, 2 (presented with 1 midway exp. value, 600 steps)	1 for upper and lower bounds (1 x 2 x 4)

midway experiment). After midway experiment result table (Table 20) and associated charts (section 12.1), we present experiments conducted in base run (Basic Model) conditions, in order to be able to compare Improved Model and Basic Model (section 12.2). Then we present experiments for 4 criteria (fund needed wallet ratio, fund needed, time to expiration, previous number of successes) with changing initial values of 4 novel parameters (section 12.3).

12.1 Midway Experiment results

Using Midway Experiment output, Table 20 presents average values for Measure for Utilisation of Resources (MUR) metric for increasing portions of projects and their entrepreneurs, when selected with associated criteria, and funded with small and equal loans or with full amount needed. As can be tracked in the table, for increasing selectivity (going upwards in the table), experience of entrepreneurs, observed through previous number of successful projects, positively diverges from other criteria for reaching higher effectiveness in resource allocation, with our settings and

measurement methods. Apparently, in Improved Model with Midway Experiment conditions, using previous experience for entrepreneur selection is a relatively better decision. Yet, while apparently effective, like in Basic Model, using this criterion might lead to inequality in the population via divergence between successful entrepreneurs and others, possible harms of which should properly be thought of, observed, handled, and prevented.

Table 20. Average MUR Values of 20 Replications for Selection Criteria of Improved Model for Equal but Limited Funding and Full Funding in Midway Experiment Conditions

Ratio of Projects Selected	Equal but Limited Funding				Full Funding			
	Fund Needed	Fund Needed Wallet Ratio	Number of Previous Successes	Time to Expr.	Fund Needed	Fund Needed Wallet Ratio	Previous Number of Successes	Time to Expr.
5%	0.008454	0.005685	0.016045	0.005767	0.009958	0.009977	0.019178	0.00995
10%	0.010133	0.006654	0.015998	0.006778	0.012178	0.012087	0.019588	0.013938
15%	0.011417	0.007585	0.01631	0.007878	0.013143	0.013554	0.019989	0.016736
20%	0.012184	0.008471	0.01584	0.009199	0.014089	0.014398	0.020543	0.017997
25%	0.013046	0.009308	0.016053	0.01044	0.014802	0.015222	0.020512	0.018694
30%	0.013746	0.01022	0.016236	0.011859	0.015087	0.015708	0.020511	0.019121
35%	0.014222	0.010793	0.015742	0.012997	0.01578	0.016612	0.02097	0.019666
40%	0.014739	0.011542	0.016137	0.013849	0.015995	0.016945	0.02086	0.019636
45%	0.015194	0.012126	0.016389	0.014655	0.016174	0.017555	0.020925	0.020279
50%	0.015714	0.012765	0.016451	0.014868	0.016432	0.017992	0.020721	0.020363
55%	0.015958	0.01343	0.01665	0.015457	0.016534	0.018199	0.020985	0.020538
60%	0.016292	0.013966	0.016845	0.015457	0.017201	0.018772	0.021155	0.020668
65%	0.016709	0.014397	0.017063	0.015687	0.017154	0.019061	0.021095	0.020973
70%	0.016862	0.014938	0.017106	0.016041	0.01749	0.019326	0.021199	0.020857
75%	0.017045	0.015441	0.0173	0.016209	0.018032	0.019898	0.021083	0.021171
80%	0.017065	0.015841	0.017296	0.016357	0.018248	0.020062	0.021222	0.021055
85%	0.016972	0.016237	0.017539	0.016272	0.01874	0.020252	0.021374	0.021153
90%	0.017452	0.01687	0.017415	0.016682	0.019362	0.020635	0.021212	0.021119
95%	0.017555	0.01702	0.017565	0.017219	0.019993	0.021197	0.021321	0.02125
100%	0.017565	0.01725	0.017323	0.017308	0.021151	0.021484	0.02144	0.021427

The results of midway experiments for fund needed (Figure 31a, Figure 32a), fund needed wallet ratio (Figure 31b, Figure 32b), number of previous successes

(Figure 31c, Figure 32c), and time to expiration (Figure 31d, Figure 32d) criteria are shown below for equal, limited distribution of funds to selected projects as well as for giving total amount needed to fully fund selected projects. These midway experiments' average MUR values of 20 replications, as well as 2 standard deviations above and below are presented in associated charts.

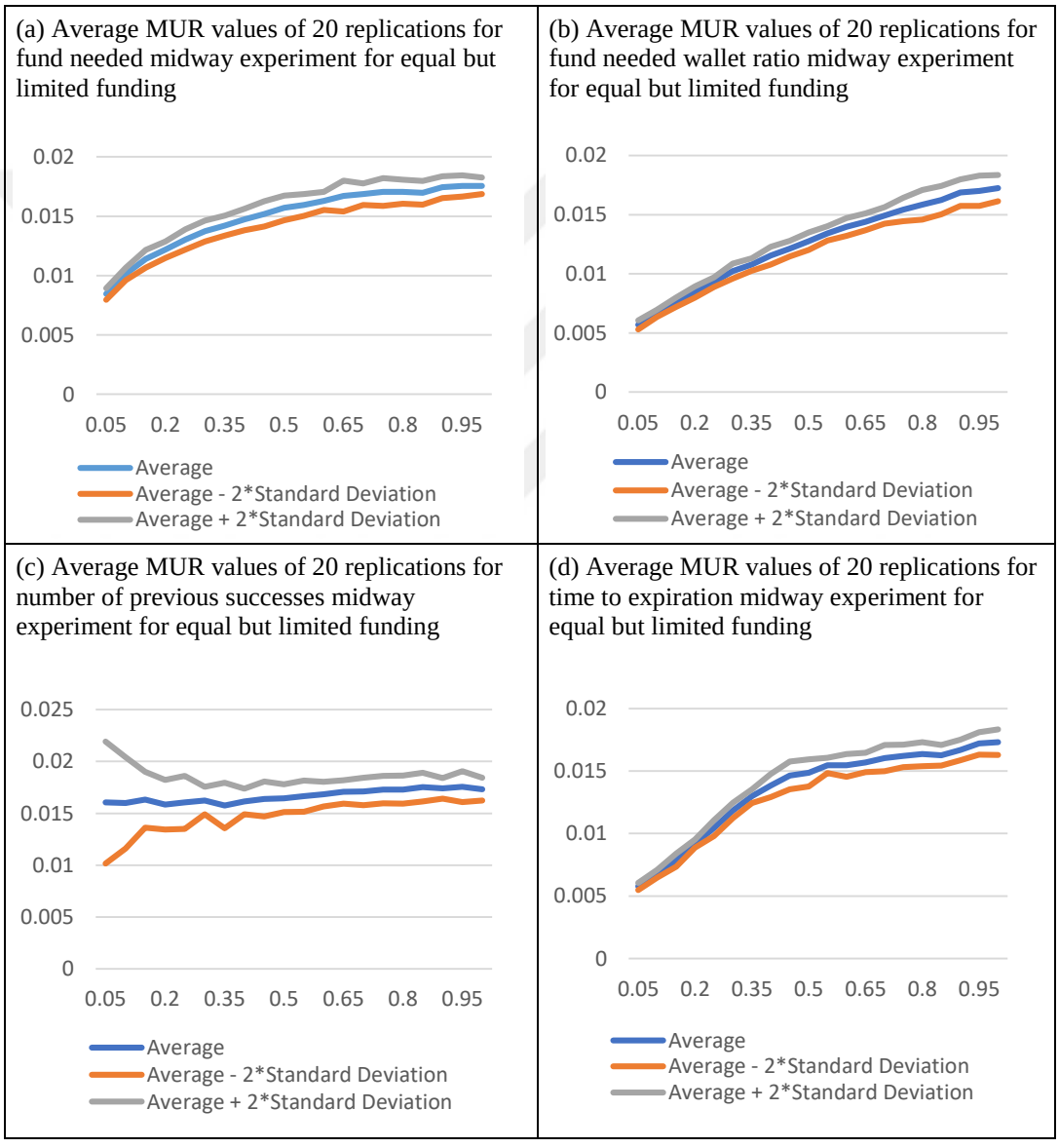


Figure 31. Midway Experiment results for equal but limited funding of the selected projects

