An Essay on Micro Heterogeneity and the Evolution of Inequality

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Dedication

This dissertation is dedicated to my beloved wife for her spiritual guidance.

Acknowledgments

I wish to acknowledge those who have walked alongside and supported me over the course of my four-year long Ph.D. They have guided me to discern what is unseen and comprehend underlying truth. I would love to thank each and every one of them. I especially would like to thank Dr. Axtell and Dr. Olds who have always inspired and enlightened me for greater things yet to come. I also would like to thank Dr. Tian and Dr. Luna; by the delight of whose wisdom I was able to initiate my research. Finally and without hesitation, I would like to thank Karen who has helped and advised me to complete my Ph.D in time.

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Abstract

AN ESSAY ON MICRO HETEROGENEITY AND THE EVOLUTION OF INEQUALITY

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The level of inequality has increased over the past several decades and reached at the historically high level in many developed countries. Yet, the traditional theory of supply and demand in labor has failed to elucidate the emergence of prevailing inequality from bottom up. In fact, its scope on inequality has been limited and overlooked the emergence of inequality through interactions of heterogeneous sub-systems in micro level. In this dissertation, therefore, I have used Agent-based Models as an alternative to traditional methods to understand the evolution of inequality given micro heterogeneity and bridge the gap between the theory and real world.

In the first two chapters, I have studied how behaviors of ill-motivated heterogeneous individuals cause inequality to rise and severe crises. In the first chapter, it has focused to compare and contrast macro behaviors such as inequality and growth when the compensation system is vulnerable to free riding or not in an otherwise identical economy. The model results have demonstrated that if the compensation is ill-defined, individuals became selfish – free riders – and the economy became volatile hence experienced constantly rising inequality followed by crises.

In the second chapter, it has examined the effect of such ill-defined compensation system on inequality and growth via consumption channels – demand-driven recession. The simulation outcomes have revealed that even a mild income concentration in the hands of a few in the beginning could cause a terrible economic recession eventually because such an income squeeze led a decrease in consumption of the poor and middle class which in turns, drags down a whole economy. It has confirmed the wide-spreading belief that if the poor and middle class cannot afford to buy goods and services, it causes a collapse of an economy eventually.

In the last chapter, I have explored that when information – characteristics – about goods is the object of preference rather than goods per se, contrast to the traditional theory of supply and demand, how such a change in the preference object affects market equilibrium and inequality in a barter-based economy. The simulation results have demonstrated that, depending on the ratio of characteristics of goods, even after finitely many numbers of trades, MRSs of goods do not necessarily converge to the optimal level. In other words, many agents are not content with their after-trade endowments but can't be helped because existing goods do not suit them to be Pareto optimal. When it comes to inequality, GINI coefficient, an index for measuring the level of inequality is limited to capture dynamics of the change in wealth over trades within a period. Thus, it is not clear that the change in the object of preference affects the evolution of inequality over trades as well as over time.

Chapter 1: Rent-seeking behavior, Inequality and Long-run Economic Growth

1.1 Introduction

Humans are designed to pursue the greatest happiness – or maximize their utilities – by doing whatever yields such happiness to themselves. Furthermore, it is often believed, especially in a study of economics, that individuals are willing to make an endeavor only when they can pursue their own-interest, which may or may not benefit others. Hence, an individual's effort to chase one's own dream may produce a negative externality on others and hurt a whole society. However, traditional economic theories have argued that it is unlikely the case if individuals are compensated for the work they have done – those who are more productive earn more as a result.

In such a competitive thus fair society, economic theories have believed that two distinctive phenomena occur. First, those who are paid less than their colleagues are willing to work more or acquire additional skills in order to receive equivalent or higher earnings than their peers. Consequentially, everyone does one's best. Second, Smith (1776) claimed that the collective behavior of individuals' self-driven actions produces an unintended yet positive externality – *the invisible hand*[1] – which benefits a whole society.

In other words, the unintended benefit is emerged, e.g., the benefit of team work through individuals' interactions and it is distributed to the members of the society fairly. Further, as people are compensated more that they suppose, they desire to be more productive or simply work more. Through this mutual feedback, the trickle down effect, the economy continues to grow and converges to its steady state level, if there is.

[1] He introduced the term, *the invisible hand*, to describe such unexpected social returns coming out from individuals' actions and interactions.

Hence, the conventional wisdom posits that (income) inequality, produced by different compensations for different productivities, is a necessary and useful condition that may prevail along with economic growth. Moreover, many economists including Arthur M. Okun (1975) insisted that we cannot achieve perfect equality and perfect efficiency simultaneously, hence need to sacrifice one for another – equality for economic growth. This type of inequality, therefore, is nothing but a matter of course and something that individuals, as the member of a society, ought to admit and perceive.

Despite the necessity of this type of inequality, Kuznets (1955) had a quite positive future that inequality, once high, would gradually diminish. During the course of development explained above, especially in the early stage, there may be an inefficient allocation of the surprise bonus – a few would receive more than the fair amount and the rest less due to several physical limitations. This kind of inefficiency has been observed in many cases including the two Industrial Revolutions in human history. Those who lived in or near a big city benefited from economic growth first and then others in the remote area.

However, he argued that the larger social returns become, the more number of people will enjoy the benefit. As more people enjoy the benefit of the "invisible hand," the income gap among people is reduced and an economy becomes fairer. From his perspective, a few would benefit from economic growth in the early phases of industrialization, yet eventually, everyone becomes better off due to spill-over effect. As a consequence, inequality rises and falls in the course of economic development; it follows an inverted "U" shape curve – Kuznets' hypothesis.

In principle, such a hypothesis built upon the profound economic foundation should explain the evolution of inequality in a single country, as its economic status moves from poor to developing and eventually to advanced. However, on the empirical ground, Kuznets' hypothesis is not strong enough to stand. Experimental studies show little support for it. Further empirical evidence for his hypothesis is even more disappointing across nation boundaries Banerjee and Duflo (2003); Barro (2000); Perotti (1996). In this regard, Piketty has reasoned that Kuznets' hypothesis was formulated in large part for the wrong reasons, and its empirical evidence is very weak. "The sharp reduction in income inequality... between 1914 and 1945 was due above all to the world wars and the violent economic and political shocks... It had little to do with the tranquil process of intersectoral mobility described by Kuznets" Piketty and Goldhammer (2014).

The view of Piketty has recently garnered increased support because of wide spread data showing that, in reality, society is actually closer to "winner takes all." Although, the "average" wellbeing has been increasing over thirty years, the share of national income of the richest 1 percent has doubled – 10 percent to 20 percent – since 1980s in the United States. More surprisingly, that of the top 0.01 percent has quadrupled, from just over 1 percent to almost 5 percent Economist (2012a). When it comes to the speed of real income growth in the US, the difference in numbers is more dramatic. From 1993 to 2012, the top 1 percent's real income has grown 86.1 percent while the bottom 99 percent's 6.6 percent Saez (2013). This state of affairs is not limited to solely the US. Inequality in western countries has increased monotonically in the past quarter of a century; it has reached the point where it was on the eve of the Great Depression Perotti (1996).

Given the dissatisfaction with the poor performance of Kuznets' hypothesis, economists have added more new elements such as the financial depth of an economy, extent of government spending or state-sector employment, openness of the economy and so on in expectation of improving our understanding of the behavior of inequality – known as augmented Kuznets' hypothesis Milanovic (2011). Speaking concisely, it had a better fit to the empirical data yet, hardly significant.

Having the considerable incompatibility between the hypothesis and empirical studies and limitations that previous studies have came up against, I pursued three following questions in this chapter. First one is closely connected with the theoretical assumptions that dwells behind the Kuznets' hypothesis. His hypothesis was built upon marginal productivity theory – competitive hence fair compensation for all. Such an assumption becomes the fundamental force that motivates individuals work hard and together in micro level hence aggregately, guided by *the invisible hand*, an economy thrives while inequality rises and falls.

Nonetheless, the hypothesis has not been proved even at the theoretical level. Thus, I conducted a thorough examination on his hypothesis in silico in order to justify its theoretical legitimacy. If Kuznets' hypothesis does not have any theoretical flaw, the result may lay out that the lack of empirical justifications is the consequence of applying an irreverent hypothesis, not applying an imperfect hypothesis like many economists have argued; Kuznets' hypothesis is right but it may not be the right one that economists have been looking for.

Had it been so, what would be the true drivers behind human behaviors that lead what we have observed for the past 30 years or so? Stiglitz (2013) offered an alternative hypothesis that may perform better in the real economy; the society may be rather governed by rent-seeking behavior, not marginal productivity theory. He claimed that excessive inequality has been the result of market distortions, the invention of seizing asymmetric information and socio-economic power, with incentives directed not at creating new wealth but at taking it from others, from the poor to the rich.

In fact, throughout history, rent collecting has been a prominent business, which has led the eventual concentration of wealth in the hands of a few. Although the appearance has changed over time, the deep structure of capital has stayed in a status quo; capital has never been dynamic but rent-seeking Piketty and Goldhammer (2014). Piketty introduced a capital/income ratio β, the ratio of the total stock of capital to the annual flow of income $\frac{r}{g}$, and presented that its historic value has been very closed to 5 and 6 in many advanced countries. According to traditional supply-and-demand theory, β should converge to 1. The contradiction may demonstrate that the empirical r, is greater than the true r, which is r*; r = r* + rent.

Moreover, many devastating crises, from South Sea bubble in 1720 toward the Great Recession in 2008, highlighted two big stylized facts: there were booms and extremely greedy speculators Economist (2014). A few tried to corner the market in a boom and the aggregate of such a behavior inflated a bubble, distorted market, and eventually, doomed a whole economy. If history is any guide, rent-seeking behavior may have a lot to do with what we have seen.

Last but not least, I noticed that while many policy makers were convinced that the progressive tax scheme discourages the rich and dulls growth with lower inequality – trade-off, academic studies were rather inconclusive. Therefore, I implemented hypothetic scenarios in the model to explore the potential effects of redistribution policies on efficiency and equality – whether social benefits of wealth transfer through taxation surpass its costs or not.

This chapter is organized as follows. In the following section, I described the specification and design of the model employed in this research. I presented the simulation outcome of the two different economies in Section 1.3, and analyzed the underlying mechanism of the dynamics I observed and discussed it as I compared the output to empirical evidence together with policy suggestions in Section 1.4 and 1.5. Finally, I drew a conclusion in Section 3.5.

1.2 Methodology

1.2.1 General features

Although previous studies have provided valuable insights, it also revealed that statistical analysis used in those studies has encountered several limitations for identifying the relationship between inequality and economic growth. First, the quality of data often is not sufficiently satisfactory to perform the in-depth analysis. Even worse, it is not available in some countries. Second, it failed to verify whether the real world actually works as traditional theories assumed. Instead, previous analyses take the underlying assumption for granted and conducted researches.

Third, existing researches have only tried to measure the direct relationship between inequality and growth. However, since inequality and growth are nothing but macro phenomena generated by individuals' actions, it is crucial to appreciate micro dynamics – how individuals act and interact – in order to understand how macro phenomena emerge. "What is seen is not made out of what was visible (Hebrews 11:3) In this sense, existing analyses are limited to deduce and interpret micro dynamics because it employed the macro-level data which is produced by merging and averaging out micro-level data – "a whole is greater than the sum of its parts" (Simon, 1996). It lost its explanatory power on micro dynamics that give rise to the relationship between inequality and growth.

Therefore, I implemented the Agent-Based model (ABM, hereafter) framework constructed by Axtell (1999) and added a few features on top of it accordingly. It is noteworthy that this approach is not something completely different from traditional ones. ABMs still share several critical features of principal economic models such as utility maximizing individuals, profit maximizing firms, and the concept of Nash equilibrium.

Beyond the features that the conventional methodology has, ABMs also capture what have been overlooked in conventional theories: individuals' heterogeneities, bounded rationalities, the interactions among agents in a decentralized markets and change of behaviors based on the interchange of information in the market and so on. In addition, it allows the interactions among agents from which the macro phenomena endogenously emerged instead of being assumed from the outset and simply summed up to the aggregate level and the mutual feedback between macro behaviors and micro motives. Since ABMs are able to incorporate those underlying features and show how a system evolves from bottom-up in silico, they often generate new and surprising insights about the dynamics of a system that cannot be captured by conventional methods.

1.2.2 Firms

Each firm produces output, Y_t, as a function of H_t, $H_t = \sum_{i=1}^{n} h_{i,t}$[2], is the aggregate level of labor that a firm hires for every time, t. The firm v produces output as follows:

$$Y_{v,t} = Y(H_v) = a_v H_{v,t} + b_v H_{v,t}^{\beta_v},\ a_v > 0,\ b_v > 0,\ \beta_v > 1 \tag{1.1}$$

[2] n is a number of employees in the firm and $h_{i,t}$ is individual i's labor supply.

It is newsworthy that it is assumed that the production function has increasing returns to scale ($b_v > 0$[3]) in contrast to the traditional assumption, decreasing returns to scale. Increasing returns in production means that the output increases by more than proportional change in inputs, thus, when agents work together they produce more than they do separately.

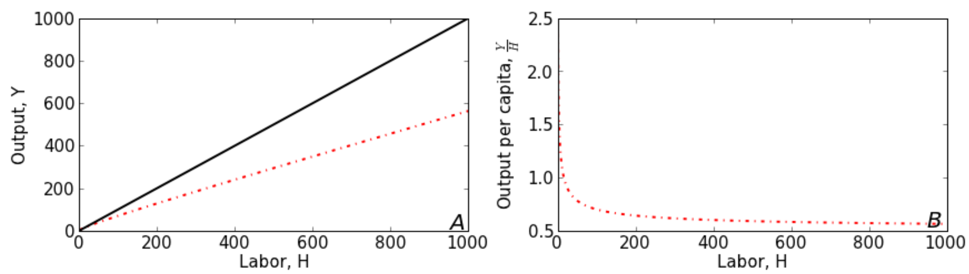

Figure 1.1: Decreasing returns to scale in production
Graphical representation of the level of output in panel **A** and average output in panel **B** in a firm given given parameters (a=0.5, b=1.0, β=1.5, h_i=1.0, $\forall$ i=1,...,1000). The solid black line represents the 45° line. The total output increases at a decreasing rate while the average output monotonically decreases over the size of a firm.

This is a very critical assumption in this analysis. Suppose there is decreasing returns to scale in production (Figure 1.1). The more number of employees a firm has, the less the average output will be. Given price, whether the profit is distributed fairly or unfairly, per person wage is decreasing over the size of a firm. Then, there is no incentive for individuals to work together since they can produce more by working alone unless they are forced to work together. This society would never grow from the beginning but remain still as if a hunter and gatherer society.

On the other hand, with an assumption of increasing returns to scale, workers can produce more than what they do separately, they are willing to work together as long as employees are compensated more than they can make on their own in Figure 1.2. First, this can explain the emergence of a complex economy from the scratch. Not only that, this assumption could also endogenize and visualize at least a part of *the invisible hand*, if not all. Since the individual hand refers to the unintended returns generated by individuals'

[3]Constant returns to scale if $b_v = 0$.

interactions, the difference between the total production of a firm and the sum of output that each worker can produces alone can be interpreted as an unintended benefits that emerged from group work.