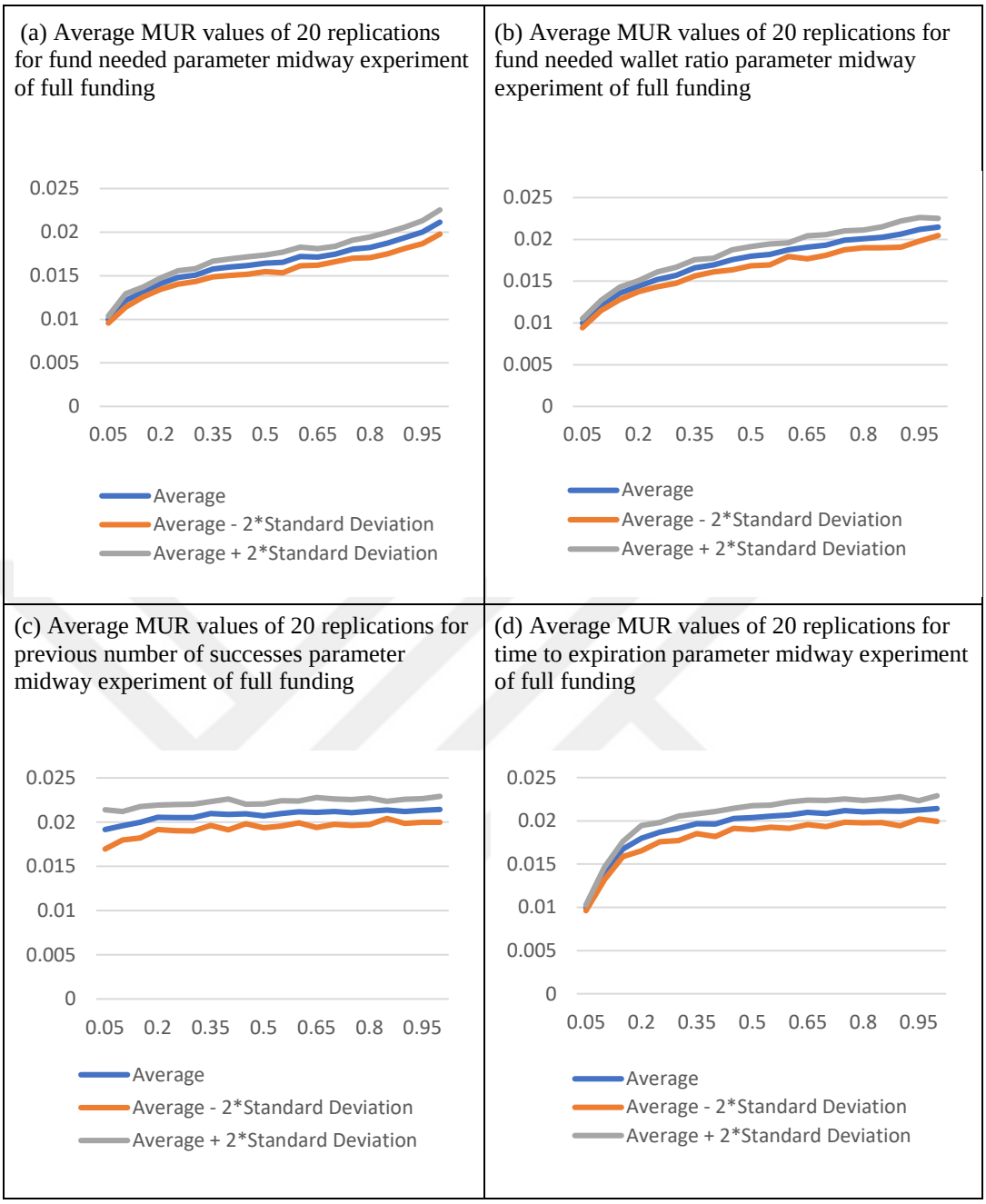


Figure 32. Midway Experiment results for full funding of the selected projects

As seen in Figure 31 for equal funding, and Figure 32 for full funding, three criteria's (fund needed, fund needed wallet ratio, time to expiration) initial values considerably affect the resulting MUR Value of simulations, which is our main measurement of effectiveness for associated allocation mechanism. These charts demonstrate that increasing initial values for these three parameters lead to higher final MUR values as well. The range of resulting MUR values are similar, between

0.005 and 0.025. An important exception here is number of previous successes criterion (Figure 31c and Figure 32c), which does not seem to be largely altering resulting MUR values.

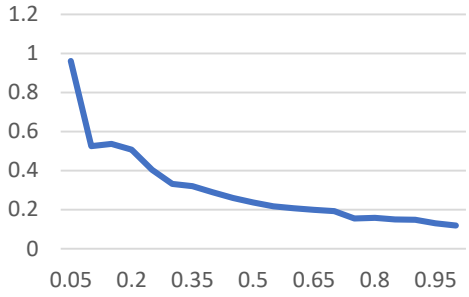
12.2 Results for comparing Midway Experiment results with Improved Model's experiment with base run conditions

In order to compare the presented average Midway Experiment results with the Basic Model, we conducted singular (1 replication for each) simulations for 4 criteria in base run (Basic Model) settings with equal distribution of small amount of funds and funding projects totally. Output of these simulations may be tracked in Figure 33 and Figure 34. Comparison of Figure 31 and Figure 33 shows that for equal funding, compared to the Basic Model, our new conditions for Improved Model decreases the effect of two campaign selection criteria on resulting MUR value. In base run conditions, while fund needed wallet ratio parameter (Figure 33b) and previous number of successes parameter (Figure 33d) do not appear to cause a large change in MUR values for equal funding, the other two of the four criteria, namely fund needed parameter (Figure 33a) and time to expiration parameter (Figure 33c), result in a very large increase in MUR values when associated initial values for criteria parameters approach to zero, perhaps suggesting an exponential relationship. However, these two parameters do not cause such large in MUR value in Midway Experiment conditions, and on the contrary, when approaching to zero, they lead to a drop in MUR value. When Improved Model introduces concepts of loan default, referral and partial funding, for equal funding of selected projects with a limited amount, the new system seems to respond less (or differently) to changes in initial conditions for some of the criteria, and this might be because Improved Model is actually a dynamic

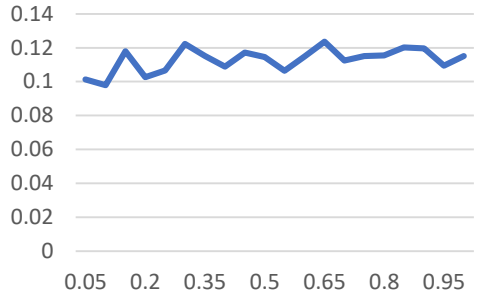
system with changing number of entrepreneurs through both loan defaults and referral.

For loaning method of full funding, we can observe a similar pattern among selection criteria results of the experiment with base run conditions: fluctuations in resulting MUR Values between 0.075 and 0.105. Aside from time to expiration (Figure 34d) and for 3 of 4 criteria (Figure 34a, Figure 34b, Figure 34c) lower values of initial parameters bring about higher MUR value output, however we cannot observe an exponential-like relation as in two of simulation cases of equal funding with small amount of loans (Figure 33a, 33c). This might be interpreted as importance of method of project selection in equal and limited distribution of resources. We might further infer that if this method is applied due to scarcity of resources in an imaginary online microcredit platform, limited distribution of scarce resources is more crucial to be targeted to those projects with the least need for extra funds (fund needed parameter) and the most urgent (time to expiration parameter) ones. Associated Midway Experiment results for full funding conditions show reversed effect for selection criteria (Figure 32), with less MUR values for stricter conditions, and this might be because in Midway Experiment, loan defaults are effective, and fully funding projects increases number of previously completed projects by entrepreneurs, causing their default probability to decrease.

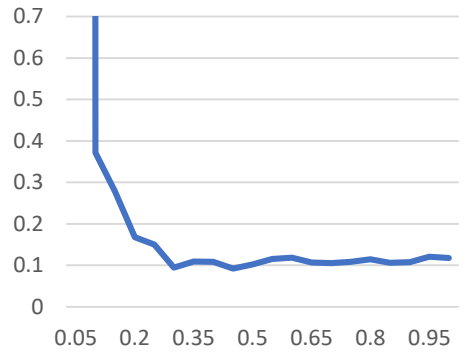
(a) MUR values for increasing fund needed parameter in base run conditions for equal but limited funding



(b) MUR values for increasing fund needed wallet ratio parameter in base run conditions for equal but limited funding



(c) MUR values for increasing time to expiration parameter in base run conditions for equal but limited funding



(d) MUR values for increasing previous number of successes parameter in base run conditions for equal but limited funding

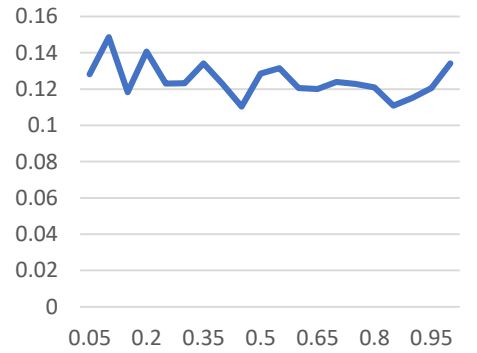


Figure 33. Results of experiments in base run conditions for equal but limited funding

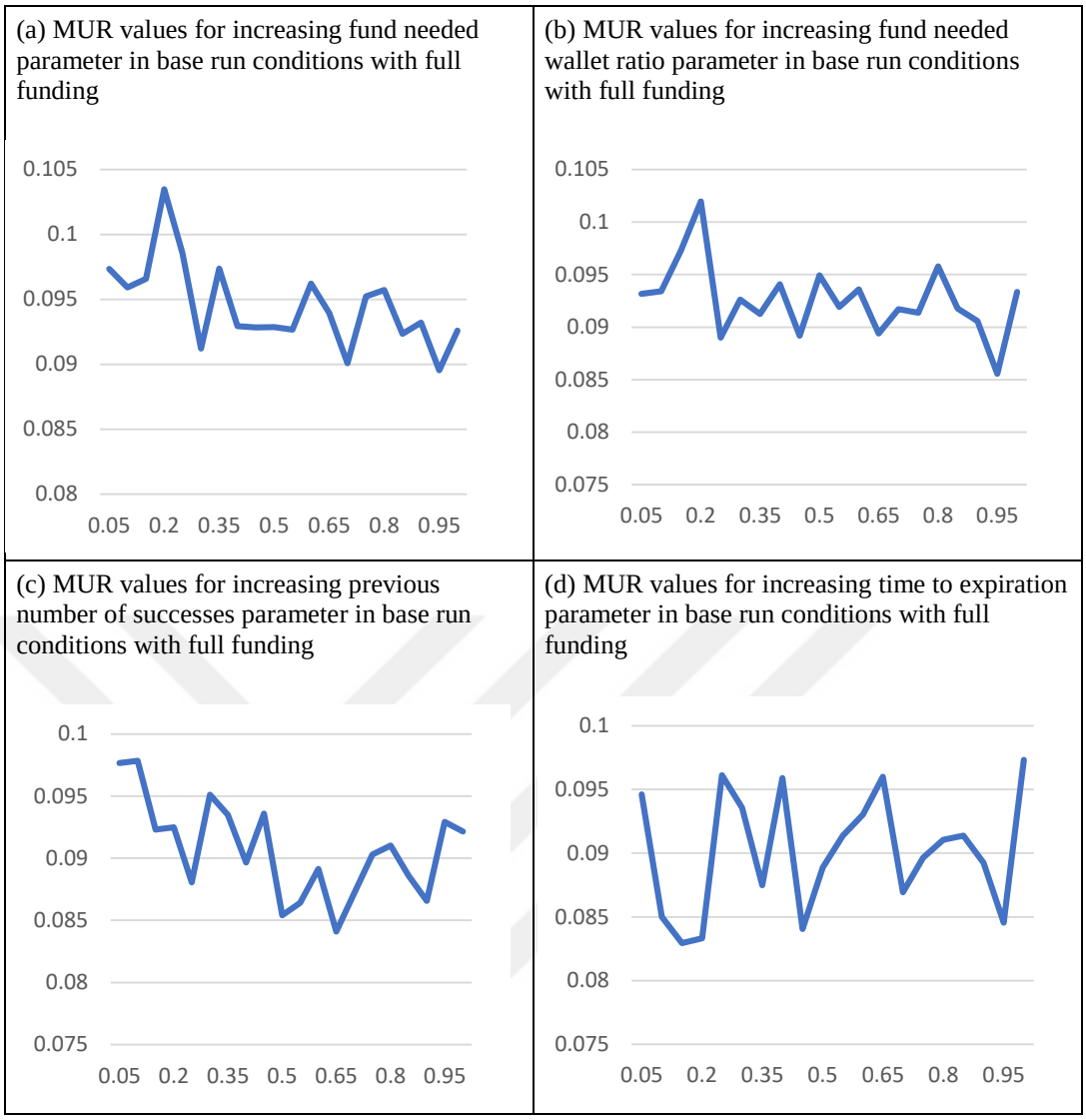


Figure 34. Results of experiments in base run conditions for full funding

12.3 Results for upper and lower bound experiments

A closer look at each novel concepts' effects on utilisation of resources for higher and lower values of added parameters of the Improved Model might help us elucidate their impact on the resulting system better. Figure 35 and Figure 36 presents the outcome of maximum default rate experiments for all 4 criteria. The first thing we might notice in four charts is when there is no default of loans in a simulation (max default rate equals to zero, orange lines), resulting MUR value is considerably higher. We may interpret this as, if any online microcredit platform aims to utilise its

funds in an optimised, effective fashion, then probability of defaulting of loans should be lowered. Frequent loan defaults might be prevented via background checks for entrepreneurs, project viability assessments and other precautions and these might be vital for very sustainability of microcredit platform itself.

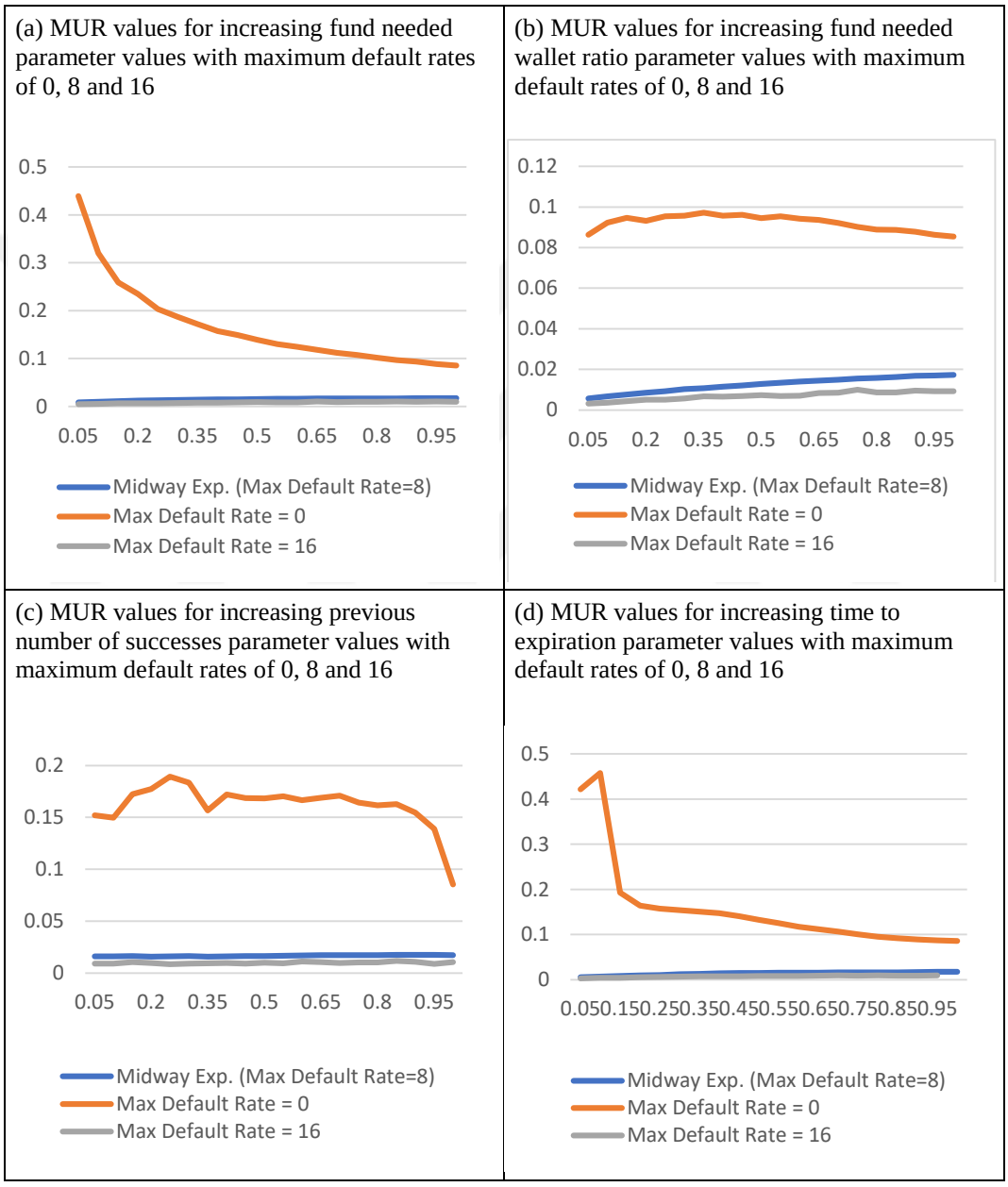


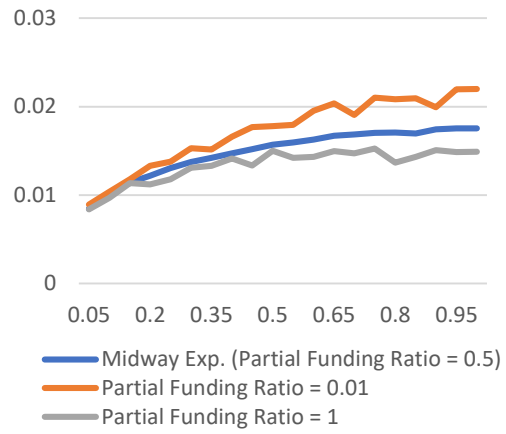
Figure 35. Experiment results for maximum default rate parameter with equal but limited funding



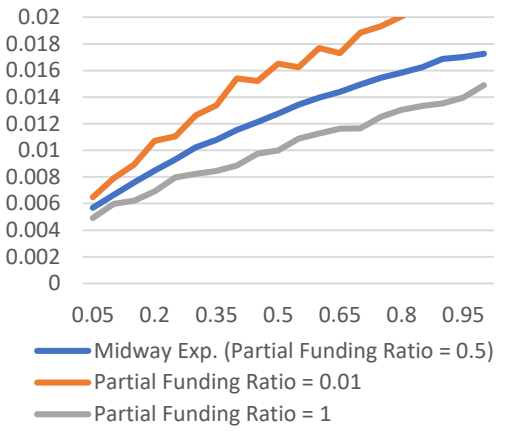
Figure 36. Experiment results for maximum default rate parameter with full funding

Next criterion we examine is partial funding ratio, whose simulation results may be viewed in Figure 37 and Figure 38. Availability of partial funding means provided that a certain threshold is passed (partial funding ratio), we supply the sum of money gathered for the project when its campaign ends, regardless of its ability to find total amount it requires. Partial funding reasonably increases the total amount of microcredit distributed as it funds campaigns that otherwise would go unfunded, however, does it do this effectively? At first sight, we might notice that in full funding experiments (Figure 38), partial funding ratio is clearly ineffective on MUR value output. This is logical because full funding method already funds all the selected projects fully, therefore there is no partially funded projects in effect. For equal and limited distribution of resources, a higher threshold for partial funding ratio seems to decrease resulting MUR value for all four selection criteria (Figure 37). This may lead us to think that, in equal funding conditions, however small, funds gathered should be supplied to associated projects for better resource utilisation, at least in our simulation setting.