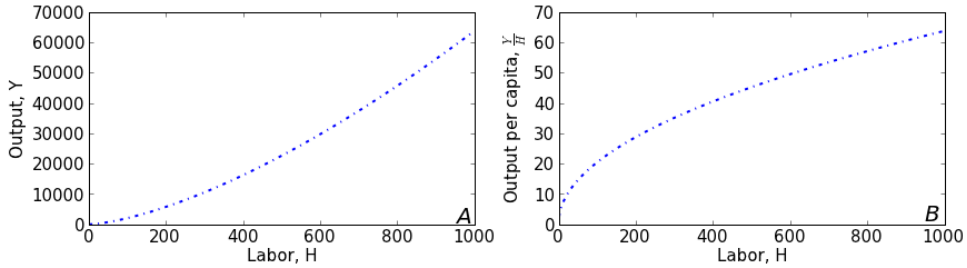

Figure 1.2: Increasing returns to scale in production
Graphical representation of the level of output in panel **A** and average output in panel **B** in a firm given given parameters (a=0.5, b=1.0, β=1.5, h_i=1.0, $\forall$ i=1,...,1000). The total output increases exponentially over the size of a firm and the average output increases at a increasing rate first and decreasing rate later.

One criticism that this assumption may face is whether the aggregate production function is governed by the law of increasing returns to scale as well. Many economists concern that if there is increasing returns in the aggregate production, the economy continues to grow without converging to its equilibrium up to the point where it cannot due to physical restrictions, which is against empirical evidences. However, it does not only depend on the production function itself, but also the compensation protocol in a society and the demand a firm expects. For example, Axtell (1999) shows that the aggregate production function would be governed by the law of constant returns to scale which corresponds with empirical stylized fact as well.

Alongside increasing returns to scale in production, there are two compensation rules implemented in this experiment: the competitive – fair – and non-competitive – unfair – distribution system. In the former case, individuals get paid for the work they have done. In the latter, on the contrary, agents share the total output equally in a firm, $\frac{Y_t}{n_t}$ regardless of their labor supplies.[4] I will discuss two different mechanisms and how agents' labor

[4] Y_t is an output that a firm produces, and n_t is a number of employees working at the firm at time t.

decisions are altered over time in a respective system more in detail in following sections.

1.2.3 Agents

Each individual is designed to maximize her utility, represented in a Cobb-Douglas function, with respect to consumption and leisure. Since each agent spends all her time on consuming and enjoying leisure[5], individual i's utility function can be written as a function of her labor supply, $h_{i,t}$, given labor supplies of the rest, $H_{-i,t} = \sum_{j=1}^{n} h_{i,t},\ j \neq i$ as following.[6]

$$U(c_{i,t}, l_{i,t}) = U(wh_{i,t} + G_t, l_{i,t}) = (wh_{i,t} + G)^{\theta_{i,t}} (l_{i,t})^{(1-\theta_{i,t})} \tag{1.2}$$

$$st.\ \ h_{i,t} + l_{i,t} = \omega_{i,t},\ \omega_{i,t} = 1\ \forall\ i, t,\ 0 < \theta_{i,t} < 1$$

$$wh_{i,t} = f(Y(h_{i,t}, H_{-i,t}))$$

$$\text{G is subsidy if G} \geq 0, \text{tax otherwise}$$

Since it is assumed agent's rationality is bounded, regardless whichever way a firm's output is distributed, an individual i only knows other employees' most recent labor supplies, $h_j,\ \forall\ j,\ j \neq i$, in the firm where she is working and thereby reckons what the possible outcome will be, $Y_t = Y(h_{i,t}, H_{-i,t-1})$. She is not able to access others' labor decisions who are activated after her and vice versa. Then individual i's optimal level of labor supply is determined in a following way.

$$h^*_{i,t}(\theta_i, H_{-i,t}, n_t) = \arg\max_{h_i} U_{i,t}(h_{i,t}; H_{-i,t}, n_t))$$

[5]Consumption is the function of individual's labor supply $c_{i,t} = wh_{i,t} + G_t, h_{i,t} \in [0, \omega_{i,t}]$ and her leisure is $(\omega_{i,t} - h_{i,t})$

[6]For simplicity, $\omega_{i,t} = 1$ and $\theta_i \in (0, 1)\ \forall\ i, t.$ G is subsidy if G ≥ 0, tax, otherwise.

Precisely, under the competitive compensation rule,

$$h^*_{i,t} = \arg\max_{h_{i,t}} U(h_{i,t}, l_{i,t}) = \arg\max_{h_{i,t}} U(\frac{h_{i,t}}{H_t} Y(h_{i,t}, H_{-i,t}) + G, 1 - h_{i,t}) \tag{1.3}$$

and in the case of the non-competitive distribution system,

$$h^*_{i,t} = \arg\max_{h_{i,t}} U(h_{i,t}, l_{i,t}) = \arg\max_{h_{i,t}} U(\frac{1}{n_t} Y(h_{i,t}, H_{-i,t}) + G, 1 - h_{i,t}) \tag{1.4}$$

Moreover, the equilibrium in a firm corresponds to each of its employees' optimal labor supplies h^*_i, using H^*_{-i} in place of $H_{-i,t}$ such that $H^*_{-i,t} = \sum_{j=1}^{n} h^*_{j,t},\ j \neq i$. This leads to that Nash equilibria exist in any firm and there exists a set of agent labor supply levels that Pareto dominates the Nash equilibrium, as well as a subset that is Pareto optimal Axtell (1999).[7]

1.2.4 Existence of rent

I operationally defined rent as the traditional economics has done: an additional payment to a factor of production, in this case labor, in excess of its opportunity cost. As it is described previously, agents do not seek rent always but only when the environment is favorable. Simon (1996) argued that human beings are quite simple although it is recognized as complex behaving systems. He continued that, "The apparent complexity of our behavior over time is largely a reflection of the complexity of the environment in which we find ourselves..."

I believed that the non-competitive compensation system, implemented in this chapter, would provide such an environment where individuals are well motivated to seek rent at the cost of others. On the contrary, the rent-seeking behavior could not be found in the

[7]These were not pursued in this chapter; those interested in could refer to Axtell (1999)'s paper. He analytically scrutinized and proved such propositions in a very elegant way.

world where the compensation distribution is perfectly competitive – each individual gets paid proportion to her relative labor supply. Thus, it is convinced that agent's true wage – or opportunity cost, per se – is revealed and so is the corresponding utility level in this framework. By comparing given individual's wage and utility under two different payment system while holding other things equal, I found rent analytically in Figure 1.3.

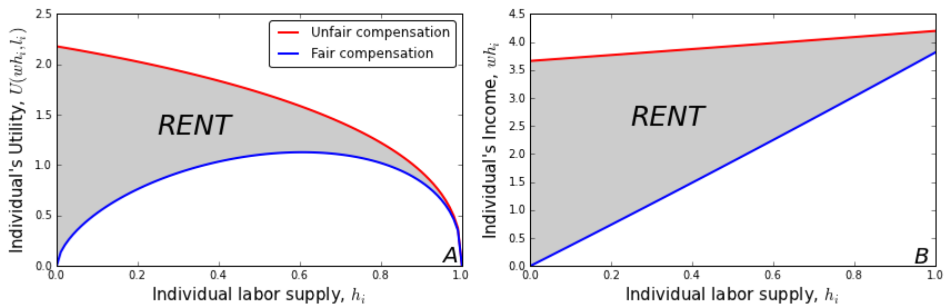

Figure 1.3: Graphical representation of rent under two different compensation schemes
Graphical representation of rent as operationally defined in this chapter under two different compensation schemes. **A** is a graph of individual utility vs. individual labor supply. **B** is a graph of individual income vs. individual labor supply. The shadowed area represents the amount of rent that individual could receive under the egalitarian share scheme. The data is generated in a typical run given parameters (a=0.5, b=1.0, β=1.5, $H_{-}i$=10.0, G=0.0, θ=0.6, and ω=1.0) in each respective model. It is found that the level of rent is increasing as an individual diminishes her labor supply under the unfair wage system.

In Figure 1.3, each solid line, however colored, represents individual i's corresponding utility (Figure 1.3 panel A) and income (Figure 1.3 panel B) over her labor supply level, 0 to 1, in respective distribution structures. In Panel B, the blue line (the competitive system) symbolizes the true benefit – or the true opportunity cost – and anything surpasses it should be considered as rent. Clearly, under the unfair distribution system, individual i earns more since she collects rent on top of her true wage, and the amount of rent increases as she reduces her labor supply, in this case, very close to 0.

1.2.5 Dynamics

It is noteworthy that this model is not numerical. There are no explicit equations that govern a whole system. Instead, I built a micro system where individuals' decision-makings are regulated by the equations described above. This bottom-up approach allows us to observe the micro interactions as well as the emergence of macro phenomena. For the robustness of results, 1000 simulations were conducted for each compensation scenario.

In the closed economy I established, there are N number of agents, indexed by i, $i \in [1,N]$, $N \in \Re$. There is only one factor of production, labor, which is used to produce a perishable good X. Each Individual gets paid for her labor in the unit of the good in the manner described in the previous section. In addition, each agent has a social network that consists of k, $k \in \Re$, number of other individuals and interact only with those in her network.

Table 1.1: Model attributes

Parameters	**Values**
constant returns coefficient, a	uniform$(0, \frac{1}{2})$
increasing returns coefficient, b	uniform $(\frac{3}{4}, \frac{5}{4})$
increasing returns coefficient, β	uniform $(\frac{3}{2}, 2)$
endowments, ω	1
willingness to work, θ	uniform(0.01,0.99)
number of neighbors	3 if poor, 10 otherwise
agent activation order	random
time calibration, t	one month
number of agents, N	1,000
number of simulations	1000
run time, T	500

In the original model, k is randomly – Erdös-Renyi graph – distributed between 4 and 6, but I assumed in this model that an individual who earns higher income has a larger network. Various empirical studies supported such an assumption: each individual's network size is positively correlated with her productivity and income (Goldberg et al., 2013; Lipina et al., 2013; Noble et al., 2007). For simplicity, an agent who belongs to the bottom 40 percent has a network size of 3 and 10 otherwise.[8]

[8] I also tested the model with the random network assumption and found that it does not affect the outcome both qualitatively and quantitatively.

The sequence of events is as follows. Initially, each agent starts up a new firm, and at every time t where $0 \leq t \leq T$, 4% of the total population is activated. Once activated, each agent can search jobs through her network , starts up a new one, or remains in the current firm. An individual chooses whichever alternative that yields her the greatest utility and updates her labor strategy accordingly. Once all activated individuals complete their tasks, each firm begins to produce given the level of labor and distributes the outcome to its employees according to an assigned rule. Model attributes are given in Table 3.1.

1.3 Results – typical run

1.3.1 Competitive compensation system

When the output of a firm is distributed to its employees competitively, in Figure 1.4 panel A, it is found that real GDP per capita – real gross domestic product of a society divided by its population size – grows at an increasing rate in the beginning and decreasing rate later thus asymptotically converges to the equilibrium, natural level of GDP per capita.

Inequality measured by GINI coefficient – 0 if everyone shares the same income and 1 if a single individual has all while the rest has nothing – soars in the early course of economic development but decreased monotonically afterward and asymptotically converged to its respective equilibrium, which is slightly higher than the initial level in Figure 1.4 panel C). Figure 1.4E depicts one of the most important discoveries in this research. It is observed that inequality rises and falls alongside the level of per capita income; inequality clearly and nicely follows an inverted ”U” shape in GDP and GINI phase space diagram.

1.3.2 Unfair compensation system

Under the unfair compensation rule, it is observed that GDP per capita rises and falls repetitively over the simulation period in Figure 1.4 panel B. Its time-series behavior is quite different from what is found in the former type of distribution system. There is no unique equilibrium toward which it converges. Instead, its movement is quite chaotic and repeats itself in a range between 0.6 and 0.8.[9] The level of inequality also fluctuates over the time period, similar to that of per capita income in Figure 1.4 panel D. There is no typical pattern can be found in the inequality trend as well.

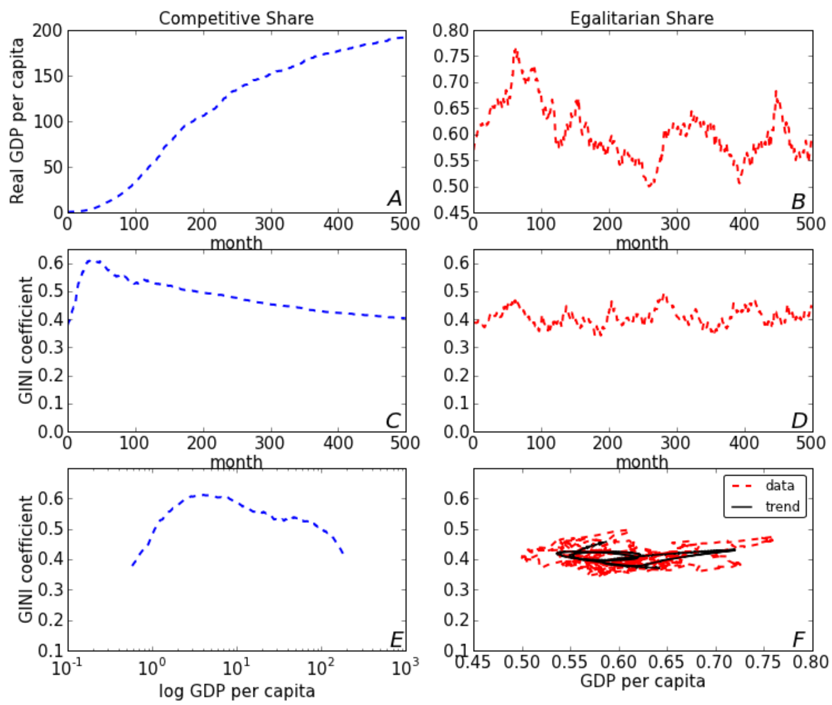

Figure 1.4: Simulation results of fair and unfair share models

A and **B** demonstrate the Real GDP per capita over the simulation period under the fair and unfair share, respectively (1000 runs in each scenario). **C** and **D** illustrate the level of GINI coefficient over the same period in the respective scenario. **E** and **F** draw the trajectory of GINI coefficient over the income level. It is noteworthy that panel E and F are not time-series graphs but GDP-GINI phase space diagrams. GDP per capita continues to rise while inequality rises and falls under the competitive wage system while both of them repeatedly rise and fall under the egalitarian wage system.

This finding articulates that the dynamics of the identical economy with different compensation mechanisms are different from one another. There is neither nice and monotonic behavior nor equilibrium in the latter scenario. In addition, unlike to the previous scenario, per capita income and inequality rise and fall almost randomly – no observable systematic

[9] It is important to note that the y-axis scale is different in Figure 1.4 panel A and 1.4 panel B.

behaviors between two of them. Nonetheless, when projected in the GDP-GINI phase space diagram in Figure 1.4 panel F, the trend of inequality over the level of income per capita is quite fascinating, which is discussed in detail in the following sections.

1.4 Discussion

1.4.1 Kuznets' hypothesis

Under the competitive compensation scheme, agents always offer an amount of labor that is not only optimal personally but also locally[10]. In fact, that is the only way of maximizing their utilities given circumstances. Since workers do provide their optimal level of labor at every time, it is always better to work together given increasing returns to labor in production – existence of *the invisible hand*. Therefore, whoever activated in each period is willing to join the largest firm in her network if it is not hers.

However, not all agents is able to derive benefits, but only a few – 4 percent of population. Thus, in the beginning, only a few can form groups to work together and create more wealth than they can separately. The rest is still working alone and makes a little compared to those in larger firms – there are many single firms and a few small or mid-size firms. This is why real GDP per capita rises little by little in Figure 1.4 panel A. Meanwhile, since almost everyone receives pretty much the same amount of income and a few makes more, inequality soars up substantially in Figure 1.4 panel C. An increase in a few's incomes makes little change in average income in the economy but enlarges the income disparity sharply.

Nevertheless, as a number of individuals, who are activated at least once, increases, the size of firms rises – more people are working together, so are the output of firms and their wages – the rate of change may vary though. For example, if an individual who works alone join a big firm, her wage rises up dramatically and more then someone who transferred from a mid-size to big one. Due to this catching-up process, not only the aggregate output increases but also per capita output rises significantly. Moreover, this positive externality

[10]An individual's labor supply may not be globally optimal since they are bounded rational. Rewards for those who make the same effort may be different from firm to firm.

continue to gain momentum, which in turn, a number of individuals who are benefited from growth – transferred from a small to large firm – jumps. As the share of growth per person increases at a faster rate, around the fiftieth month in the simulation, the difference in income begins to diminish over time. Eventually, when resources – human labor – are allocated very efficiently – near perfectly, the economy experiences steady and sound growth with a reasonable level of inequality.

This is precisely what Kuznets has claimed a half century ago, and the model outcome evidently legitimizes his hypothesis. Given such consistency, I can conclude that in a world, where individuals' behaviors are institutionalized by marginal productivity theory – fair compensation, inequality rises and falls alongside the economic development. Furthermore, based on the contradiction between the model result and empirical data, I can fairly claim that marginal productivity theory is not the pertinent driving force beyond human behaviors that leads to a high inequality in reality.

1.4.2 Rent-seeking behavior

When the distribution system poorly reflects individuals' relative efforts, for example, everyone in a firm shares the output equally in this study, individuals are motivated and willing to take advantage of others by reducing their labor supplies. Agents, whether they are activated or not, continuously exploit other workers until either the majority of other workers in a firm adjust their labor supplies accordingly or leave the firm hence there are a few employees from whom they collect rents. Moreover, the amount of rent the individual can attain gets larger as the firm grows in Figure 1.5. The red-colored dotted line, plotted against the left-hand side y-axis, represents the level of rent in terms of utility an individual gains over the size of a firm given parameters.

Surprisingly, when an individual is able to seek rent, she always chooses the level of labor where she can not only maximize her utility but also the rent she can possibly earn as a by-product even though the only motive she has is the maximization of her utility, not rent. The black dotted line, plotted against the right-hand side y-axis in Figure 1.5

demonstrates the largest gap between utilities an individual can achieve under the fair and unfair compensation systems over the firm size – sum of other employees' efforts. This is a numerical representation of the shady area in Figure 1.3 panel A as varying the volume of H_{-i}. Given this concurrence, it is concluded that individuals can maximize the rent that they can earn as maximizing their utilities by offering the level of labor which is only optimal in personal level but not optimal in social context as described in Figure 1.3.

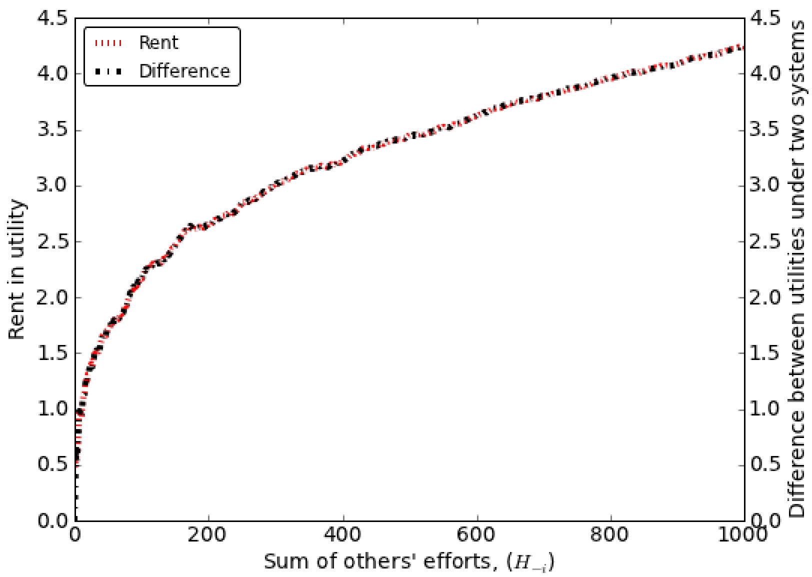

Figure 1.5: Rent in terms of utility and the difference between utilities an individual achieves under two systems

Given (a=0.5, b=1.0, β=1.5, $H_{-i} = \sum_{j=1}^{n} h_j,\ j \neq i\ \forall n = 1, ..., 1000$, $h_j \in (0, 1.0)$, The red dotted line, plotted against the left-hand side y-axis represents the rent an agent can achieve in terms of utility under the unfair compensation system. The black dotted line, plotted against the right-side axis, illustrates the largest difference between the utilities she obtains under the unfair and fair compensation systems – she earns it as a by-product, which is coincidentally equal to the maximum level of rent she can achieve.

Nevertheless, such behaviors do not prompt any immediate macro-scale stresses. Since there are increasing returns to scale in production – the invisible hand, the benefit of working together is large enough to offset the cost of rent-seeking behavior in the early stage of development. Individuals are still paid more than they are when they work separately. In aggregate level, therefore, per capita income as well as inequality keep rising up to the second point ② from ① in Figure 1.6.

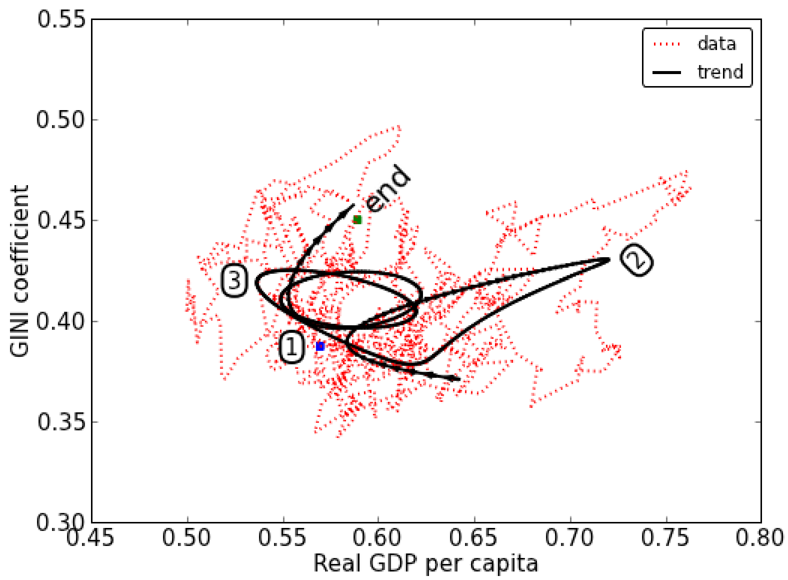

Figure 1.6: The trajectory of GINI coefficient over GDP per capita under the egalitarian regime

Each arrow captures the direction of the trajectory. Circled numbers are marked where critical events occurred in an economy; ① is the initial point, ② is where the cost of rent-seeking behavior dominates the benefit of increasing returns in production, ③ is the revolution point what Marx insisted. It is observed that the trajectory moves from ① to ③ through ②.

However, the more agents seek rents as much as they can, the higher the cost is that a society ought to bear for the rent-seeking behavior. As the rent-seeking behavior continues to prevail, the economy approaches to the critical stress point, ②, where the cost of exploiting others starts to overwhelm the benefit of working together in Figure 1.6. Beyond the stress point, the rent-seeking behavior becomes too severe and collective such behaviors produce negative externality so that the economy experiences a recession: the average income as well as inequality decline together.

Since individuals are continuously looking for rents as motivated regardless of the state of the economy, the situation gets worsen. In a deepening economic recession, it is found that the rich gets richer and the poor gets poorer – inequality continues to rise, and the entire economy falls into a deeper recession. At this stage, agents diminish their labor supplies very close to zero to squeeze last drop of rent they can obtain from others. A few individuals may start up new firms, but soon it is conquered by rent-seekers and make little wealth. As a consequence, inequality over per capita income is backward bent and reversed up in Figure 1.6 moves toward ③.

Piketty argued that this may be the phase where the current global economy is, and moreover, Marx warned that the emergence of a depressive dynamics – increasing inequality with decreasing per capita income – may drive dramatic socio-economic instabilities that can lead to, in his terms, a revolution of proletariats. Since this research is limited in a boundary of economics, it could not offer any possible explanations on a psychological aspect of revolution.

Nevertheless, the results could provide a possibility of revolution in the eyes of economics. Once the rent-seeking behavior become too dreadful, beyond ③, all activated individuals start to leave the current firm and initiate a new one while majority of population pay their ill-motivated behaviors. Yet, they are only a few; many others still provide close-to zero amount of labor. As some lazy workers join the newly formed firms while the rest is still lazy, existing and new employees in new firms begin to reduce their labor supplies once activated to seek rents.

Soon, the cost of rent-seeking behaviors catches up the benefit of working together in those firms. Thus, the economy could not grow as high as it does in the beginning unless all are forced to start all over again from the scratch, for example, after-war recover. Rather, it fluctuates continually as individuals repeat the above process over and over. This is the reason why the trajectory circled around in a chaotic way beyond point ③.

Given simplicity of this model, it is hard to claim that the results confirm what Piketty and Marx said and forecast our near future. Instead, if this model reflects the core system deep inside of the real world, – individuals are motivated to seek rents due to the systemic imperfection and asymmetric information, we may want to take the model outcome more seriously to gain some insights on the relationship between inequality and growth. In fact, history, from the French Revolution to the Great Depression and Recession, has told that once a society reached the revolution point, people made extreme decisions. In the following section, it is examined whether what the model produced have implications against historical data.

1.4.3 Empirical Validation

So far, I have compared and contrasted micro dynamics and macro behaviors that difference compensation systems produce in an otherwise identical economy theoretically. However, it is also important to validate hence verify the simulation outcome against the empirical data for the applicability and pragmatic intuitions and implications. For the empirical validation, I collected data from five different advanced counties, the United States, the United Kingdom, France, Denmark, and Norway, to examine the correlation between inequality and growth especially during the Great Depression and Great Recession in Figure 1.7. I intentionally chose those developed countries to explore the sole effect of those crises on inequality and growth with the exclusion of side effects as much as possible. To measure inequality, the top decile income share is used as a proxy before GINI Index was invented. GINI coefficient is used as an indicator otherwise.

Inequality over per capita income in most of chosen countries, however they are measured, followed the very similar pattern to what the model produced under the unfair compensation system during both crises. In the U.S., inequality rose while GDP per capita fell during the Great Depression in Figure 1.7 panel A as well as Great Recession in Figure 1.7 panel B. Similar behaviors can be found in France as well as Denmark during those downturns in Figure 1.7 panel E and F for France and G for Denmark.

It is a little different in a case of Great Britain. Since this country experienced the income polarization with lower average income during the post-war recession – after WWI – and resolved the issue – by looking at the data, the Great Depression did not turn the society upside down again severely as in other regions. Rather it shocked the economy as

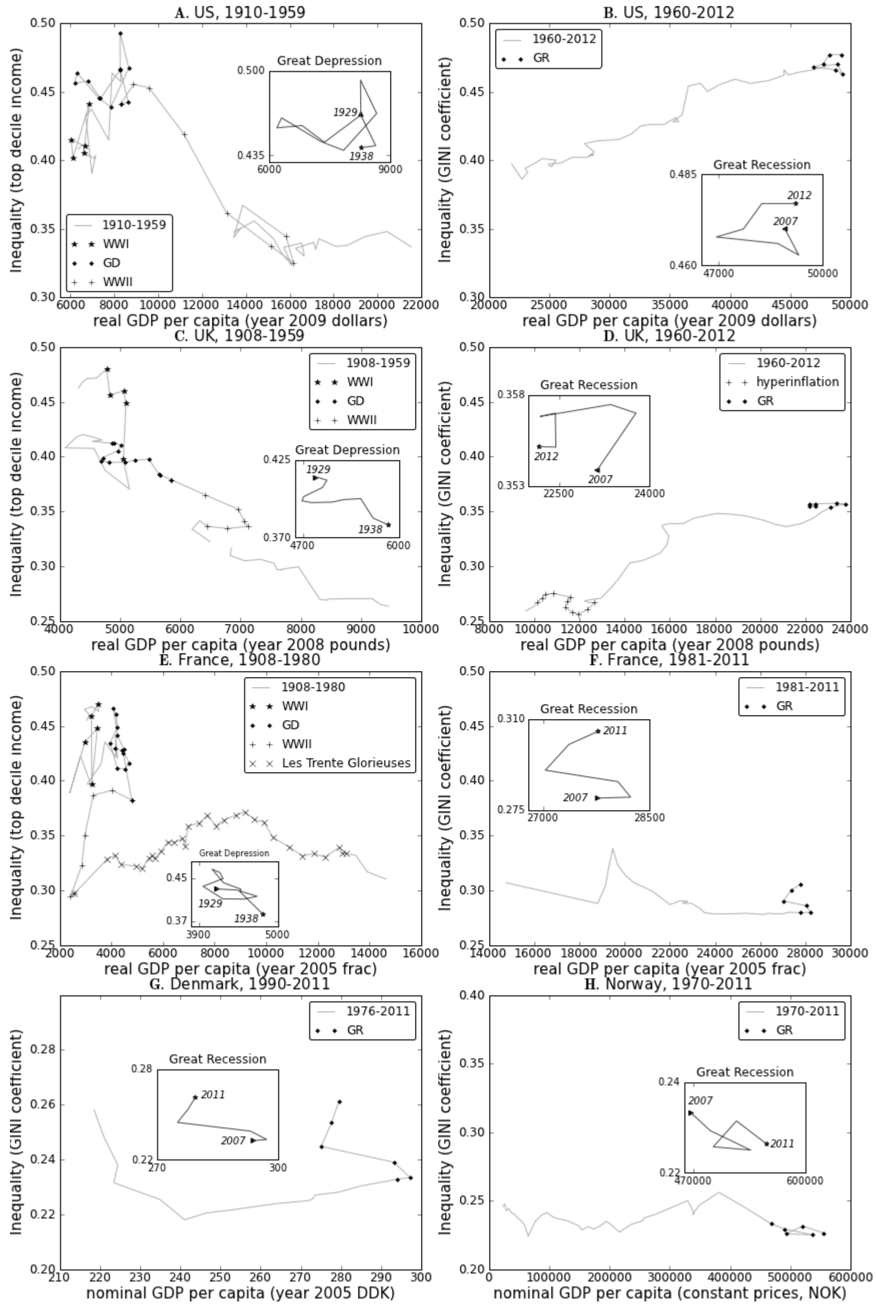

Figure 1.7: Empirical data of inequality and per capita income on the phase-space diagram
The U.S. data from 1910 to 1959 is represented in panel **A** with the inset is between 1929 and 1938 and in **B** from 1960 to 2012 with the inset is between 2007 and 2012. The U.K. data from 1908 to 1959 and from 1960 to 2012 in **C** and **D** with respective insets are between 1929 and 1938 and between 2007 and 2012. French data from from 1908 to 1980 and from 1960 to 2011 in **E** and **F** with respective insets are between 1929 and 1938 and between 2007 and 2011. Denmark from 1990 to 2011 in **G**. Norway from 1970 and 2011 in **H**. Data Source: Officer and Williamson, 2012; Piketty, 2014; Solt, 2009; Statistics Denmark; Statistics Norway

typical ones would do – both inequality and per capita income went down in Figure 1.7 panel C.

During the Great Recession, the level of inequality was not changed much whereas per capita income was dropped by around 6-7%. This is mainly because the richest 1% was also suffered from the Great Recession as much as the rest was. Statistics showed that the income share of Top 1% has fallen since late 2000s. A possible explanation for this phenomena is as following. Most of the rich was directly or indirectly concerned in the financial industry in U.K.[11] which is, as many economists believe, the origin of the cause for the Recession. If it were from other industries, it would have been observed the similar pattern in this country as well.