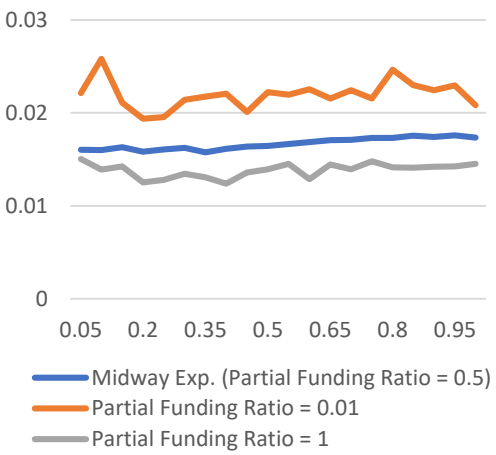
(a) MUR values for increasing fund needed parameter with partial funding ratio of 0.01, 0.5 and 1 for equal but limited funding



(b) MUR values for increasing fund needed wallet ratio with partial funding ratio of 0.01, 0.5 and 1 for equal but limited funding



(c) MUR values for increasing previous number of successes parameter values with partial funding ratios of 0.01, 0.5 and 1 for equal but limited funding



(d) MUR values for increasing time to expiration parameter values with partial funding ratios of 0.01, 0.5 and 1 for equal but limited funding

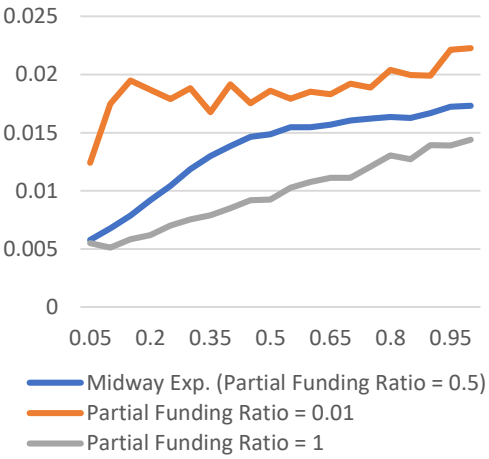


Figure 37. Experiment results for partial funding ratio parameter with equal but limited funding

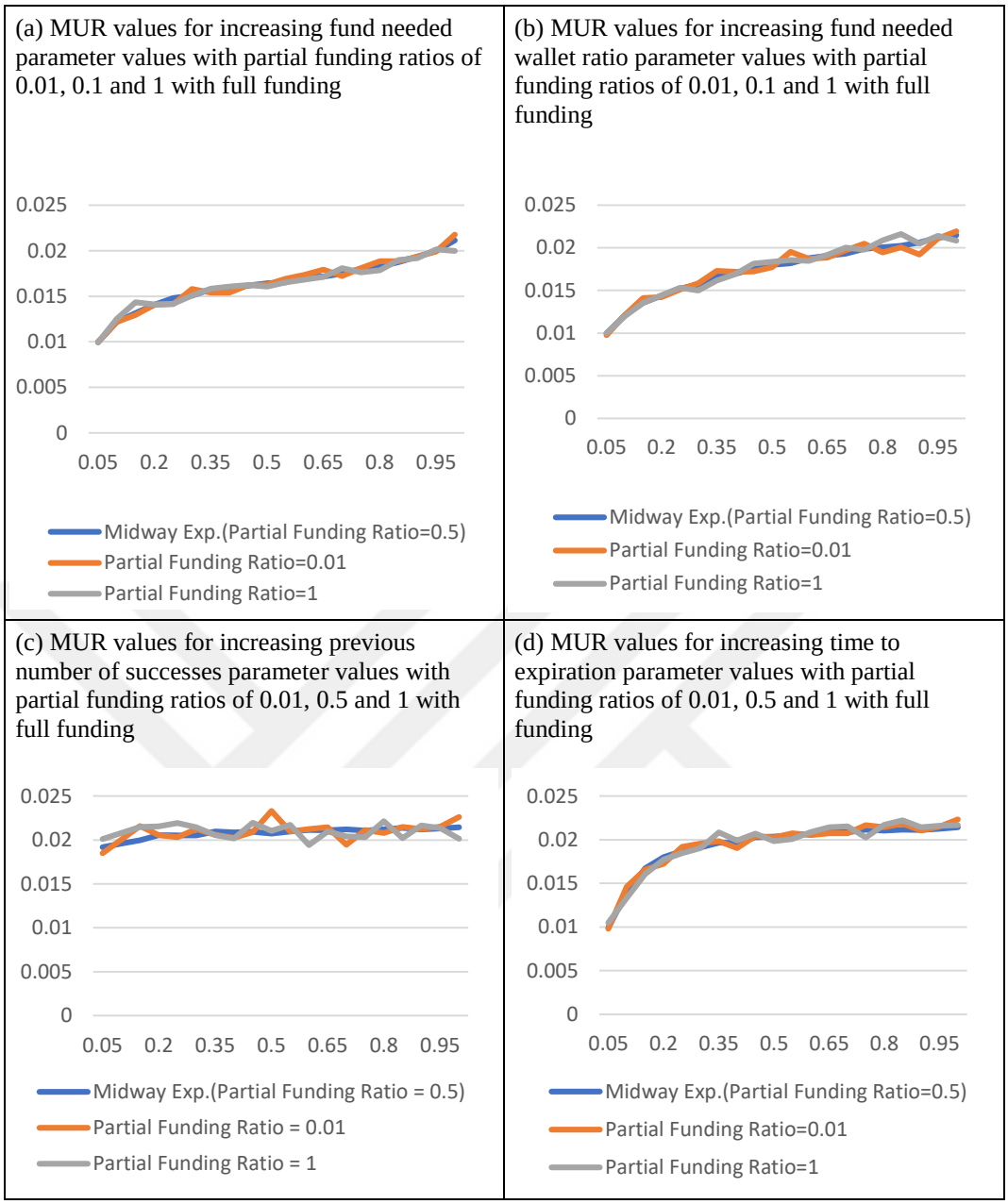


Figure 38. Experiment results for partial funding ratio parameter with full funding

In Improved Model one of major additions to Basic Model conditions is growth of population of entrepreneurs on the course of simulation via referral system. This was arguably an essential and necessary improvement over base run to approach real-life conditions because it is hard to find an actual microcredit platform to serve a static set of user base. In our simulation settings in order for an existing entrepreneur to be able to invite new potential entrepreneurs, they are required to demonstrate their reliability by successfully completing a specific number of projects (1, 3, or 5) beforehand. However, for equal but limited funding Figure 39, and for full funding Figure 40 show that with our model settings, assumptions and initial parameter values, this measurement taken is not effective at altering utilisation of resources (in terms of MUR value). This might stem from the fact that our simulation period is rather long (5000 time steps) and existing and new entrepreneurs reach this threshold of successful projects sooner or later. Therefore, previous number of successes needed for referral is not one of decisive parameters that determine resource utilisation in our simulation experiments.

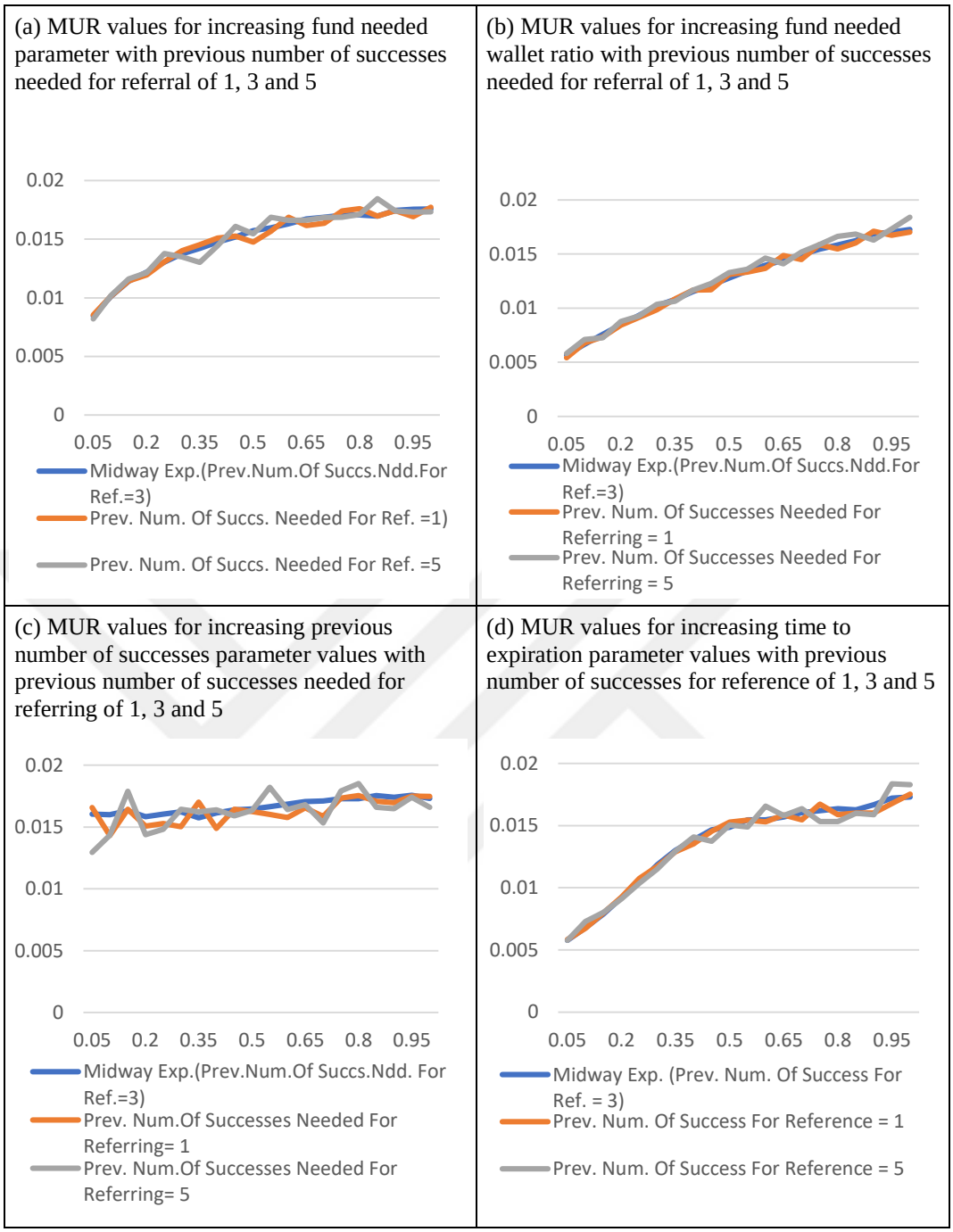
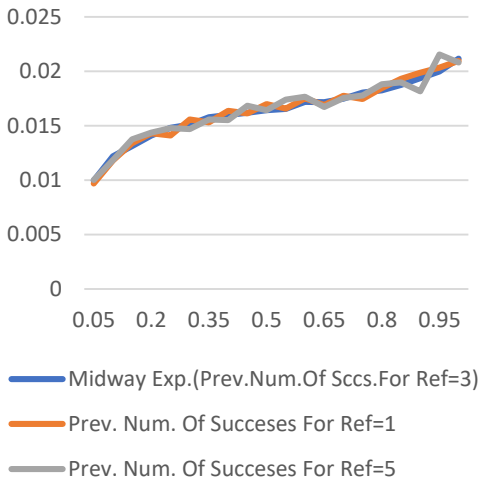
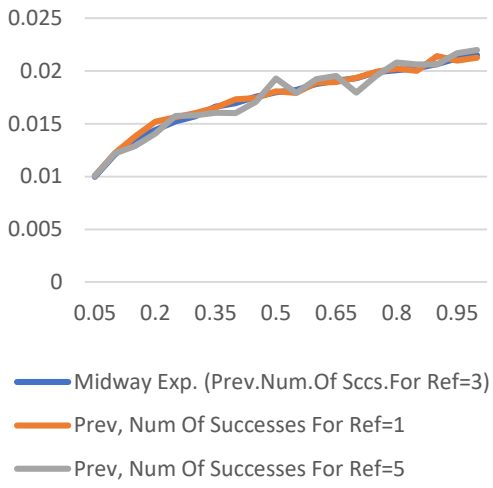


Figure 39. Experiment results for previous number of successes needed for referral parameter with equal but limited funding

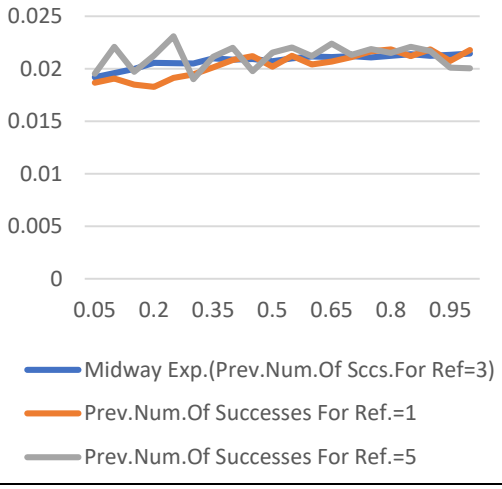
(a) MUR values for increasing fund needed parameter values with previous number of successes for referral of 1, 3 and 5 with full funding



(b) MUR values for increasing fund needed wallet ratio parameter values with previous number of successes for referral of 1, 3 and 5 with full funding



(c) MUR values for increasing previous number of successes parameter values with previous number successes needed for referral of 1, 3 and 5 with full funding



(d) MUR values for increasing time to expiration parameter values with previous number of successes for referral of 1, 3 and 5 with full funding

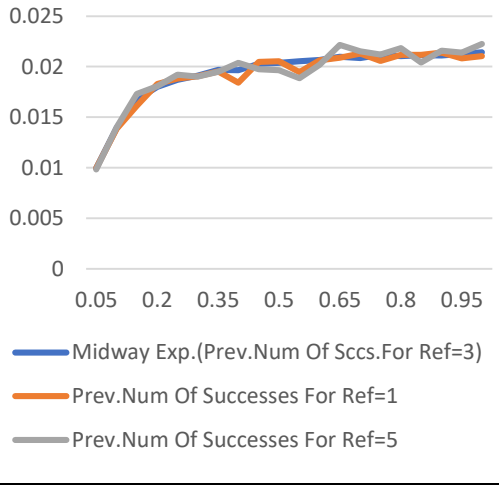


Figure 40. Experiment results for previous number of successes needed for referral parameter with full funding

Our last parameter to be tried with different values to determine its overall effect on resource utilisation is allowed referral count. In these experiments we allow entrepreneurs that meet the condition of previous 2 (midway value) successful projects to bring 1 or 2 new entrepreneurs by referral. We examine the case of no referral for comparison purposes as well. Inclusion of referral system turned out to be a tremendously influential decision on outcome of the experiments. Especially for the case of referring 2 new entrepreneurs led to massive (and accelerating) growth in our model population, requiring colossal time and processing resources for simulation to progress. This forced us to limit this specific simulation experiment to 600 steps. This rapid growth of the model can logically be expected since if every agent brings another agent in a specific period of time, population growth becomes exponential. Yet, this increase in population of entrepreneur agents does not seem to mean an increase in utilisation of resources as well. As can be tracked in charts of both Figure 41 and Figure 42, the case of no referral gives the highest MUR value output, then comes midway value of 1 referral and the case of 2 referrals results in the lowest MUR value output. If we are to deduce a real-life meaning and recommendation from this result, this would be the proposition that being cautious for new members and rapid growth is important for online microcredit platforms. If our assumptions and model settings are valid, then bigger size may not mean bigger success.

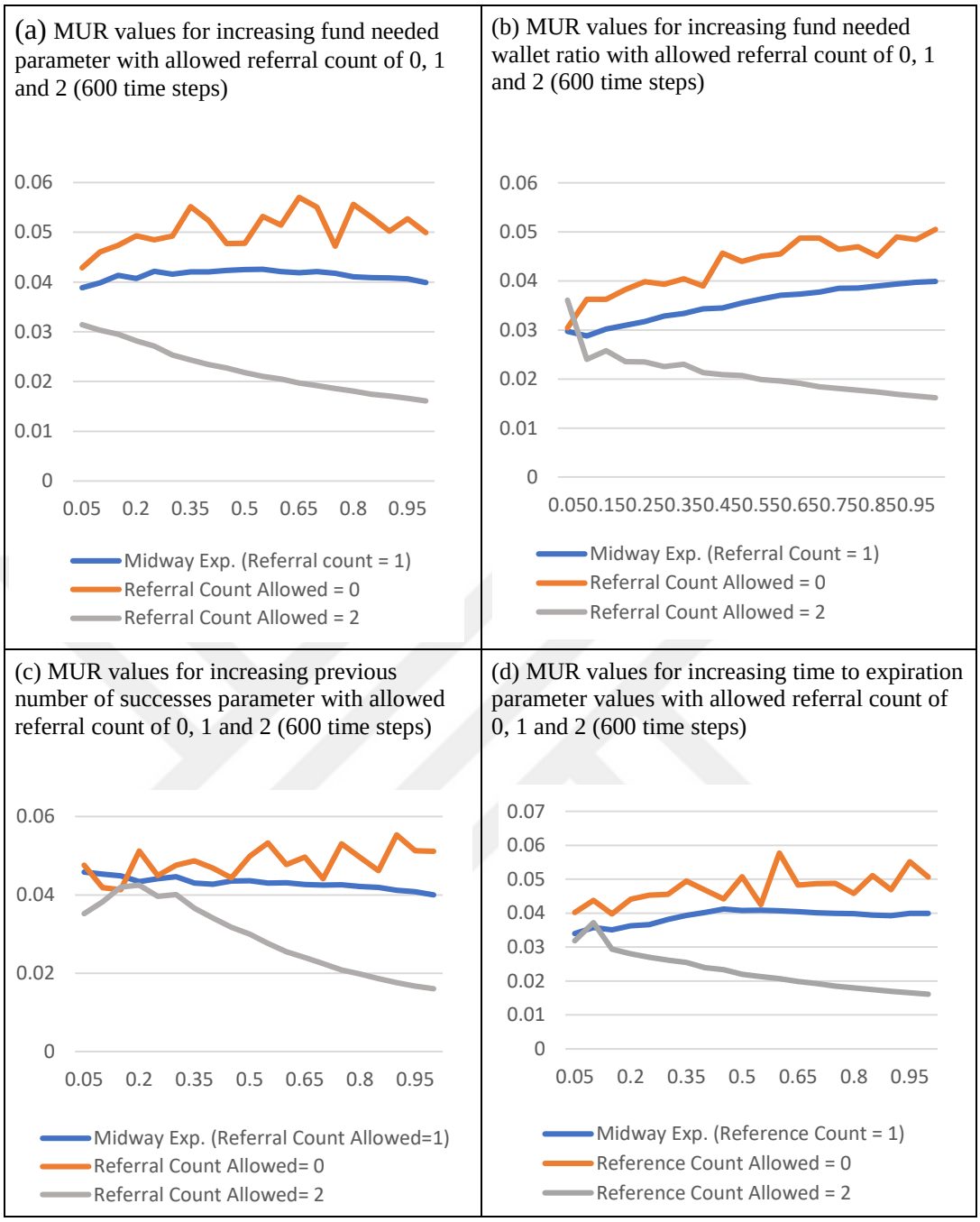


Figure 41. Experiment results for allowed referral count parameter with equal but limited funding