In a few countries, like Norway in this example, income gap among population was not widened but stable during the crisis unlike to other countries above. Only the level of per capita income was diminished but it returned to where it was without affecting inequality in Figure 1.7 panel F. This economy was damaged little, relatively speaking, and stabilized itself swiftly. The key difference between Norway and other countries among many is that Norway is a country which has established and practiced a thorough income transfer system – not only taxation but also sovereign wealth fund – relatively well. Since income is fairly allocated in the nation, there may be small or little room for individuals to seek rent. Having said that, it is suspected whether the latter type of pattern can be replicated in the hypothetic experiment with the progressive taxation policy. Therefore, I explored the impact and direction of taxation on inequality and growth in economies with two different distribution mechanisms in the following section.

1.5 Taxation

According to traditional economic theories of supply and demand of labor, the market intervention, i.e., taxation in this chapter, from the visible hand – the government – may

[11] From 2006 to 2009, the financial sector accounted for 10% of GDP, the highest of all G7 countries. The second highest was Canada at 6.7%.

discourage tax payers due to the substitution effect. Such discouragement is expected to lead a decrease in production and labor demand which in turn, a decline in wages and the aggregate consumption as well. Furthermore, critics of taxation have argued that income transfer programs may encourage the recipients to reduce their labor supplies due to the income effect.[12] The advocates of those theories argue that raising tax not only reduce inequality but also hold back economic growth for sure.

However, although critics of high inequality held the traditional view if the workers are fairly compensated, they claimed that the benefits of taxation may exceed its cost in an economy where rent-seeking behavior dominates. Recent discussions insisted that even if the discouragement effect may exist, its impact on growth is much less than what the conventional theories forecasted in the above economy. In addition, they continued that progressive taxation on an individual's whole income source including capital gains – so called Buffet rule – can be used as a tool to counterbalance rent-seeking activities. Thus, it is worthy to examine if the policy leads our society to where traditional theory anticipated, or somewhere better than that.

$$\Delta h^* > 0, \text{ if } G_t > \frac{1}{1-\theta_{i,t}}(\theta_{i,t} - h_{i,t})w_{i,t} \tag{1.5}$$

$$\Delta h^* < 0, \text{ otherwise}$$

Analytically, it is ambiguous to examine the impact of taxation on individuals' decision makings – how the policy changes agents' labor strategies ($\frac{dh_{i,t}}{dG_t}$) – given their heterogeneities as well as that on a whole economy. It can only provide an explanation how an individual adjusts her behavior given an amount of subsidy and her attributes in Equation 2.8. Hence, I ran a simple experiment for this analysis in silico – collecting 40% of the income of the top 20% and distributing it equally to the bottom 40%.

[12] Precisely speaking, the substitution effect – the higher wage is, the more labor an individual offers – is dominated by the income effect– the higher wage is, the less labor an individual offers.

It is observed that the long-held belief turned out to be true in a perfectly competitive world in Figure 1.8 panel A and B; the level of average income as well as that of inequality are shifted down throughout the simulation period as the policy is introduced. Since workers provide (locally) optimal amount of labor given the output that their firms produce, $Y_{v,t}$, additional non-labor income does not make those who receive a subsidy work hard but less on average. Hence, the total labor in a given firm is reduced and so is the output according to Equation 1.1.

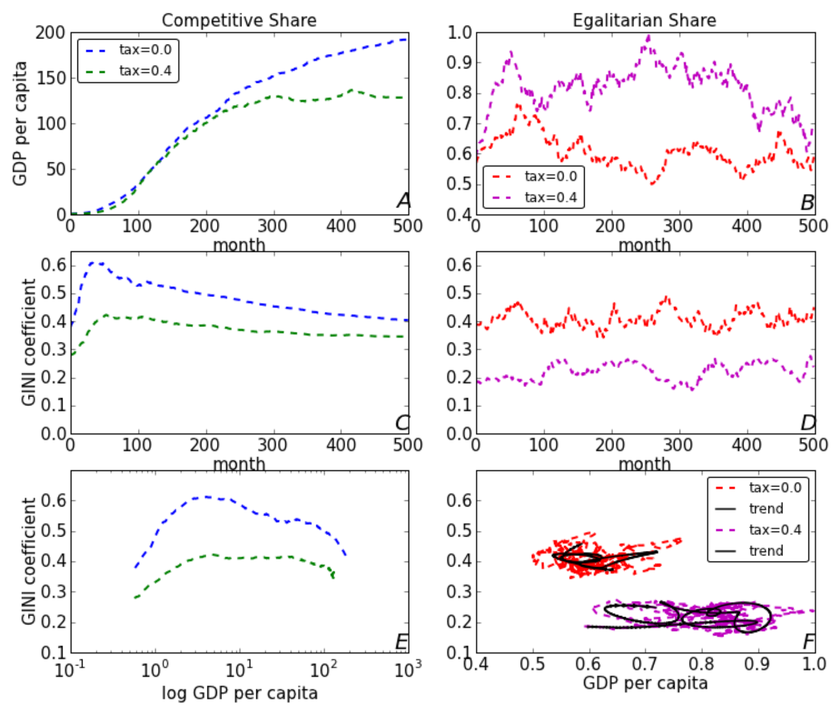

Figure 1.8: Simulation results of fair and unfair compensation models under two different tax regimes

A and **B** demonstrate the level of GDP per capita over the simulation period when there is no tax (dotted line) and 40%- tax (solid line), under the competitive and non-competitive compensation system, respectively (1000 runs for each tax regime). C and D illustrate the level of GINI coefficient over the same period when there is no tax and 40%-tax under two different scenarios. E and F draw the trajectory of GINI coefficient over income when there is no tax and 40%-tax. It is noteworthy that panel E and F are not time-series graphs but GDP-GINI phase space diagrams. Under the fair wage system, there is a trade-off between growth and inequality where as both GDP per capita and inequality are improved under the unfair compensation system.

Due to the change in production results from a change in the factor of production in firms, non-beneficiaries also adjust their labor supplies. Through this adjustment algorithm, the economy finds and settles down in a new equilibrium where per capita income and inequality are lowered. Under the competitive distribution system, the impact and direction of the policy is quite unsatisfactory; the economy is able to coordinate itself very efficiently hence any external interventions may not make the society any better.

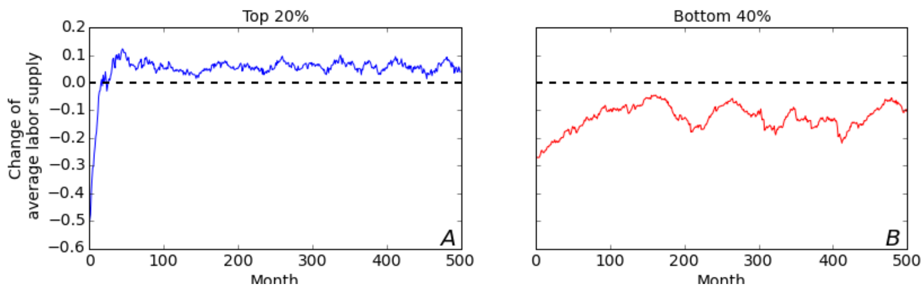

Figure 1.9: Change of labor supply of tax payers and recipients
This figures show the change of average labor supply of tax payers – the richest 20% and that of recipients – the bottom 40% respectively in panel **A** and **B**. Initially, The average labor supply of the top 20% as well as the bottom 40% are decreased due to the substitution and income effect in the beginning, but, later, that of the top 20% is increased while the bottom 40% is still discouraged.

On the other hand, in a world where the compensation system fallaciously designed, in micro level, moreover only in the beginning, what critics of such a policy have insisted is confirmed. Both tax payers and beneficiaries are discouraged hence reduce their labor supplies respectively in the beginning of the simulation. In Figure 1.9, the average of labor supply of the top 20%, who pay taxes, and that of the bottom 40%, recipients, drop by around 0.5 and 0.3, respectively. However, in macro level, the result is quite opposite. Per capita income is shifted up whereas inequality is shifted down than those from the baseline model, respectively.

According to Equation 2.8, given a tax rate, when individuals provide the optimal level of labor or little less, where $h^* \approx \theta$, all individuals, regardless of their income level, cut their labor supplies due to the substitution and income effect accordingly. Since all individuals are self-employed and provide optimal level of labor supplies initially, the discouragement effect appear only over the period. However, even in the beginning, such a discouragement is soon canceled out by the benefit of group work as more self-employed individuals join other firms and produce more than they could when they work alone. GDP per capita continues to rise while inequality to fall by the redistribution program.

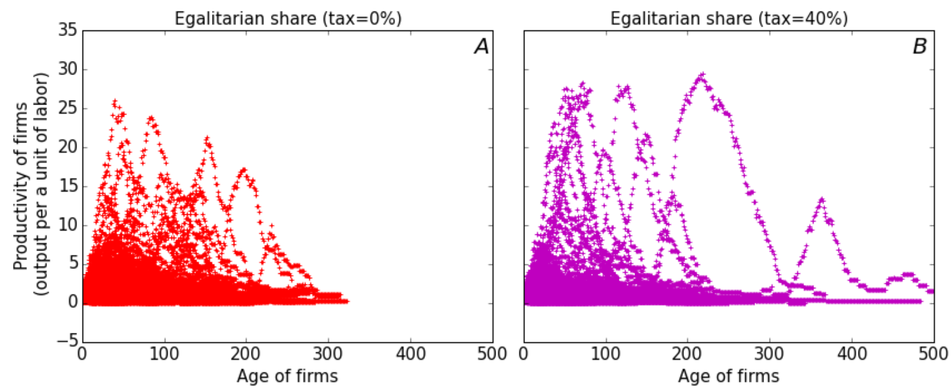

Figure 1.10: Age and productivity of firms under the unfair compensation system
This scatter-plots illustrate how the age of a firm is related with the level of productivity, measured output per a unit of labor, of the firm when the tax rate is zero (**A**) and 40% (**B**) respectively. It is noteworthy that the data is collected in each simulation period. When the rate is 0, it is likely that as a firm gets older, its productivity decreases. While such a pattern hold when the rate is 40%, some old-enough firms once again highly productive hence live long and proser.

Moreover, when a majority of individuals work together hence the labor supplies they provide (h_i^*) are far below the optimal level (θ_i), the impact and direction of the policy depends on each individuals working environments. In such a economy, if the level of productivity of a firm is relatively high, most if not all, of workers have to pay tax[13]. Because their labor supplies are far below the optimal level, they are encouraged to work more contrast to the traditional belief. The average labor supply is increased by around 0.05 to 0.1. As they work more, the productivity of the firm increases and attract other workers more. Then, as there are more workers at the firm, the output as well as wage increases which in turn, attract more workers. Through such a virtuous cycle, the firm gets bigger and survive longer in an economy – survival of the fittest.

[13]Since the wage is the same for every worker in a firm, ($w^* = \frac{Y}{n}$), if one has to pay tax, the others as well

On the other hand, in a low-productivity firm, most, if not all, of workers receive subsidies hence reduce their labor supplies even more. As a result, the total output the firm produces diminishes and so does the wage. It motivates current workers to leave the firm and the firm cannot hire workers due to the lowered wage. Along with the prevailing rent-seeking behavior, the firm soon disappear out of the economy more quickly. Figure A.4 supports such an explanation. it is found that when there is no tax, the level of productivity of a firm is decreasing as the firm gets older in panel A. On the contrary, when a tax rate is 40%, there are some firms which are old enough while its productivity rather rises as it gets older.

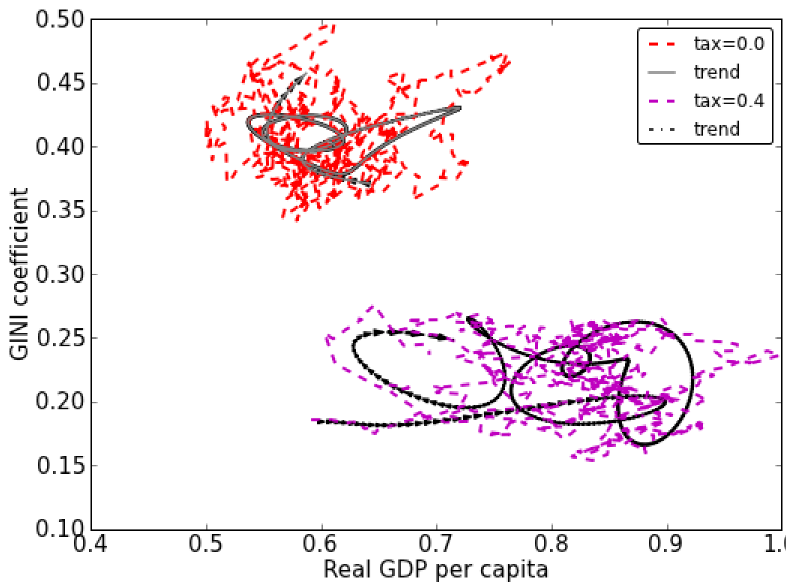

Figure 1.11: The impact of taxation on inequality over per capita income under the unfair compensation system

The dotted red line and solid gray line illustrate how inequality, measured by GINI coefficient, changes over the income level without the taxation policy in the unfair share system. The dotted purple line and black line demonstrate the same behavior with 40% tax in an identical economy. When the rate is 40%, the trajectory moves rather horizontally back when it experiences crisis.

Therefore, In macro level, due to the longer existences of high-productivity firms , GDP per capita increases while holding inequality quite constant due to the income redistribution effect. Nevertheless, such a positive effect on growth does not last in long-run. The higher the output of the former type of firms produces, the greater amount of rent that workers gains. Once the rent-seeking behavior becomes too severe so that it is better for workers to leave their firms, the firms as well as a whole economy perish. Subsequently, the economy collapses to the bottom and repeat the same course of action over and over in Figure 1.8 panel B.

Another interesting result in this experiment can be observed in the GDP-GINI phase space diagram in Figure 1.11. The movement and direction of the trajectory after it hits the stress point is quite different given a policy. While the the trajectory is backward bent beyond the stress point under the no-taxation policy, it just horizontally moves back and return to where it was under the redistribution policy. As suspected, the latter type of behavior is very similar to what is found in Norway which has actively practiced the progressive income distribution policy.

There are two crucial keys for success in this artificial economy. First one is willingness to work, θ. Second is luck; it is the activation order[14]. Given θ, Under the fair compensation scheme, the unintended wealth generated by luck is eventually shared by a whole society through trickle-down effect. Hence, any market intervention is nothing but redundant.

On the other hand, when the compensation system is not competitively designed, such wealth-by-luck is not fairly distributed among the member of a society. It only falls into hands of a few. In such a case, government intervention is strongly recommended to allocate the wealth-by-luck in a more efficient and fairer way. The taxation policy does not only make a whole economy better on average (higher GDP per person with lower inequality), but also stabilizes the economy at the cost of a nation's wealth only in the time of crises. Based on pieces of evidence, it is confirmed that the policy may be a very solid and effective tool to prevent an excessive exercise of ill-motivated behaviors and self-destruction of an economy but to uphold the invisible hand and govern a society good enough, if not optimally.

[14]earlier activated an individual is, more likely such an individual becomes rich.

1.5.1 Sensitivity Analysis

Given advantages of the redistribution policy under the unfair compensation system, it is very crucial to examine the robustness of the result over different tax rates. For the sake of analysis, I varied the tax rate from 0% to 60% with an increment of 10%.[15] It is noteworthy that the model is identical otherwise. The compensation is unfairly distributed in each firm and the government collects taxes from the the richest 20% and distribute it to the poorest 40% equally.