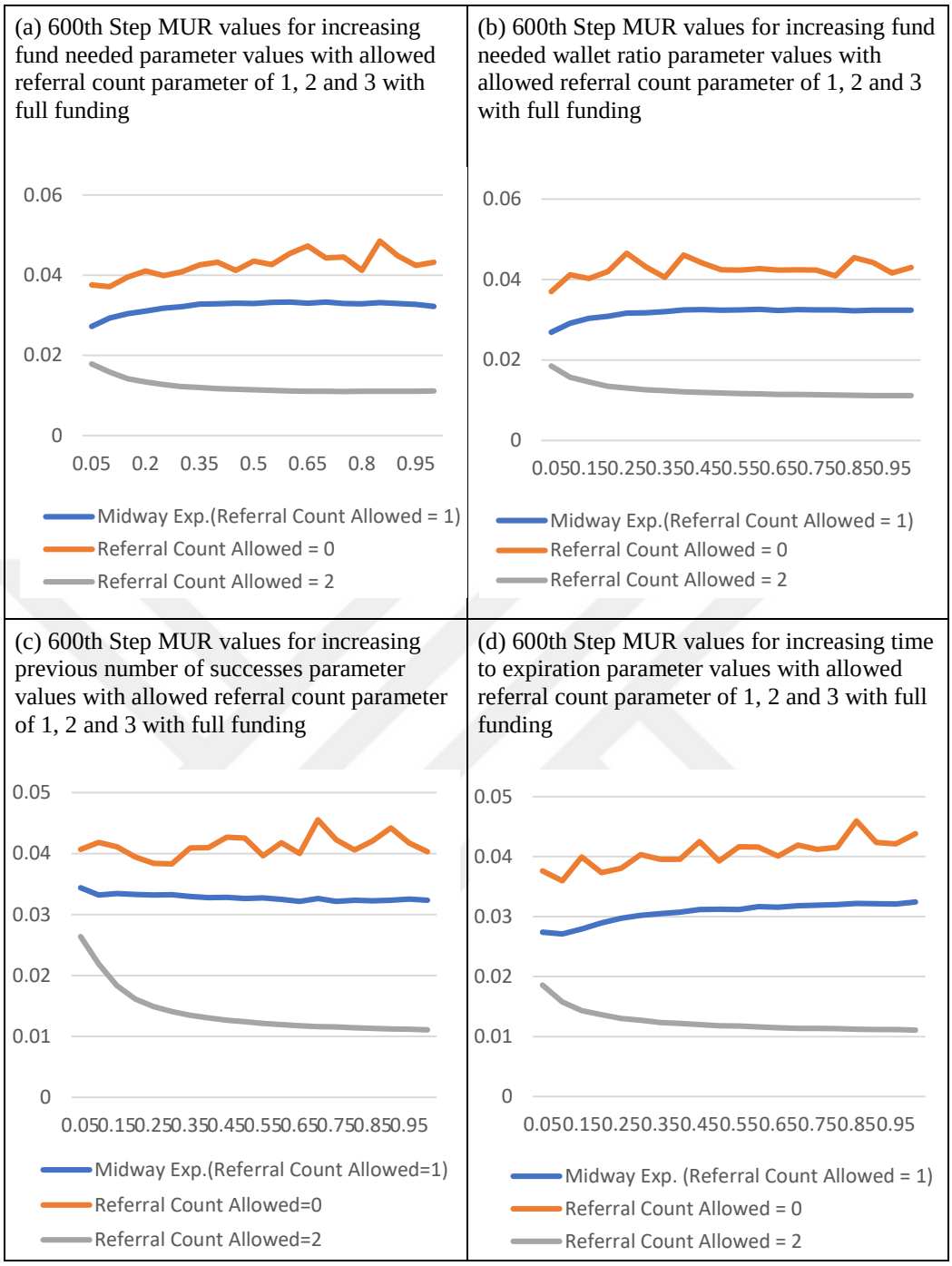


Figure 42. Experiment results for allowed referral count parameter with full funding

After describing and demonstrating the results of the two models about lending to examine how effective it could be made through algorithm-driven methods, next chapter will discuss these results, state the possible implications of them, and conclude the essay.

CHAPTER 13

DISCUSSION OF THE RESULTS OF THE SECOND ESSAY

In this second essay, our area of interest has been P2P microlending, and particularly we analysed, modelled and simulated automated relending systems of online non-profit microlending platforms. Our agent-based simulation basically attempted at answering, if possible, to the question of which projects should be funded for raising the effectiveness of monetary resources available. We examined the methods of selecting projects whose funding campaign are about expire, funding the entrepreneurs who have completed most number of successful projects before, and the projects that need the least amount of additional funds. We constructed two models for this purpose. Our Basic Model covers a simulated simple automated relending mechanism in which available funds are distributed to, gathered back from, and redistributed to selected entrepreneurs. We examined two main methods of funding the projects, equal but limited funding of selected projects and funding the selected projects fully. We assess the efficiency of this gathering-redistribution cycle with our specific metric, MUR value. Our second, Improved Model built on the Basic Model and introduced loan defaults, partial funding and referral system, as well as a novel criterion for selecting projects based on ratio of gathered funds and total needed funds. We present and discuss the results of using these two methods, Basic Model, Improved Model and their applicability to real-life situations, and results pertaining to new concepts added to Improved Model.

Our Basic Model examines and simulates the automated relending process with absence of loan defaults and in static conditions, i.e. entrepreneur and project count do not change throughout the simulation. In this respect, this Basic Model

might be considered as resembling the system of a mature, stable P2P microlending platform. That is, if a platform becomes established with little or no growth and if loan defaults become ineffective, the stability in gathering-redistribution cycle might, in our opinion, be represented by our Basic Model. Because there are two main methods of funding of loans in our Basic Model, its results might be presented and examined in findings of funding through the two methods.

Equal funding of selected projects includes distributing the same, small amount of funds to every entrepreneur selected according to specific criterion. When this method of funding was employed in the Basic Model, the effective method of selecting projects to allocate resources was according to the fund needed by them. That is, the projects whose campaigns require the least amount of extra resources may be selected as an effective way of utilising the available resources. If there is even more scarcity in resources available, compared to the amount needed to fund the selected funds, then selecting projects according to time to expiration appears reasonable. Funding the campaigns that are about to expire may help utilise scarce resources more effectively. When we turn our attention to real-life examples of relending mechanism, these results for equal funding could be applicable to Zidisha's Pay It Forward (Zidisha, n.d.-b) concept as they use repaid loans to distribute small amount of funds to many entrepreneurs with ongoing campaigns. There is an option to automate the lending and relending process of the contributions given monthly.

Funding the selected loans fully is our second method of resource allocation in our Basic Model. When this method is employed, our simulation results suggest that it may be more effective to select projects according to previous number of successes. Selecting entrepreneurs with proven previous success is arguably a safe way to utilise the resources, yet, possible side effects of internal inequality among

entrepreneurs and underfunding of needy entrepreneurs should properly be dealt with. This result for full funding might be useful for microloans given by field partners of Kiva, since they select an entrepreneur, fund their project fully and then present their story in their website for gathering small interest-free loans from philanthropists. Selecting experienced entrepreneurs with demonstrable previous successful projects might help to achieve better effectiveness in utilisation of resources.

Improved Model might be thought of as applicable to a new initiative for online P2P microlending since it has continued growth with referral system as well as a chance for loans to default. For new and developing online microcredit platforms, the results of Improved Model could be more useful, and the case of midway experiment might be taken as an example for selection of projects to fund. Because in the midway experiment of the Improved Model selecting projects according to any criteria lowers MUR values and only selecting according to previous number of successful projects is relatively harmless in this sense, entrepreneurs chosen to be lent might be determined randomly if there are adequate resources. If there is a lack of resources to fund all of the projects, selecting entrepreneurs according to previous success might be a relatively better decision. Of course, precautions should be taken such that funding experienced and successful entrepreneurs does not cause inequality or prevent resources from being distributed to where they are most needed. This result might hopefully help future philanthropic P2P microlending initiatives in allocating their resources throughout their growth stage.

Loan defaults, in our experimental settings, has been found to be detrimental for resource utilisation in terms of MUR metric. This detrimental effect increases

with increasing default rate as well. This holds true for both equal but limited funding and total funding of selected projects. This finding underlies seeking and finding ways to reduce and, if possible, prevent loan defaults in microlending platforms. We may add other risks that leads to nonperforming loans (theft, fraud etc.) to this problem. The method Zidisha found for increasing repayment rate is starting with small (or very small) loans and gradually increasing loan size for a specific entrepreneur. Because Zidisha works with no intermediaries, and because its default rate was 6.8% in 2015 (Feldman, 2016), this method appears to be a good solution for reaching higher repayment rate for direct loans. We humbly recommend this method to Kiva, which aside from its normal operation in most countries through working with field partners, distributes direct loans in the US. These direct loans' repayment rate (74%) is considerably lower than that of loans given through field partners (97.1%) (Kiva, n.d.-b). To the best of our knowledge, As of March 3, 2024, the smallest loan being gathered for Kiva US category is 6500 USD (Kiva, n.d.-c) in Kiva.org website. If, these direct loans by Kiva are distributed with the gradual growth approach Zidisha adopts, repayment rate might substantially increase, in our opinion.

Partial funding, which enables utilisation of funds gathered for a loan even if its total amount is not reached, benefitted equal but limited funding of funds function), while not affecting full funding of loans, in our simulation. If funds are sent to associated entrepreneur only when their project is fully funded, by definition, partial funding is not possible. However, in the case of equal funding of projects with small amount of loans, partial funding raises MUR values, which, if our assumptions are true, signifies an increase in effectiveness of utilisation of funds. Furthermore, in our simulation conditions, if a smaller portion of loan is required for partial funding,

the rise of MUR value is higher. This result may suggest that, however small, gathered funds might be of benefit to both entrepreneurs as well as the overall system. Kiva practises partial funding since 2019 (Fisher, 2019), yet, because most of their loans are pre-imbursed (Fisher, 2019) and fully funded before the associated campaign to gather funds begins, our study cannot clarify whether this practise is really helpful for better utilisation of funds or not. At the very least, we are probably able to assume that these extra funds, which seem to be for partial funding of particular loans but are actually novel funding for associated field partners, may help with the financial health of field partners, thus may benefit the overall system. Zidisha, as another functioning microlending platform, leaves the decision of partial funding to borrower (Zidisha, n.d.-a), and this method, in our opinion, can be thought of as a good compromise between growth of the system and usefulness of the fund to the borrower. Although, with our assumptions, our simulation suggests that however small, funds lent might help effectiveness of the overall system, small portions of a loan might not enable the associated entrepreneur to realise the project they plan. Even a worse result might be total waste of associated resources, not helping, or even harming the borrower. Therefore, Zidisha's method of borrower-decided partial funding is worthy of praise, in our humble opinion.

Referral system was another major addition to our Basic Model in order to construct the Improved Model. In our simulation conditions this addition resulted in rapid, perhaps even too rapid, growth. The very quick rise in count of entrepreneurs raised the cost of running the simulation as well as calculation of associated measurements. This even prompted us to shorten the cases of simulation for referral system examination. Addition of referral system did not bring about an increase in MUR value as well. On the contrary, it led to a drop in this metric, and enabling

invitation of two referrals caused even a greater drop in MUR value. In our simulation conditions, therefore, higher growth did not mean better effectiveness. If application of this result to real-life conditions is accepted as possible, then growth at all costs does not seem to be the best way for utilisation of resources. If P2P microlending platforms target growth of the borrower base, we may humbly suggest that they should ensure that this is not an uncontrolled growth. Growth may come with an added cost of less effectiveness, at least if our assumptions and way of assessment of these phenomena are correct.

All in all, in our simulation conditions, P2P microlending platform that is ideal in terms of effective utilisation of resources would minimise loan defaults, enable partial funding if selected loans are not fully funded, and grow in a controlled and planned fashion, if growth is targeted. In times of growth such as beginning stage of a microlending platform, like in our second Improved Model, and when there are abundant resources, selecting the entrepreneurs with more successful previous projects might be a better decision for effectiveness in resource utilisation. However, in times of maturity of a microlending platform, in the case of lack of resources, selecting campaigns about to expire or needs the least amount of extra resources might be a more reasonable choice.

Further work on simulation of automated relending and P2P microlending may analyse possible inequality effect by selecting successful, experienced entrepreneurs over newer ones, investigate possible loan default prevention strategies such as help by referrals or group lending, include sector-based and gender-based selection of entrepreneurs using their corresponding statistics about loan size, loan term and default rate.

Lending, if it is not made extra harmful via charging interest or encouraging lavish spending, may allow helping more than one person with same amount of money. It is hoped that our work contributes future endeavours for enhancing and stimulating this charity side of it.

CHAPTER 14

CONCLUSION

This dissertation tried to examine, model, simulate and understand specific forms and cases of giving and lending, in two separate essays. First essay is a macro level analysis of effect of giving behaviour on inequality reduction in its both compulsory (taxation) and voluntary (almsgiving) forms. First phase of this study examined their effectiveness in separately while second phase investigated their synergistic effect on alleviating inequality. Second essay, with a micro level approach, analysed automated relending mechanism in P2P microlending platforms and studied whether it is possible to find relatively more effective selection criteria for relending, for better utilisation of funds.

In first essay, we began with an agent-based simple abstract economy model in which only one type of transaction between agents - fixed-amount money transfer exists. In this model, which we named as Base Model, simulation reached exponential monetary distribution, as suggested by econophysics literature. We employed this model for purposes of comparison about inequality level with, as well as building block for, later models. For assessment of inequality level in each model, we defined a specific metric, P value, which equals the proportion of total wealth of top wealth decile to that of bottom half of population. Second model of the first essay, namely Taxation Model, introduced taxation of every member's transactions as a form of compulsory giving, that is used for social assistance to poorer members of the population. This model showed that taxation and social assistance through it are effective in inequality reduction. Third model, Almsgiving Model, investigated the effect of almsgiving as a portion wealth, particularly Islamic practise of zakat, on

inequality. This model, obtained findings that almsgiving as a portion of wealth (zakat), when practised by every individual, reduces inequality, and demonstrated that its effect holds true-- in random conditions as well, not necessitating to give alms to poorer groups to be effective. Additionally, we observed that there might be optimal conditions for inequality reduction through almsgiving as portion of wealth. For instance, if given after every transaction by every individual, approximately 7.5% - 10% of wealth given as charity is found to be an effective value for giving to random recipients from around bottom 75% of population, as it apparently leads to equality maximisation and in these conditions giving more than 10% of wealth appears to raise inequality again. Hence, just like compulsory giving (taxation), voluntary giving (almsgiving) is found to decrease nonuniformity in wealth distribution of a population in our simulation conditions, and we might recommend them both to be used for any future efforts to decrease inequality. Being effective in even random recipient conditions, and apparently being able to adjusted for minimum inequality, our findings on almsgiving as a portion of wealth are hoped to benefit charity organisations such as The Giving Pledge or Effective Altruism communities.

In the second phase of the first essay, we developed the Fusion Model, to investigate the combined effect of both compulsory giving (taxation) and voluntary giving (almsgiving as a portion of wealth - zakat) on inequality reduction. Fusion Model explored differing rates for compulsory and voluntary giving to analyse their substitutability on lowering wealth inequality. Furthermore, a linear regression analysis was conducted in order to obtain regression equations presenting substitutability relation between them. Associated findings support the argument that substitutability exists between compulsory and voluntary giving. This study may

contribute to future efforts to encourage almsgiving, especially almsgiving as a portion of wealth, since it, if practised by every individual, appears to be able to become a voluntary initiative that is as valuable as a mandatory policy instrument, taxation, for inequality reduction.

Second essay of the dissertation focused on a practical matter with a micro level approach, and examined automated relending mechanism of P2P microlending platforms. Its first model, Basic Model, involved distribution of loans to selected entrepreneurs' project campaigns of various sizes and terms by a central treasury, gathering them back, and relending them to others. This lending-gathering cycle occurs at every time step of simulation and the model attempts at finding the selection criterion that enables relatively better utilisation of funds. Basic Model included loaning methods of equal funding with small amounts and full funding for projects, which are selected according to criteria of previous experience of entrepreneurs, time left to expiration of project campaigns and amount of additional funds needed for projects, and measured these criteria's effectiveness in resource utilisation through a specific metric, MUR value. Next model of the second essay, Improved Model, extended Basic Model to introduce the concepts of loan default, partial funding, growth of borrower base through referral system, as well as an extra criterion for project selection, ratio of gathered funds to total needed funds for a project. Results of the second essay pointed out that, in our simulation settings, for a static borrower base, and for the condition of equal funding of loans with small amounts, selecting those projects which need less amount of extra funds or whose campaigns are about to expire appears to be a relatively better choice for resource utilisation. This finding might be of importance to aid lenders' decision making on which projects to fund via automated relending mechanism, in

the condition of scarce resources and absence/non-effectiveness of loan defaults. When full funding of selected projects is preferred or loan defaults are effective in the system, opting for selection of entrepreneurs according to their previous experience, (number of successful projects completed before), is apparently a more reasonable decision. Additionally, if our simulation conditions are applicable to P2P microlending ecosystem, an ideal P2P microlending platform should allow partial funding of loans, minimise the effect of loan defaults, and avoid uncontrolled growth, for a more effective utilisation of its resources.

The important findings of the two essays this dissertation includes are summarised in Table 21.

Table 21. Important Findings in the Essays of the Dissertation

First Essay	First phase	In our simulation conditions, both taxation and almsgiving (zakat) are effective at reducing inequality. Almsgiving as a portion of wealth reduces inequality when recipients selected randomly from all of the population and wealthy agents may obtain alms as well. For certain values of almsgiving out of wealth inequality apparently approaches its minimum level, after these values giving more raises inequality again.
	Second phase	In our simulation conditions, taxation and almsgiving are substitutable and they might be used to calculate and examine inequality level in a population.
Second Essay	First phase	In our simulation conditions, effectiveness in resource utilisation in microcredit distribution by automated relending mechanism can be increased If microcredit loans are distributed via equal but limited funds, for instance in the condition of scarcity of resources, time left to expiration of project campaigns or additional funds projects need may be used as selection criteria for microcredit distribution. If selected projects are funded fully, for instance when there are abundant resources, previous experience of associated entrepreneurs is a better selection criterion for resource utilisation.
	Second phase	In our simulation conditions, loan defaults adversely affect resource utilisation in microcredit distribution to a high extent. In the presence of loan defaults, selecting projects according to previous experience of entrepreneurs is a relatively better decision. For better resource utilisation, a P2P microlending organisation might enable partial funding, prevent loan defaults and control its growth, according to simulation results.

This dissertation is concluded with the hope that, one day, with the help of combination of good intentions, abundance provided by future appropriate technology, as well as fair distribution; hunger will be eradicated, poverty will be remedied, suffering caused by inequality will be alleviated and social justice will be maintained so that there will be no need to write any more dissertations like this. Or, even better, they will be written for humanity's social progress, inclusive social progress, or its pure joy.

APPENDIX A

PROGRAM CODE FOR THE FIRST ESSAY

```
::This program code shows Base Model, Taxation Model (Model 1) and Almsgiving
;;Model (Model 2) of first essay in the same code. Therefore, if it was run (after any
;;debugging operation if needed), it would behave like Fusion Model of the second
;;giving experiment. It should cover all simulation needs of first essay via parameter
;;changes and commenting unnecessary code. For demonstration purposes it shows
;;the case of ten per cent taxation on transactions given to poorer half of the
;;population as well as one fortieth of wealth of every individual to given to random
;;other individual from whole of population. Programming language is Netlogo, and
;;the code uses and extends simple economy model of Wilensky and Rand (2015).

globals [ alms taxation-ratio target-population-ratio-for-taxation-redistribution target-
                    population-ratio-for-almsgiving-redistribution almsgiving-
                    ratio ]
turtles-own [ wealth ]

to setup
   clear-all
   create-turtles 500 [
     set wealth random 200
     set shape "circle"
     set color green
     set size 2
```

```
    ;; visualize the turtles from left to right in ascending order of wealth
    setxy wealth random-ycor

    ;; Model 1 - Taxation
    set taxation-ratio 0.1
    set target-population-ratio-for-taxation-redistribution 0.50

    ;;Model 2 - Almsgiving (Zakat)
    set almsgiving-ratio 0.025 ;;(one-fortieth of wealth)
    set target-population-ratio-for-almsgiving-redistribution 1 ;;(random receiver
                                ;;from whole of population)
  ]
  reset-ticks
end

to go
  ask turtles with [ wealth > 10 ] [ transact ]   ;; transact and then update your
                                location
  ;; prevent wealthy turtles from moving too far to the right
  ask turtles [ if wealth <= max-pxcor [ set xcor wealth ] ]
  tick
end

to transact
```

```
  ;; give ten dollars to another individual for trade (Base Model) and this transaction
                        ;;is taxed (Model 1)
  set wealth wealth - 10

  ask one-of other turtles [ set wealth wealth + (10 * (1 - taxation-ratio)) ]

  ;;social assistance to the poor by taxation (Model 1)
  ask one-of other min-n-of (count turtles * target-population-ratio-for-taxation-
                        redistribution) turtles [ wealth ] [ set wealth wealth + (10 *
                        taxation-ratio) ]

  ;;give a share of your wealth to another individual for peace (Model 2)
  set alms wealth * almsgiving-ratio
  set wealth (wealth - alms)
  ask one-of other min-n-of (count turtles * target-population-ratio-for-almsgiving-
                        redistribution) turtles [wealth] [ set wealth (wealth + alms) ]
end
```