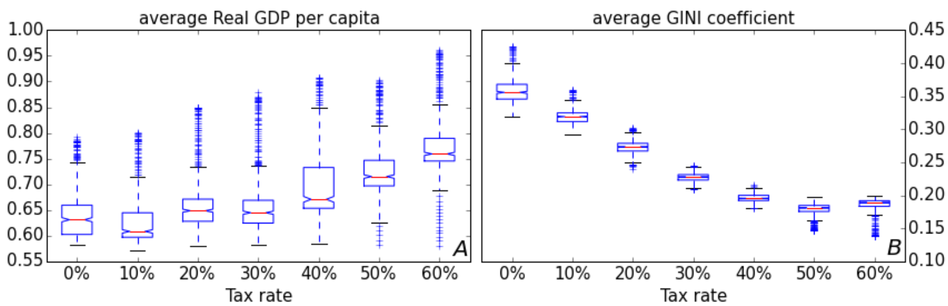

Figure 1.12: Average level of GDP per capita and GINI coefficient in an unfair economy
Panel **A** and **B** demonstrate the box plot of the average level of per capita income and inequality respectively in an unfair economy. The solid red line represents the median value of respective data. It is found that the average level of per capita income rises and that of GINI coefficient falls as the tax rate increases.

The simulation result given a tax rate is qualitatively very similar to what is illustrated in the previous section. It is found that the average level of real GDP per capita of an economy increases while that of inequality decreases over the rates in Figure 1.12. Per capita income rises by 0.1, from 0.65 to 0.75 whereas inequality drops by around 0.15 from 0.35 to 0.2. Of course, when the tax rate is too high, i.e., 60% in this chapter, inequality bounces back because the income of the poor exceed that of the rich hence their status is reversed.

Given individuals' psychological neutrality on tax rates[16], as tax rate increases, the

[15] Although 60% tax rate is unrealistic, it is important to investigate up to which tax rate the previous qualitative simulation result holds hypothetically.

[16] In reality, people may be too upset if the tax rate is high to make rational decisions, however, agents in this model are rational, however bounded, so they do not make any unreasonable behaviors.

natural selection process, explained in the previous section – hard-working firms survive and prosper longer, is more strengthened, thus, an economy with a higher tax rate becomes more prosperous. Figure 1.13 demonstrates that the frequency of rejuvenation of a firm, which are old enough hence more likely to fade away sooner or later, increases as the tax rates rises.

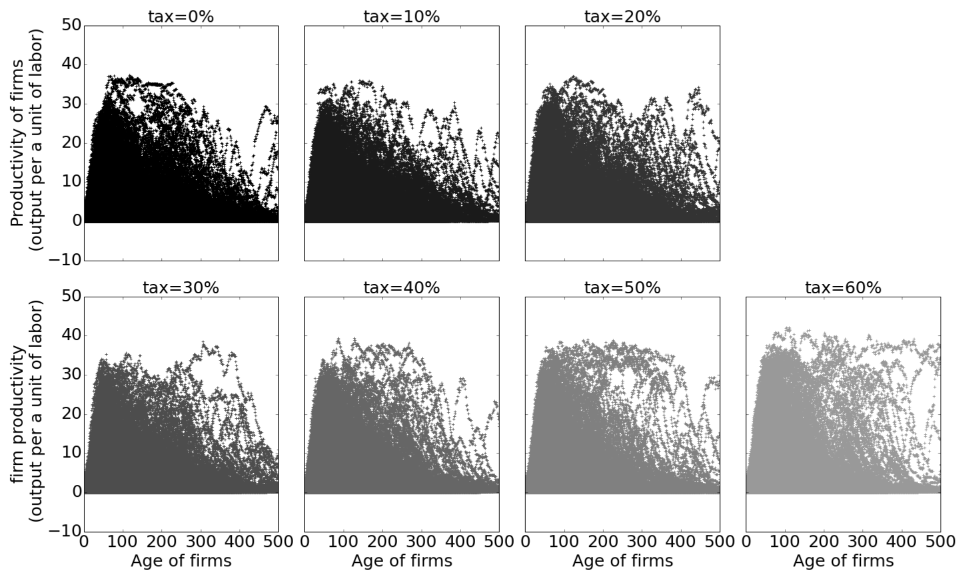

Figure 1.13: Age and productivity of firms under the unfair compensation system
This scatter-plots demonstrate how the level of productivity, measured output per a unit of labor, of a firm is related with its age given a tax rate. It is noteworthy that data is collected throughout a whole simulation not a single simulation.

The result of the sensitivity analysis indicates that the benefit of taxation exceeds its cost even at the extreme level, 60%. It implies that although the wage distribution system may not be perfectly designed, the more number of people are either willing to or forced to work hard and seek less rent, and the higher per person income and the lower inequality are. The collective action of such behaviors holds inequality low and helps the entire economy grow further. The empirical study by Ostry and Berg (2011) shows that there is a negative correlation between inequality, measured in GINI in net income, and the duration of growth spells, where the minimum spell growth is 5 years, which is also found in this experimentation.

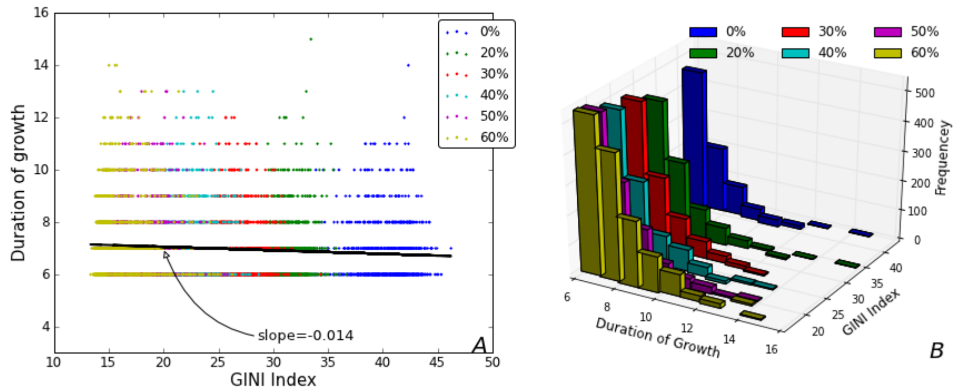

Figure 1.14: Relationship between inequality and the duration of growth
Panel **A** and **B** demonstrate the casual relationship between inequality and duration of growth in 2D and 3D respectively. It is noteworthy that the minimum duration of growth is 5 years. It is found that regardless of the tax code, an economy which experiences lower inequality is more likely to thrive further.

I calculated first the yearly data transformed from the original data collected monthly in the model, and second, the duration of continuous growth with the average inequality, measured in GINI Index[17], for the same period. The data with 80% tax rate intentionally excluded in this analysis for the sake of simplicity. The result is presented in Figure 1.14. The result confirms that there is a negative relationship between inequality and the growth spell within a scenario and between scenarios in Figure 1.14. Furthermore, this graph can speak out more than what the empirical data can. This result can explain not only the correlation but also the casual relationship between inequality and growth. The lower inequality is, the higher the duration of growth is.

1.6 Conclusion

In this chapter, I explored the relationship between income inequality and economic growth given two different – fair and unfair – compensation structures in otherwise identical

[17]GINI Index is a percentage representation of GINI coefficient – GINI coefficient multiplied by 100.

economies. If individuals are perfectly compensated in an economy, rising inequality alongside the invisible hand is a necessary condition for economic development – it motivates people to work hard. As economy grows, however, inequality falls sooner or later, as Kuznets hypothesized, hence people should not concern about inequality no matter how high it is. In this case, the government can only reduce inequality at the cost of economic growth; no Pareto improvement can be made by any government interventions.

On the other hand, if the rent-seeking behavior prevails in a society, the model outcome demonstrated that even though inequality and income per person grow together for the same reason explained in above scenario, such an behavior soon hurts a whole economy. Moreover, once the rent-seeking behavior becomes too extreme and exceeds the societal tolerance level, the economy could not help but breaks down itself; inequality continues to rise while per capita income falls. Such a consequence confirms the stylized fact – GDP per capita fell and inequality rose during the Great Depression as well as Great Recession. In such a circumstance, government intervention for restricting the ill-motivated behavior through redistribution policies is strongly recommended because the policy would boost economic growth while holding inequality constant.

Chapter 2: The Biased Compensation Rule and Demand-side Driven Crisis in the Long run

2.1 Introduction

There are two different perspectives concerning inequality, however it is measured, in a field of economics. One is that it is a consequence of quantitatively different rewards for different skills and talents. Another is, inequality is nothing but a result of unfair compensations among individuals for almost identical labor. In a world we have lived, of course, both types of inequality have been coexisted for thousands of years. The underlying solicitude is, therefore, not which perspective is correct, but which perspective is more seemly in the society.

If the difference in individuals' efforts and productivities accounts for a majority part of inequality, since we cannot have perfect equality and perfect efficiency simultaneously, it has been believed that we ought to sacrifice one for another as Okun (1975) insisted. He continued that those paid unfairly soon receive a fair – not necessarily equal – share of the growth for the concession that they made even though it may not take place in near future.

On the other hand, although critics of excessive inequality still hold Okun's view on inequality and growth when the former type of compensation rule dominates the latter, they also agree that the severe inequality is destructive for long-run economic growth if the biased compensation is largely responsible for rising inequality. They believe that such inequality is the cause and result of the disobedience of the basic principles of this society, i.e., *fairness* and *fair play* – omnia vincit labor. Once the violations become severe hence exceed the social tolerance level, it reciprocally hurts even those who have economic and political dominance through various channels, leaving aside whether the violation comes to be known to the public.

In traditional economics, it has been long believed that the discrepancy in ability rather than discrepancy in wages leads to the difference in wages. However, recent studies and discussions, from Piketty and Goldhammer (2014) to Sommeiller and Price (2014), discover that our long-held faith has not been hold over several decades at least. Considering possible measurement issues, it is generously agreed that the level of inequality is at historically high level in the U.S. as well as in other developed countries. For example, the share of national income of the richest 1% has doubled – 10% to 20% – since 1980s in the United States, and, that of the top 0.01% has quadrupled, from just over 1% to almost 5% (Beddoes, 2012).

Moreover, from 1978-2013, the average CEO compensation, which includes salary, bonus, restricted stock, grants and options exercised, from top 350 firms in the United States has increased by a little less than 1000%. During the same period, that of a typical worker has increased only by 10.2% (Mishel and Davis, 2014). After the Great Recession, the ratio between the average CEO compensation and that of an average worker became 243:1 (Stiglitz, 2013). This phenomena is not limited to solely the United States. The average (price adjusted) income of top 10% is about 9.5 times higher than that of bottom 10% in OECD countries (Cingano, 2014). However, the growth of productivity and GDP (Gross Domestic Product) per capita is relatively negligible in those places and times.

These stylized facts suggest that the economic system, not only in the U.S. but other countries, has been distorted somewhat in various ways. First, it signifies that the income distribution system has malfunctioned over several decades; the most part of ever-growing inequality is caused by unfair compensations. More importantly, such market impairments indicate that the fundamental precepts of our society are at risk: the belief that hard work and fair play pays off and the trust in the basic fairness. Last but not least, the degree of the distortion may be approaching toward the maximum social tolerance level.

As a consequence, individuals' economic concern has been directed not at creating new wealth but at transferring it from others, form the poor to the rich (Stiglitz, 2013). Inequality in this kind of a society "serves as a wedge between growth and living standards, funneling income largely to those at the top of the scale and thus making it harder at any given level of economic growth for living standards to grow as they have in more equitable times or for poverty to fall during business cycle expansions" (Bernstein, 2103).

Therefore, in this chapter, I pursued an analysis of the linkage between income concentration and growth through demand-side channels in an artificial economy where the compensation is not competitively made but institutionalized in order to favor a few. In addition, based on calibrated and empirically validated model, I examined income redistribution policies such as taxation and minimum wage, to gauge its respective effect on economic efficiency and equity and to offer policy implications.

This chapter is organized as follows. The following section reviewed literatures related to the distribution of income and its effect on economic growth. Section 3.2 described the specification and design of the model employed in this research. The simulation outcome is presented and the underlying mechanism of the dynamics is analyzed and discussed against empirical data in Section 2.4. The policy suggestions are provided in Section 2.5, and Section 3.5 concludes.

2.2 Literature review

Many economists have believed that when individuals get paid competitively – they are compensated for the work done – according to marginal productivity theory, inequality is nothing but the barometer which represents an individual's relative level of productivity given hours of work in a society. Under such an environment, those who earn less wages than others are willing to work more and acquire additional skills in order to be more productive and remunerated more. High inequality may exist but must be tolerable in the beginning of growth, since it motivates less-skilled individuals in a way described above and the collective of such actions improves the well-being of a whole economy – "Trickle-down effect" (Kuznets, 1955; Lazear and Rosen, 1979; Mirrlees, 1971). Furthermore, as the economy grows, more people become better-off, and consequentially, inequality diminishes over time and does no harm on long-run economic growth. Inequality rises and falls in the course of economic development – Kuzntets' hypothesis(Kuznets, 1955).

There are many empirical literatures that have attempted to study the relationship between income inequality and economic growth – how inequality affects growth, and vice versa. Those studies however, demonstrated no consensus on the direction and its impacts. Some argued inequality has a positive impact on growth (Forbes, 2000; Halter et al., 2014; Li and Zou, 1998), and some others stated negative (Banerjee and Duflo, 2003; Knowles, 2001; Ostry et al., 2014), while the others insisted that it has an insignificant effect (Barro, 2000).

Given unsatisfactory empirical analyses, Stiglitz (2013) offered an alternative hypothesis that may perform better in a world we are living. He claimed that excessive inequality has been the result of market distortions, the invention of seizing asymmetric information and socio-economic power, with incentives directed not at creating new wealth but at taking it from others – from the poor to the rich (Stiglitz, 2013). If the distribution system an economy has is not perfectly competitive contrast to the traditional belief – as you sow, so you shall reap, an individual's economic behaviors and decisions may be rather influenced by rent-seeking rule, not marginal productivity theory.

In the previous chapter, I have examined those hypotheses and confirmed that inequality follows an inverted-"U" curve as it rises and falls in the course of economic growth – Kuznets' hypothesis – under the fair compensation scheme. On the other hand, when the distribution system is falsely designed so that it explicitly motivates individuals to seek rent at the cost of others, the inverted-"U" curve is not found. Rather, it is observed that the trend of inequality over per capita income in the model is very similar to that in the real world. Along with Stiglitz's argument, such an analysis may suggest that it is very likely that the real economy is governed by rent-seeking behavior not by marginal productivity theory.

Another conventional belief that is held among many (Classical) economists is that majority of wealth in a society should go to the hand of a few richest individuals – the capitalists – so that they are able to accumulate a large amount of capital and invest it in improving exiting industries and supporting new industries, which in turn, leads a better economic performance (Kaldor, 1955; Ricardo and Hartwell, 1971). If it is distributed to non-capitalists, it is afraid that they may waste the wealth in less productive ways. This argument has the deep-seated faith in Say's law. "As each of us can only purchase the productions of others with his own productions – as the value we can buy is equal to the value we can produce, the more men can produce, the more they will purchase" (Say and Biddle, 1851).

However, Keynes interpreted this mechanism by contraries. He criticized that since the level of marginal propensity to consume of the rich is lower than that of the rest – riches do not buy more goods just because they have more money in their hands, the consumptions of the rich as a percentage of their incomes are much lower than that of the rest. Hence, the more wealth goes to the riches, the less the aggregate demand an economy stands up to. As the total demand shrinks, the "capitalists" do not expand investment and go as far as to curtail the current production; as a consequence, less wage for the workers. In this regard, the president of the United States during the 2014 State of Union emphasized, "When middle class families can no longer afford to buy the goods and services that businesses are selling, it drags down the entire economy, from top to bottom" (Krueger, 2012).

Recent studies hold this argument. Due to the economic expansion in early 2000s, many homeowners, especially middle class, experienced the sharp increase of their house values. This wealth effect – the more wealth an individual has, the more she spends – drove the overall consumer spending higher and higher although the real income, price adjusted, was not increased as much (Bernstein, 2103; Rajan, 2011). Once such illusion was busted in 2007, the wealth effect reversed, people began to cut their spending. The rest of the story followed what Keynes anticipated. Another study revealed that during the Great Recession, "if another \$1.1 trillion had been earned by the bottom 99% instead of the top 1%, annual consumption would be about \$440 billion higher. This would be a 5% boost to aggregate consumption" (Krueger, 2012). Given criticisms and stylized facts, it is not convincing that the majority of wealth in an economy should go to the hand of a few capitalist who can make "the pie" bigger according to what traditional economic theories have taught.

The line of such an argumentation is very logical and garners increased support recently, nonetheless, there are few empirical attempts to identify the demand-side channels through which inequality influences economic development and vice versa. Therefore, I pursued the following question in this chapter. The preservable squeeze on the income of the poor and the middle-class, in the long-run, squeezes the rich therefore a whole economy. I conducted a thorough examination on this hypothesis in silico in order to justify its theoretical legitimacy as well as empirical practicability. Upon calibration and validation against empirical data, I implemented hypothetic scenarios in the model to explore the potential effects of different redistribution policies to examine whether social benefits of direct or indirect wealth transfer surpass its costs or not.

2.3 Methodology

2.3.1 General features

Erstwhile empirical studies have revealed the limitations that the statistical analysis, through which micro level dynamics is postulated based on macro level data, has confronted in various ways. First, the quality and availability of income distribution data varies from country to country and from time to time. Such heterogeneity of data deterred economists to examine the linkage among social phenomena including what this chapter is focused on. Second, in the current analytical methodology, the micro-foundation is either obtained by setting the aggregate equal to a "representative" individual or by summing up over all individual decisions and confronting these sums on an aggregate level (Lengnick, 2013). It have been assumed that an aggregate-level phenomenon is directly coupled to micro-level dynamics, i.e., individuals' interactions.

However, in many other fields, studying any large enough system, which consists of many sub-systems that interact with each other, exhibited that its aggregate behavior cannot be directly inferred from micro level behavior. It is often believed that "A whole is greater than the sum of its parts" (Simon, 1996). An economic system is a likewise complex of course complicated structure which have have many interrelating subparts. Therefore, it must be assumed that both inequality and growth are emerged from those individual-level interactions rather than summed up.

Moreover, unlike to other disciplines analyzing non-organic system, those aggregate behaviors again institutionalize individuals' behaviors, the interactions of which in turn change the underlying configurations of the macro systems; even further, such interminable mutual feedbacks have taken place over and over. Due to these never-ceasing reciprocal interactions, finding evidence in the data to support their predictions was problematic while theories and hypotheses are clear and persuasive (Bernstein, 2103).

Third, traditional macro-economic methodology has been evolved along with the concept of general equilibrium hence the analysis is bounded to the equilibrium status of an economy. Such an analysis is very useful particularly when generating quantifiable solutions given equilibrium occurs. However, some systems may not have an equilibrium and more importantly, some others may have multiple equilibria and randomly move form one to another instead of (asymptotically) converging to one of them. Since an economy is an organic system which evolves over time and space as explained above, it is more likely that it has multiple equilibria and haphazardly move around among them. In such a case, the analysis which is built upon the assumption of equilibrium could not provide much insight on the economy.

In this chapter, therefore, I presented a highly stylized Agent-based model (hereafter, ABM) of an artificial economy. ABM hitherto has gained a multitude of attentions as an alternative approach toward economic dynamics. Although it shares crucial assumptions and wisdom from traditional models yet unlike to the traditional approach it allows the interactions among agents and between micro and macro systems from which the macro phenomena are endogenously emerged instead of being assumed from the outset and simply summed up to the aggregate level .

In addition, ABM is able to embed empirical hence more realistic insights about imperfect and asymmetric information, bounded rationality, imperfect competition and so on. In the model I proposed, for example, agents make optimal decisions which maximize their utilities respectively – how much to consume and leisure they want – as others in traditional models yet given imperfect and asymmetric information. Furthermore, their decisions are continuously adjusted in timely and myopic manner as their environments evolve hence they are only locally optimal. They behave bounded-rationally given time but adaptively over time.

Furthermore, ABM helps to identify and understand the origin of causes – "what is seen was not made out of what was visible" – and its effect by pinning down the casual relationship not correlation among various macro behaviors, i.e., in this research, income inequality and economic growth.Therefore, ABM can offer a better dynamic framework that is able to replicate stylized dynamics of the real economy more closely thus suits our respective interests better. Last but not least, it can generate data in the model; heterogeneity of data is no longer concerned in this research.

In the analysis that follows, I extended the model presented in Axtell (1999)'s research. The main similarities are, first, there are increasing returns to scale in production. Second, unlike to other ABMs Lengnick (2013), Gaffeo et al. (2008), Salle et al. (2013), and Salle et al. (2012), it allows that firms can emerge and perish endogenously. By doing so, the model is able to replicate some empirical trends in the period of economic boom as well as in the recession.

Since Axtell (1999)'s model is a stylized framework that abstracts from the real economy for the sake of studying dynamics of firm behavior, it intentionally excluded the demand side process. In order to suits the purpose of this research, however, it is important to understand the endogenous and implicit interactions among firms and consumers in the goods market. Therefore, I implemented two additional critical features in this model.

First, there are decentralized goods markets. This assumption reflects the one of critiques toward the general equilibrium assumption. Markets have long been thought of as black-boxes that could be represented by the intersection of a supply and a demand curve in traditional economics (Ballot et al., 2014). Thus, it has been restricted to embed the heterogeneity of markets and its dynamics. However, markets may emerge from the bottom-up process through decentralized interactions instead of being organized and governed by *the auctioneer* (Riccetti et al., 2014).

Lengnick (2013) stated that, "real markets might be characterized by multiple equilibria, coordination problems, instability, perpetual novelty or even chaos. Instead of assuming equilibria from the outset it should be shown that it is an emergent phenomenon of market economies." In this model, thus, it is not presumed that all markets are efficiently coordinated by an Walarsian auctioneer. The markets are decentralized and spontaneously evolve toward a stable or an unstable equilibrium or multiple equilibria; Walarsian equilibrium may not exist in those markets all the time given such a structural design.

Second, individuals do not consume all of what they earned but some. Keynes criticized that the level of consumption is not equal to one's income but increases in the proportion to individual's income – marginal propensity to consume, beyond the minimum requirement threshold level. It is crucial, therefore, to understand individuals' consumption activities in decentralized markets subject to budget constraints to identify the channels through which severe income concentration on a few affects dynamics of micro fundamentals hence macro phenomena such as inequality and growth.

2.3.2 Firm

There is only one factor of production, which is labor, and one commodity good, named X. Each firm, k, produces $Y_{k,t}$ according to the following production function for every period, t, where there is a n number of employees and each worker, j, offers $h_{j,t}$ amount of labor. The total amount of a factor of production is, therefore, $H_{k,t} = \sum_{j=1}^{n} h_{j,t}$.

$$Y_{k,t} = Y_{k,t}(H_{k,t}) = a_k H_{k,t} + b_k H_{k,t}^{\beta_{k,t}},\ a_k > 0,\ b_k > 0,\ \beta_{k,t} > 1,\ \forall\, k, t \tag{2.1}$$

It is noteworthy that there are increasing returns to scale hence the output of a large firm is always greater than the sum of that of many small firms although the total number of workers are the same.[1] Upon production, each firm compensates its employees as well as CEO with the wage that it has already determined in the previous period. Then, it goes to goods markets and sells its product at the price that is also chosen in the previous month. Whichever not sold becomes its inventory that can be sold in the future because it does not decay over time. The profit of a firm is calculated as accordingly.

$$\pi_{k,t} = p_{k,t} * Q_{k,t} + p_{k,t} * newInv_{k,t} - \sum_{j=1}^{n} w_{j,t} - w_{CEO,t}, \forall\, k, t^2 \tag{2.2}$$

$$\begin{aligned} p_{k,t+1} &= p_{k,t} * (1 + uniform(-0.05, 0.05)) \\ w_{k,t+1} &= w_{k,t} * (1 + uniform(0.0, 0.05)),\ \text{if } \pi_{k,t} \geq 0 \\ w_{k,t+1} &= w_{k,t} * (1 - uniform(0.0, 0.05)),\ \text{otherwise} \end{aligned} \tag{2.3}$$

When $\pi_{k,t} \geq 0$, $\alpha\%$ of profit, which is 30% in the baseline model, is added to CEO's next period compensation and the rest to the workers equally. In addition, the firm hires more employees in the next period up to 10. If $\pi_{k,t} < 0$, on the contrary, CEO's next-period income is reduced by up to 1% while employees' up to 5% and the firm fires up to 3 individuals[3]. Regardless of the sign of profit, each firm either increases or decreases the price for the next period, $p_{k,t+1}$, up to 5% at even odds. This can be understood as a strategic behavior because some firms increase their prices while their market shares get larger, and vise versa.

[1] I do not intend to elaborate this assumption in detail here. Please refer to Axtell (1999)'s paper for your interest.

[2] At any given time t, $p_{k,t}$ is a firm k's price for good X, $Q_{k,t}$ is the amount of X sold, $newInv_{k,t}$ is the amount of X produced but not sold, $w_{j,t}$ is the employees' wage and $w_{CEO,t}$ is the compensation for CEO.

[3] if there are less than 3 employees including CEO at the firm, it goes bankrupt

2.3.3 Agent

For simplicity, there are only three activities that each individual is able to perform; work, consumption and leisure. Because consumption does not require any labor, given one unit of labor, $\omega_{i,t} = 1$, each agent $i, i = 1, 2, ..., N$ has to decide how much she wants to offer as a labor and the rest for her leisure. As described in the previous section, agents do not consume all their incomes but a portion of them beyond the minimum level. Agents can use own savings only if their incomes are insufficient to meet the minimum requirements.

Each individual's consumption, thereby, can be described as a function of $\delta_{i,t}$, level of autonomous consumption, and $\gamma_{i,t}$, marginal propensity to consume, income, $m_{i,t}$, and wealth, $B_{i,t}$ in equation 2.4. In order to reflect the reality, marginal propensity to consume is inversely related to individual's relative income level. Moreover, since agents do not consume all their incomes, their corresponding utility can be written as a function of wealth including wage and leisure, not consumption and leisure in equation 2.5.

$$c_{i,t} = \delta_{i,t} + \gamma_{i,t} * m_{i,t}, \ \forall\, i, t, \ \text{if } m_{i,t} > \delta_{i,t} \tag{2.4}$$

$$c_{i,t} = \delta_{i,t}, \ \forall\, i, t, \ \text{otherwise}$$

$$U_{i,t} = U_{i,t}(m_{i,t}, l_{i,t}, B_{i,t}), \ \forall\, i, t \tag{2.5}$$

Furthermore, there exists asymmetric information in the compensation mechanism. Individuals believe that they are very competitively compensated. As a consequence, they always provide the optimal level of labor respectively.[4] However, the actual amount of wages that agents receive are pre-determined regardless of their labor supplies; they are compensated with the amount of $m_{i,t}$ rather than $\frac{h_{i,t}}{H_{k,t}} Y_{k,t}, \forall i, k, t$. Precisely speaking, they always do their best given circumstance because they believe that they are rewarded fairly, nonetheless, such faith is not always held up – they may not be fully compensated for their

[4]It is important to clarify that it is only optimal in individual level. It may not necessarily be socially optimal.

perspiration, and more importantly, they do not know of such violations.[5] Therefore, agent i's utility maximization problem can be written as following.

$$U(m_{i,t}, l_{i,t}) = U(w_t h_{i,t} + B_{i,t} + G_t, l_{i,t}) = (w_t h_{i,t} + G)^{\theta_{i,t}} (l_{i,t})^{(1-\theta_{i,t})} \tag{2.6}$$

$$st. \;\; h_{i,t} + l_{i,t} = \omega_{i,t}, \;\; \omega_{i,t} = 1, \;\; 0 < \theta_{i,t} < 1 \; \forall \; i, t$$

$$w_t h_{i,t} = \frac{h_{i,t}}{H_{k,t}} Y_{k,t}(H_{k,t})$$

$$G_t \text{ is subsidy if } G_t \geq 0, \text{tax otherwise}$$

And her optimal labor supply, $h^*_{i,t}$, will be chosen given θ_i, individual's preference parameter, which is heterogeneously distributed among agents:

$$h^*_{i,t}(\theta_i, H_{k,-i,t}) = \arg\max_{h_i} U_{i,t}(h_{i,t}; H_{k,-i,t})), \;\; \forall \; i, t$$

Precisely,

$$h^*_{i,t} = \arg\max_{h_{i,t}} U(h_{i,t}, l_{i,t}) = \arg\max_{h_{i,t}} U(\frac{h_{i,t}}{H_{k,t}} Y_{k,t}(h_{i,t}, H_{k,-i,t}) + G, 1 - h_{i,t}) \tag{2.7}$$

It is noteworthy that the an individual's utility is a function of the total output of a firm at which the agent works and her labor supply, given G and $H_{k,-i,t}$. Hence, the optimal labor supply, $h^*_{i,t}$, is not altered when the actual amount of wage that the individual receives varies but when the total output changes $Y_{k,t}$. In other words, because of the faith described above, an individual expects her wage to change over the level of her firm's total output and adjusts her labor supply accordingly. It is more elaborated in section 2.5 in detail.

[5] This is a reasonable assumption because, in reality, average people have lived their lives honorably and honestly although there are a few individuals have not.

Table 2.1: Model parameters

Attributes	values
constant returns coefficient, a	$uniform(0, \frac{1}{2})$
increasing returns coefficient, b	$uniform(\frac{3}{4}, \frac{5}{4})$
increasing returns coefficient, β	$uniform(\frac{3}{2}, 2)$
initial price	uniform(0.09,0.11))
endowments, ω	1
autonomous consumption, γ	uniform(0,3)
marginal propensity to consume, δ	uniform(0.2,0.6)
labor/leisure preference, θ	uniform(0.3,0.9)
CEO share in profit, α	30%
number of neighbors	5 if poor, 10 otherwise
agent activation	random
time calibration	one month
number of agents	1000
number of simulations	50
simulation period	1000

2.3.4 Dynamics

In a closed economy, there is a $N, N \in \Re$, number of heterogeneous agents. The number of firms, which are also heterogeneous, index by $k = 1, 2, ..., K$, is not determined beforehand but restricted up to the population size, N.[6] The labor and goods market transactions are taken place through the networks that individuals have. Individuals have networks, size of 5 or 10, depends on their relative income levels. If an individual is poor – below the bottom 40%, her network size is going to be 5, otherwise 10. In Axtell (1999)'s model it is randomly distributed however, in reality, the more rich an individual is, the more network she has[7] (Goldberg et al., 2013; Lipina et al., 2013; Noble et al., 2007).

[6] Since There is a N number of agents so the maximum number of firm in this economy must be equal to or less than N.

[7] The result is robust regardless of the way individual's network size is chosen.