APPENDIX B

PROGRAM CODE FOR THE SECOND ESSAY

```
::This program code shows Basic Model and Improved Model of second essay in the
;;same code. If it was run without any code changes (after parameter initialisation
;;and any debugging operation if needed), it would behave either like Basic Model
;;(first block of code) or Improved Model (second block of code) of second essay.
;;Programming language is Netlogo, and the code uses and extends simple economy
;;model of Wilensky and Rand (2015).

;;1) Basic Model Code
turtles-own [
  wallet
  fund_needed
  time_to_expiration
  prev_numof_success
  fund_for_wallet
  time_after_borrowing
  time_for_repayment
  microcredits_paid_back
]

globals [
  treasure
  total_microcredits
  total_microcredits_returned
```

```
  total_lack_of_microcredits
  num_of_microcredits
  num_of_uncompleted_microcredits
]

to setup
  clear-all
  set treasure 5000
  create-turtles 500 [
    set wallet 0
    set fund_needed (random 20) + 1
    set time_to_expiration (random 20) + 1
    set time_for_repayment (random 20) + 1
    set prev_numof_success 0
    set time_after_borrowing 0
    set shape "circle"
    set color green
    ;; visualize the turtles from left to right in ascending order of fund_needed
    setxy fund_needed random-ycor
  ]
  reset-ticks
end

to go
```

```
;; select projects, fund, gather repaid/unfunded loans back and update related
                    location

ask min-n-of (count turtles with [ fund_needed > wallet ] *
                    fund_needed_GROUP_PERCENTAGE) turtles with [
                    fund_needed > wallet ] [ fund_needed - wallet ] [ loan ]
                    ;; or …[loanFull] instead of  …[ loan ]
ask max-n-of (count turtles with [ fund_needed > wallet ] *
                    prev_numof_success_GROUP_PERCENTAGE) turtles with
                    [ fund_needed > wallet ] [ prev_numof_success ] [ loan ]
                    ;; or …[loanFull] instead of  …[ loan ]
ask min-n-of (count turtles with [ fund_needed > wallet ] *
                    time_to_expiration_GROUP_PERCENTAGE) turtles with [
                    fund_needed > wallet ] [ time_to_expiration ] [ loan ]
                    ;; or …[loanFull] instead of  …[ loan ]

ask turtles with [ fund_needed <= wallet ] [
  ifelse time_after_borrowing < time_for_repayment
  [
    set time_after_borrowing time_after_borrowing + 1
  ]
  [
    set num_of_microcredits num_of_microcredits + 1
    startNewProjectAfterSuccess
  ]
```

```
  ]

  ;; prevent turtles from moving too far to the right
  ask turtles [ if fund_needed <= max-pxcor [ set xcor fund_needed ] ]
  ask turtles with [fund_needed > wallet ] [set time_to_expiration time_to_expiration
                                - 1]
  ask turtles with [time_to_expiration <= 0] [ startNewProjectAfterFailure ]
  tick
end

to loan
  ifelse  time_to_expiration > 0
  [
    set wallet wallet + 1
    set treasure treasure - 1
    set total_microcredits total_microcredits + 1
  ]
  [
    startNewProjectAfterFailure
  ]
end

to loanFull
  ifelse  time_to_expiration > 0
  [
```

```
    set fund_for_wallet (fund_needed - wallet)
    if fund_for_wallet > 0
    [
      set wallet wallet + fund_for_wallet
      set treasure treasure - fund_for_wallet
      set total_microcredits total_microcredits + fund_for_wallet
      set time_after_borrowing 0
    ]
  ]
  [
    startNewProjectAfterFailure
  ]
end

to startNewProjectAfterSuccess
  set treasure treasure + wallet
  set total_microcredits_returned total_microcredits_returned + wallet
  set microcredits_paid_back microcredits_paid_back + wallet
  set wallet 0
  set prev_numof_success prev_numof_success + 1
  set fund_needed fund_needed + (random 5) + 1
  set time_to_expiration (random 20) + 1
  set time_for_repayment (random 20) + 1
 end
```

```
to startNewProjectAfterFailure
    set treasure treasure + wallet
    set wallet 0
    set fund_needed (random 20) + 1
    set time_to_expiration (random 20) + 1
    set time_for_repayment (random 20) + 1
end

to-report top-10-pct-fund_needed
  report sum [ fund_needed ] of max-n-of (count turtles * 0.10) turtles [ fund_needed
                                ]
end

to-report bottom-50-pct-fund_needed
  report sum [ fund_needed ] of min-n-of (count turtles * 0.50) turtles [ fund_needed ]
end
;;;
```

```
  fund_for_wallet
  time_after_borrowing
  time_for_repayment
  microcredits_paid_back
  referral_count
  partial_funding_accepted
]

globals [
  treasure
  total_microcredits
  total_microcredits_returned
  total_lack_of_microcredits
  num_of_microcredits
  num_of_uncompleted_microcredits
  temp_var
]

to setup
  clear-all
  set treasure 5000
  create-turtles 500 [
    set wallet 0
    set fund_needed (random 20) + 1
    set time_to_expiration (random 20) + 1
```

```
    set time_for_repayment (random 20) + 1
    set default_probability (random-float default_rate_max)
    set prev_numof_success 0
    set time_after_borrowing 0
    set referral_count 0
    set partial_funding_accepted 1
    set shape "circle"
    set color green
    ;; visualize the turtles from left to right in ascending order of fund_needed
    setxy fund_needed random-ycor
  ]

  reset-ticks
end

to go
  ;; select projects, fund, gather repaid/unfunded loans back and update related
                              location

  ask min-n-of (count turtles with [ fund_needed > wallet ] *
                              fund_needed_GROUP_PERCENTAGE) turtles with [
                              fund_needed > wallet ] [ fund_needed - wallet ] [ loan ]
                              ;; or …[loanFull] instead of  …[ loan ]
```

```
ask max-n-of (count turtles with [ fund_needed > wallet ] *
                    prev_numof_success_GROUP_PERCENTAGE) turtles with
                    [ fund_needed > wallet ] [ prev_numof_success ] [ loan ]
                    ;; or …[loanFull] instead of  …[ loan ]
ask min-n-of (count turtles with [ fund_needed > wallet ] *
                    time_to_expiration_GROUP_PERCENTAGE) turtles with [
                    fund_needed > wallet ] [ time_to_expiration ] [ loan ]
                    ;; or …[loanFull] instead of  …[ loan ]
ask max-n-of (count turtles with [ fund_needed > wallet ] *
                    fund_needed_wallet_ratio_GROUP_PERCENTAGE) turtles
                    with [ fund_needed > wallet ] [ wallet / fund_needed ] [ loan
                    ]  ;or …[loanFull] instead of  …[ loan ]

ask turtles with [ fund_needed <= wallet ] [
  ifelse time_after_borrowing < time_for_repayment
  [
    set time_after_borrowing time_after_borrowing + 1
  ]
  [
    set num_of_microcredits num_of_microcredits + 1

    set temp_var (random-float 100)


    ifelse default_probability > temp_var
```

```
      [
        die
      ]
      [
        startNewProjectAfterSuccess
      ]
    ]
  ]

  ;; prevent turtles from moving too far to the right
  ask turtles [ if fund_needed <= max-pxcor [ set xcor fund_needed ] ]

  ask turtles with [ fund_needed > wallet ] [set time_to_expiration time_to_expiration
                                - 1]
  ask turtles with [time_to_expiration <= 0] [ startNewProjectAfterFailure ]
  tick
end

to loan
  ifelse  time_to_expiration > 0
  [
    set wallet wallet + 1
    set treasure treasure - 1
    set total_microcredits total_microcredits + 1
  ]
```

```
  [
    startNewProjectAfterFailure
  ]
end

to loanFull
  ifelse  time_to_expiration > 0
  [
    set fund_for_wallet (fund_needed - wallet)
    if fund_for_wallet > 0
    [
      set wallet wallet + fund_for_wallet
      set treasure treasure - fund_for_wallet
      set total_microcredits total_microcredits + fund_for_wallet
      set time_after_borrowing 0
    ]
  ]
  [
    startNewProjectAfterFailure
  ]
end

to startNewProjectAfterSuccess
  set treasure treasure + wallet
  set total_microcredits_returned total_microcredits_returned + wallet
```

```
set microcredits_paid_back microcredits_paid_back + wallet
set wallet 0
set prev_numof_success prev_numof_success + 1
set fund_needed fund_needed + (random 5) + 1
set time_to_expiration (random 20) + 1
set time_for_repayment (random 20) + 1

set default_probability default_probability / 1.01

if (prev_numof_success > prev_numof_success_for_ref) and (referral_count <
                                referral_count_allowed)
[
  hatch 1 [
    set wallet 0
    set prev_numof_success 0
    set time_after_borrowing 0
    set referral_count 0
    set fund_needed (random 20) + 1
    set time_to_expiration (random 20) + 1
    set time_for_repayment (random 20) + 1
    set default_probability (random-float default_rate_max)
    ;; visualize the turtles from left to right in ascending order of fund_needed
    setxy fund_needed random-ycor
  ]
  set referral_count referral_count + 1
```

```
  ]

end

to startNewProjectAfterFailure
  ifelse (partial_funding_accepted = 1 ) and (wallet >= (partial_funding_ratio *
                                fund_needed))
  [
    set total_lack_of_microcredits total_lack_of_microcredits + (fund_needed -
                                wallet)
    set num_of_uncompleted_microcredits num_of_uncompleted_microcredits + 1
    set fund_needed wallet
  ]
  [
    set treasure treasure + wallet
    set wallet 0
    set fund_needed (random 20) + 1
    set time_to_expiration (random 20) + 1
    set time_for_repayment (random 20) + 1
  ]
end

to-report top-10-pct-fund_needed
  report sum [ fund_needed ] of max-n-of (count turtles * 0.10) turtles [ fund_needed
                                ]
```

```
end

to-report bottom-50-pct-fund_needed
  report sum [ fund_needed ] of min-n-of (count turtles * 0.50) turtles [ fund_needed ]
end
```

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