The simulation sequence is following. Initially, each individual is self-employed and consumes whatever she earns. Then, whoever activated searches a job through her network and joins whichever firm that has vacancies and gives her the greatest utility. The individual can also start up a new firm or remain at the current firm at her will. Once all agents are activated and complete the job search process, each firm produces good X and compensates its workers including CEO. Individuals now search again whichever firm that has the lowest price and a positive amount of good X including their firms through the same network that they used for the job search. Then, they make a purchase of good X subject to their budget constraints. Firms calculate the profit and update the remuneration for both employees and CEO for the next period. Statistics is updated at the end, and agents begin to search for jobs again if necessary. This continues throughout the entire simulation period. The Table 2.1 describes the specific values for attributes in the model.

A single simulation is ran for 1000 months, which includes tune-up periods, about 200 months or so, to eliminate any effect of arbitrary initial conditions. For the robustness of output, 50 simulations is carried out given parameter specifications described in Table 2.1. The mean of favored variables such as per capita income and inequality, measured in GINI coefficient, 0 to 1, are computed and portrayed in respective figures.

2.4 Result

2.4.1 Baseline model – typical result

It is observed that in the beginning of the simulation, real GDP per capita, measured in the expenditure approach rises while the level of inequality, once dropped, is fairly constant in Figure 2.1 panel A and B respectively. Yet, the average per capita income is still far below the optimal level[8] due to the distortion of the compensation system. Nonetheless, this is an instance that many individuals would find themselves pleased with because economy is growing slowly but gradually thus their well-beings are improving. At the phase of

[8] In the previous chapter, I have discussed the consequence of the economy where all individuals are fairly compensated.

development, like many economists have insisted, equality is something individuals need or even are willing to sacrifice for a greater benefit yet revealed.

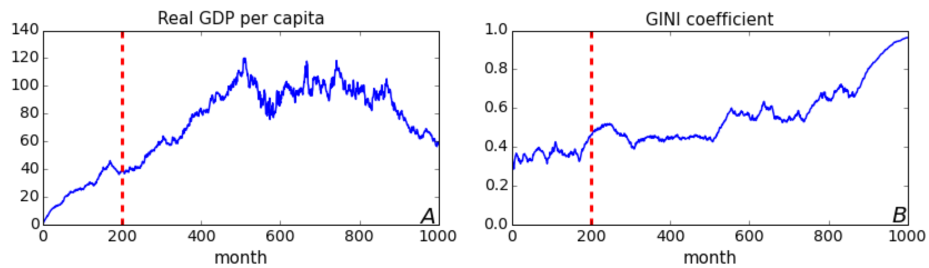

Figure 2.1: The baseline model – GDP per capita and inequality
A and **B** demonstrate the average real GDP per capita and inequality, measured by GINI coefficient, over the simulation period respectively. It shows that per capita income rises and fall while the level of inequality is constant for the first 400 months then continues to rise and drop all of sudden at the end.

However, as the economy passes the halfway point, it seems that real GDP per capita falls slowly and surely from its summit yet inequality continues to rise and is doubled by the end of the simulation period. In this period, the richer got richer and the poor became poorer. Moreover, such a worsened income polarization – mild in the beginning but becomes severe over time – along with other factors described below collectively leads economic havoc. Although it is not shown, once inequality becomes extremely high, like 0.9 or higher in this example, it drops dramatically close to the initial level and economy completely collapses – real GDP per capita is diminished closed to the initial level. This must be alarming because this is what some economists have worried based on what we have experienced recently: an adverse trade-off between efficiency and equality which they all agree that we should avoid at all costs.

What is the primary channel through which a biased compensation system causes an economic crisis? Figure A.2, which displays A chronological change of average income in four different income-classes – top 1%, top 20%, middle-class and bottom 40% – through panel A to D, provides an explanation – how above macro phenomena could be emerged. Even though the trajectory of the average income of each income-class exhibits a similar cyclical behavior – increases in a boom and decreases in a recession, the change of direction – upward to downward – occurs in a reverse order of the income class. In other words, the poorer an individual is, the more vulnerable she is to economic shocks during a crisis in this scenario.

Figure 2.2: The baseline model – average price-adjusted income by class
A, **B**, **C**, and **D** exhibit the mean level of average price-adjusted income by class – top 1%, top 10%, middle-class, and bottom 40% – over the simulation period. The average income of all classes rises and falls cyclically; yet, the poorer the class is, the earlier its income falls. It is noteworthy that scale on y-axis of each panel is different from one another.

In the beginning of the simulation, as an economy advances from an era of single-person firms to that of multi-individual firms, most, if not all, individuals tend to receive higher compensations; they become better off. However, due to the ill-designed compensation mechanism, the magnitude comes across is differed from one individual to another. As more wealth goes to the hands of a few who are already rich, average workers receive relatively smaller compared to the wage they could receive in a perfectly competitive society.

Furthermore, Such an unfair compensation among individuals soon generate more serious problems in an economy. As the rich becomes richer, they tended to spend less and less as a percentage of income and those who become poorer spent more relatively. As a result, aggregate demand in this artificial economy could not grow as high as that – equilibrium level – in a competitive system and more importantly as much as the supply does over time.

The insufficient demand – or an excess supply – in the market brings economic instability to fragile parts of the economy. Such a shock is more likely to hit small and medium sized firms first and drove some of them out of the market. In addition, all other surviving firms have to fire some employees to cope with the situation. Those who are fired become the newly poor if they are not already previously. Thus, the average income of the bottom 40% starts to shrink and so does their consumptions. However, fortunately, it aggregately did not cause any reciprocal and immediate impact on growth and inequality for following reasons.

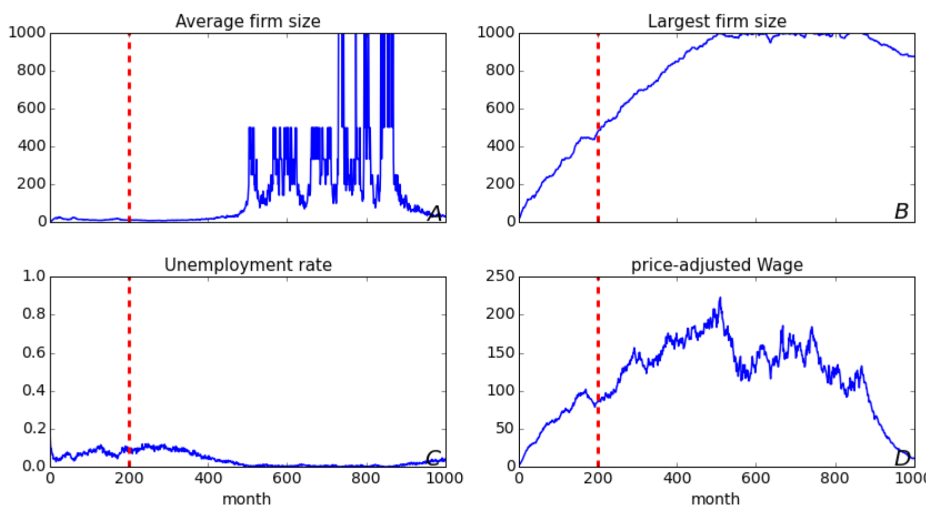

Figure 2.3: The baseline model – labor market indicators
A and **B** illustrate the growth of the average firm size and that of the largest firm size over the simulation period respectively. The average firm size repeatedly goes up and down but the largest firm continues to grow to the very end and begins to collapse as the economy does. **C** exhibits the unemployment rate and **D** shows the price-adjusted wage over the same period. It is found that the unemployment rate is very low throughout the simulation and continues to fall while the average of price adjusted wage is increased and decreased cyclically.

First, the unemployed is still able to purchase goods with their wealth since agents are designed to save a portion of their incomes. Second, some unemployed agents may decide to start up their own firms which provide them a better-than-nothing compensation. Third, even if firms go into the red – the total cost is greater than the total revenue, they could not fire as many workers as they desire but some hence the rest of employees are still able to work and get compensated. Forth, even though the consumption as a percentage of income among the rich is relatively small yet the absolute amount they spend is still sufficiently enough to support a whole economy.

As a consequence, the largest firm can grow while some of other existing firms could not help but vanish and new firms are emerging time to time. This is why in Figure 2.3 that the size of the largest firm is getting closed to the size of a whole population in panel B whereas the average firm size goes up and down dramatically in panel A for the reason explained above[9].

However, as the largest firm continues to grow, the more wealth goes to the rich, CEO, and her consumption as a percentage of her income continues to fall. Others, on the other hand, could not increase their consumptions due to budget constraints. Moreover, the wealth of the unemployed would be ran out sooner or later, the self-employed earns relatively little compared to the pervious wages they received, the biggest firm needs to cut compensations for the employed (Figure 2.3 panel D) in order to cover up the losses. It all together, makes aggregate demand shrink once again. The economy becomes worsened more and more and recycles experiences explained above. Even worse in this time, it squeezes not only the poor but also the middle class. As the average wage drops further, eventually, those employed at the largest firm is fired or leave and start their own firms or remain unemployed, which collectively destroys the rich and push the economy further down. Income squeeze fundamentally rooted into the wage manipulation alongside its side-effects brings a collapse of the economy in the end.

This analysis demonstrates that how inequality in the beginning, prompted by the mildly unfair compensation scheme, causes a intolerably-high inequality subsequently and poses a serious threat to the economy through demand-side channels. As hypothesized, the income concentration on the hand of a few, regardless of its magnitude, restricts the purchasing power – consumption competency– of the rest, which leads to lower aggregate demand. A

[9] It is a simple algebra; the closer two numbers are, the higher the average is.

decrease in demand has adverse effects on the labor market hence productions. Firms begin to reduce productions more and give workers less compensation and the demand is shifted down even further. Such sequence of reciprocal cause and effect continues until it leads to a deepening economic crisis with extreme inequality.

2.5 Policy Implication

2.5.1 General features

The baseline model is very intuitive and provides insights concerning the impact of income concentration on both growth and inequality through the demand-side channel and its direction. However, it could be still considered theoretical because it does not include any redistribution policies to exclude potential ramifications caused by such policies. It is better, therefore, to implement such policies in order to replicate the real economy more closely hence offer practicable policy suggestions.

In the pursuit of this purpose, first, I calibrated and validated the baseline model against U.S. economy from 1979 to 2010. On top of attributes in Table 2.1 which was held constant throughout this study, two policy parameters – the income tax code and ratio of the minimum wage to medium wage – are added into the baseline model. Having calibrated, the consequence of such two policies are thoroughly examined in following sections to measure its respective effect on a whole economy. Among many different redistribution policies such as severance pay and other unemployment benefits, these two policies are chosen because the impacts and directions of such policies are little known hence have been very controversial recently.

Income tax rates in the United Sates are designed and operated in a very progressive way. However, the tax code as a whole is almost perfectly flat, which is around 28% (Economist, 2012b). Due to such a loophole – little difference in rates, many economists have criticized that the taxation in the U.S. no longer functions properly to serve its bona fide goals over several decades. Furthermore, statistical analysis based on the empirical data is not adequate for identifying a genuine effect of the policy on inequality and growth. It is important, thus, to pursue such an investigation in a hypothetic scenario.

In such a scenario, it is exogenously designed that the government collects taxes, 28% of the income, from the richest 10% and equally distributes it to the bottom 40% after 200th month.[10] It is assumed that there is neither transaction cost – zero sum transaction – nor inefficiency in the process of transfer for simplicity. Individuals who receive subsidies can utilize it in the next period.

The minimum wage policy has been criticized by traditional supply and demand of labor theories that it would hamper small and mid-sized companies as it increases labor costs, followed by higher layoffs. It has been also worried that the policy may discourage benefited recipients to work less – the wealth effect dominates substitution effect. All together, advocates of conventional theories have claimed that the approval of an increase in the minimum wage pulls down aggregate demand as well as the economy.

However, empirical evidences are ambiguous in this case as well, as in taxation studies, (Autor et al., 2008; Cahuc and Michel, 1996; Card and Krueger, 2000), therefore, it is worthwhile to scrutinize the direction and impact of an increase in the minimum wage on inequality and growth. The latest data shows that the average ratio of the minimum wage to median wage is 0.38 in the United Sates, so, the minimum wage is set for 38% of the medium wage in the calibration process.

2.5.2 Calibration

It is noteworthy that the refinement of the model did not cause any consequential difference at least qualitatively although it accelerated a whole process a little, hence not challenge any enlightenments found in the previous analysis. Once the squeeze on the poor and middle class becomes extremely intolerable where the bottom 40% have only a little and the middle-class are about to disappear (Figure A.2 panel C and D), the average income of the richest 1% also plummets tremendously to the rock bottom (panel A) as well as a

[10]The number, 200, is arbitrarily chosen, but, once the model is tuned-up, the result is robust regardless of commencement of the government intervention.

whole economy (Figure A.1) similar to what is portrayed in Figure 2.1. The output of the calibrated model is presented in Appendix.

The comparison between the model output and empirical data from 1979 to 2010 in the U.S is provided in Figure 2.4. Since the simulation data is generated every period, which is assumed to be one month in the real calendar, data is averaged out every 12 periods after the tune-up process. Looking at the graphs, it is clear that the advanced model is capable of reproducing what has happened in the U.S. economy at least partially for the given period.

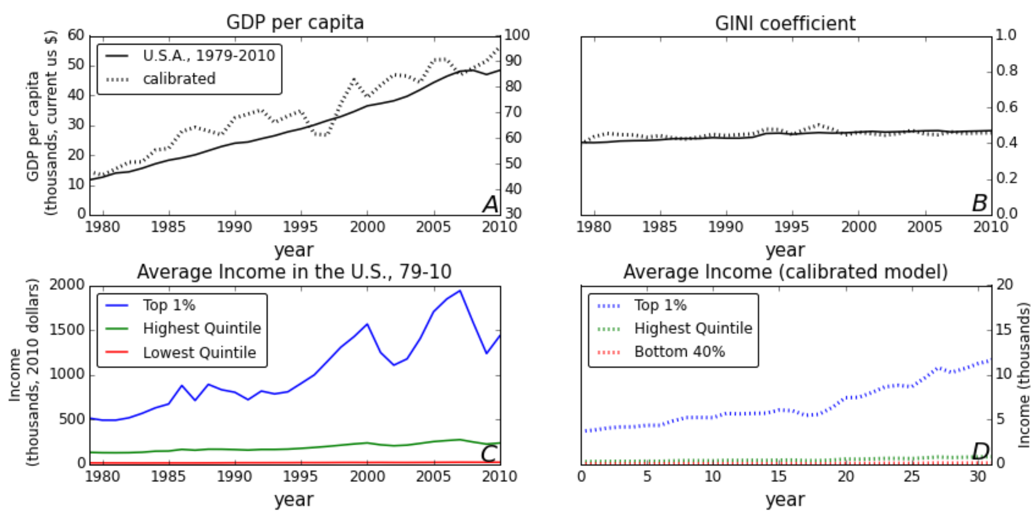

Figure 2.4: The empirical validation – U.S., 1979 - 2010

A and **B** compare GDP per capita and GINI coefficient in the U.S., from 1979 to 2010 to those obtained in the model respectively for the same length of time (21 model years). **C** illustrates the average income of top 1%, top 20%, and bottom 20% in the U.S., over the same period. **D** demonstrates the average income of top 1%, top 20%, and bottom 40% in the model for the same period of time.

Source: GDP per capita and GINI coefficient from (Solt, 2009; Williamson, 2011) and pre-tax average income by class from the (Congressional Budget Office, 2010)

In Figure 2.4 panel A, it is found that per capita income of the U.S. (solid line) and that (dotted line) of the model have grown almost identically apart from the measurement unit difference. GDP per capita in the United States rose from \$10 to \$50 thousands and that in the model from 40 to 90. When it comes to inequality (panel B), the result is remarkable. The level of inequality, measured in GINI coefficient in both cases, follows an almost perfectly similar trend over the given period both in the real and artificial world; it rose from around 0.4 to 0.5 little by little.

Moreover, the model also replicates the trend of average income of four different classes, especially those of the rich and the poor in panel C and D. The average income of top 1% has risen continuously and dramatically in both economies over 30 years, whereas that of top 20% and middle-class only did relatively little. In addition, it is demonstrated that the average income of the poor in the U.S. as well as that in the artificial economy has not increased much. Given the capability of the model for bearing some empirical resemblance, it is pursued a thorough experiment of the effect of taxation and minimum wage policy on growth and inequality to suggest some practical recommendations in the following sections.

2.5.3 Taxation

When the tax rate for the richest 10% is varied from 15% up to 70% where the current rate is 28%, it is found that the impact and direction of the policy on growth was negligible in the short-run (for about 50 months). The average real GDP per capita was not significantly different from each other, around 40, regardless of the tax rate in Figure 2.5 panel A. Meanwhile, although the level of average GINI coefficient was close to each other within a range of 0.40 to 0.45 over the rates, Figure 2.7 panel A demonstrated that it tended to decrease as the rate rose up to 50% then increase beyond the rate. In the long-run, on the other hand, the average level of GDP per capita continually decreased from around 60 to 30 in Figure 2.5 panel B as the rate is raised while that of inequality is not changed up to 50% then begins to decrease by around 0.05 in Figure 2.7 panel B .

$$\Delta h^* > 0, \text{ if } G_t > \frac{1}{1-\theta_{i,t}}(\theta_{i,t} - h_{i,t})w_{i,t} \tag{2.8}$$

$$\Delta h^* < 0, \text{ otherwise}$$

The primary causes for such behaviors are following. In the supply side, upon an increase of taxation, individuals adjust their labor supplies according to the Equation 2.8. Although it is ambiguous mathematically, Figure 2.6 demonstrates on average, those who pay tax are likely to increase their labor supplies by around 0.1 to 0.2 due to the substitution effect and those who receive benefits decrease by around 0.2 to 0.4 due to the income effect. Moreover, the higher the rate is, the greater the impact of the policy on the labor supply is holding the direction the same.

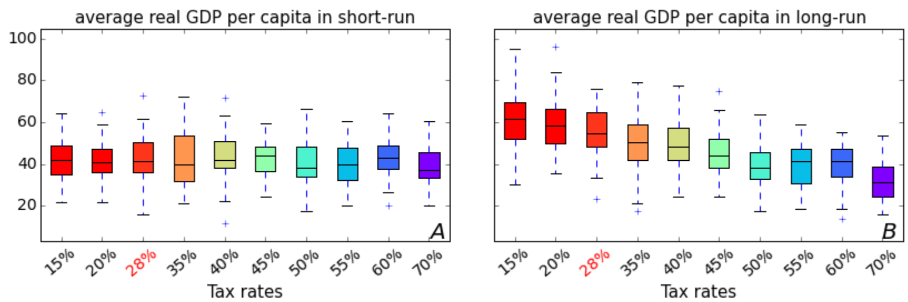

Figure 2.5: Sensitivity analysis – the tax rate and real GDP per capita
A and **B** demonstrate that box-plots of the average level of real GDP per capita over different tax rates, ranged from 15% to 70%, in the short and long run respectively. Average real GDP per capita is neither increased nor decreased much in the short-run regardless of the rate. In the long-run, on the other hand, it is negatively correlated with the tax rate. It is noteworthy that the presumed current tax is 28% and the range of y-axis in panel A and B are the same.

However, although individuals who are rich hence pay the tax work more and their firms may face an increase in production and profit, unlike those whose in the previous chapter, since a part of additional profit goes to CEOs, the wage of those individuals may not increase much relatively. Then, some of them are willing to leave their firms once activated and join others that give them lower wages so that they can evade the tax burden yet their after-tax wages become higher. The real problem is that since all employees at a firm are paid equally, it is likely the case many tax payers work at a few firms whose productivities are quite high relatively and they can leave the firm all together once they realize that they can make more at other firms. As a result, high-productivity firms are more vulnerable to the shock and likely to collapse in Figure A.4. CEOs are burdened by the tax as well yet, their after-tax income is still higher than their potential income when they move to other firms as employees, hence CEOs do not leave their firms.

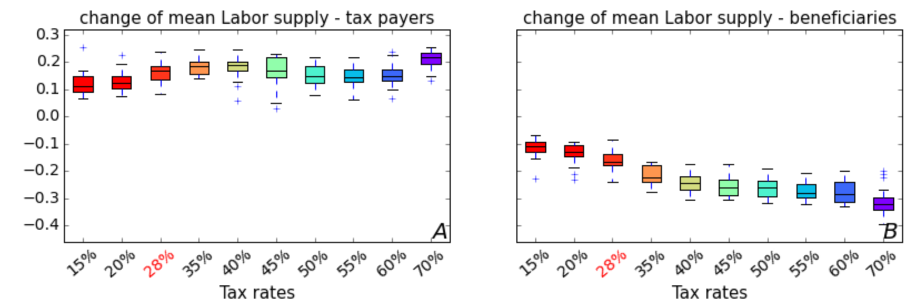

Figure 2.6: Sensitivity analysis – the tax rate and change of labor supply
A and **B** demonstrate how the average labor supply of those who pay tax and who receive benefits varied over different tax rates, ranged from 15% to 70%, respectively in box-plots. It is found that tax payers increase their labor supplies on average due to the substitution effect while beneficiaries decrease their labor supplies due to the income effect. The magnitude becomes larger yet slightly as the rate rises. It is noteworthy that it is a change among non-CEO workers and the presumed current tax is 28% the range of y-axis in panel A and B are the same.

Such a ironic shock not only has a negative impact on existing firms but also the growth of firms in the future. It breaks down whichever firms where most employees have to pay the tax. Moreover, its impact becomes bigger as the rate increases. In addition, as high-productivity firms begin to fall down, average income in this economy also begins to shrink accordingly as well as the average consumption. Not only it pulls down the supply curve but also the demand curve.

In the demand side, on the other hand, the effect is opposed to the previous one. As the rate is increased, the poor, receives more subsidies hence consumes more. Moreover, such an augmented redistribution scheme has a multiplier effect on consumption. As a more portion of the wealth, possessed by the rich who has relatively low marginal propensity to consume, is transferred to the poor who is willing to spends more than others as a percentage of income, the aggregate consumption is meant to be increased even further accordingly. In addition, such a boost signals firms to hire more workers hence increase productions higher, which, in turns, leads an increase in wages and a further stimulus to aggregate consumption.

This positive feedbacks, collectively, fuel the economy to advance.

In the short-run, when the tax rate is below 40%, it seems that the positive shock from the demand shock slightly dominates the negative shock from the supply side. Moreover, the closer the rate to 40%, the higher the magnitude of the dominance is. While the positive demand-side shock emerges immediately regardless of the tax rate, when the rate is mild, the negative supply-side shock – the break down of productive-hence-large firms – may not do so instantly.

Since large and productive firms compensate workers well enough, when the rate is below 40%, it is likely the case that even the after-tax income the employees receive is still higher than they can make at other firms. As a consequence, average GDP per capita rises and inequality falls yet slightly. However, when the rate is higher than 40%, it is reversed. the negative shock overwhelms the positive shock hence it all together only hurts the economy; average GDP per capita decreases and inequality increases little by little as the rate rises.

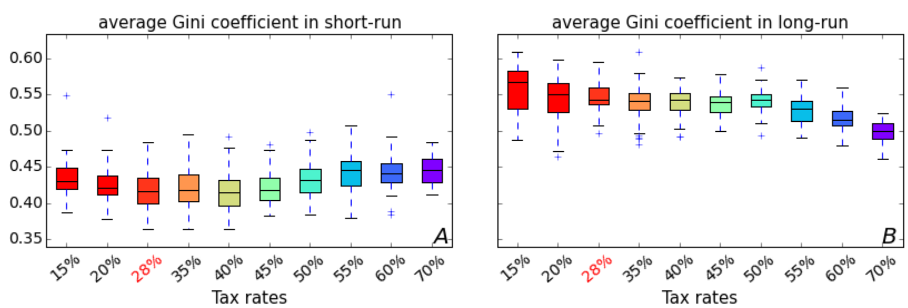

Figure 2.7: Sensitivity analysis – the tax rate and inequality

A and **B** demonstrate that box-plots of the average level of inequality over different tax rates, ranged from 15% to 70%, in the short and long run respectively. It is shown that average level of inequality was negatively correlated with the tax rate in short-run when the rate is lower then 50% and slightly increased. In long-run, it is negatively correlated with the tax rate, but it is not due to the redistribution of income as traditional theories insisted but low growth of an economy. It is noteworthy that the presumed current tax is 28% and the range of y-axis in panel A and B are the same.

In the long-run, since the largest firms could not grow further, it eventually, breaks down. Employees leave the firm for better after-tax compensations. As they leave the large firms and their before-tax incomes shrinks, so does the tax revenue and the subsidy.

Now, the supply-side shock harms the economy not only through the supply side but the demand side by weakening the positive demand-side shock. Alongside decreased subsidies due to the fall of the tax revenue, the supply-side shock aggravates the underlying problem and accelerates the vicious cycles explained in section 2.4, the economy falls more rapidly. Moreover, the magnitude of such a demolishing process in the long run becomes only worsen as the rate rises. Thus, the higher the tax rate is, the further decline in the average level of GDP per capita (Figure 2.5 panel B) and, the shorter period an economy could thrive. It is found in Figure 2.8 that the length of duration is negatively correlated with the tax rate.

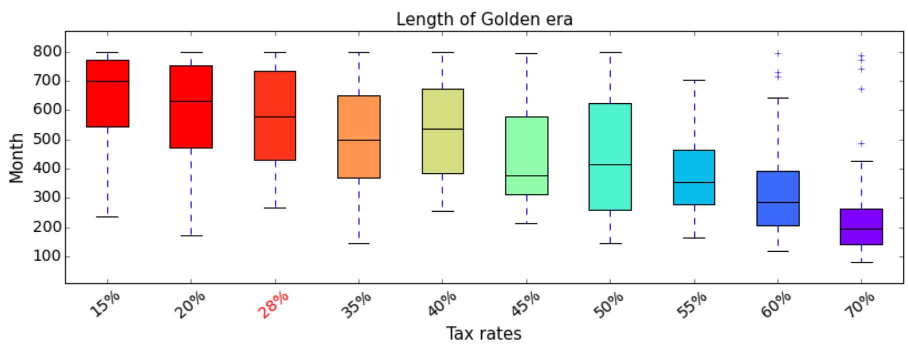

Figure 2.8: Sensitivity analysis – the tax rate and duration of subsistence of an economy
The Box-plot of average duration of an economy was able to survive given a tax rate while holding other variables constant was depicted. It is demonstrated that the lower the tax rate is, the longer an economy can thrive. It is noteworthy that the presumed current tax is 28%.

Surprisingly, however, it is observed that the average level of inequality was not affected unless the tax rate is extremely high in the long term. The main reason is that the redistribution effect of the policy continued to diminish over time and over the rates and became negligible in the long run. It only works when the rate is extremely high. Hence, inequality in an economy, regardless of its tax code, followed the similar trajectory; it continues to rise and reaches the extremely intolerable level where the economy becomes so fragile that it collapses. Yet, when the rate is extremely high, a whole process explained above took a shorter amount of time, the economy collapses even before the level of inequality becomes extremely severe relatively. The average inequality becomes lower than that in the former scenarios.

Overall, when the tax rate is increased mildly below 40%, the result shows that it has a modest yet positive effect on both growth and inequality in the short run. Meanwhile, beyond the level, the negative shock from the supply side is strengthened hence weakens the positive demand side shock and hurts the economy even more. Regardless of the rate, in the long run, the economy is collapsed as the supply shock overwhelms the demand shock more and more over time.

Although the outcome is disappointing, it should not be understood that an increase in tax up to 40% could not prevent income concentration and stimulate the economy yet only cause harm to the economy in the long-run. Rather, it needs to be understood that such consequences are emerged through the repeated sequence of reciprocal cause and effect explained above rather than due to the discouragement of workers as the traditional theory has suggested. What really this analysis suggests is, when average workers already work hard enough at their respective optimal levels, unless the fundamental problem is touched and repaired, the taxation may not be sufficient enough to mitigate underlying issues.

2.5.4 Minimum wage

When the ratio of the minimum to median wage is increased from 0.25 to 0.8 where the current ratio is 0.38, contrast to concerns that conventional theories have expressed, the simulation result demonstrates that an increase in the minimum wage neither hurt an economy in the short nor long run. Rather, it is found in Figure 2.9 that when the ratio of the minimum to median wage (hereafter RMM) is moderately high, above 0.5, it stimulates the economy slightly in the short run. In addition, the level of inequality is decreased as the RMM rises in Figure 2.10 panel A. In the long-run, both real GDP per capita and inequality are neither increased nor decreased as the minimum wage is raised.

In the short-run, as those whose wages are less than the minimum wage and who are meant to have higher desire to consume, receive more wages, collectively it shifts up the aggregate demand curve proportionally. In fact, as more money goes to those who have higher marginal propensities to consume and the less to those have lower, it stimulate the demand hence the economy. Even though small and medium size firms that have compensated their workers with below-the-minimum-wages might be suffered from an increase in labor costs, some of those firms are soon compensated by an increase in demand sufficiently enough to cover up the loss continue their businesses.

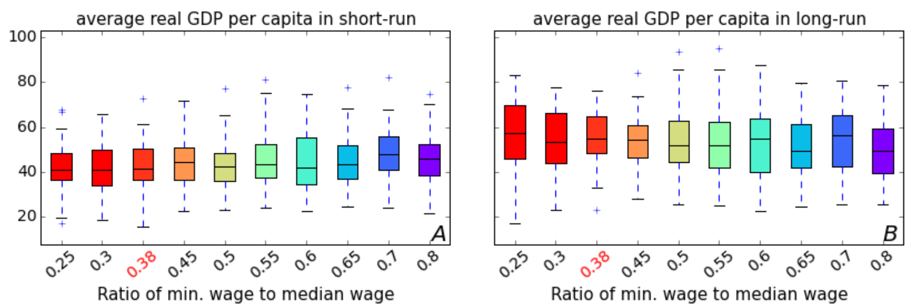

Figure 2.9: Sensitivity analysis – the minimum wage ratio and real GDP per capita
A and **B** demonstrate that box-plots of the average level of real GDP per capita over different minimum wage ratios, ranged from 0.25 to 0.8, in the short and long run respectively. Average real GDP per capita is increased moderately if the ratio is relatively high in the short-run. In the long-run, there is no statistically-significant change over the ratios. It is noteworthy that the presumed current ratio is 0.38 and the range of y-axis in panel A and B are the same.

It also strengthens small and mid-sized businesses and helps them continue to grow further through reciprocal feedbacks in the demand side channel in the economy. Firms would hire more workers hence produce more outputs to meet an increase in the overall demand correspondingly. Nonetheless, not all firms could fill their vacancies; only those firms that offered relatively high wages locally could employ additional workers. Through this selection process, the fittest firms became larger and reciprocally provide higher wages to their workers.

Though this selection process, the economy becomes more healthy and sound as individuals move to firms which have vacancies and are able to offer higher compensations. As a consequence, the demand increases even further proportionally and so is the production.

Such positive externalities therefore boost a whole economy slowly but gradually in the short run.

However, Such an impact in the demand-side is significant only when the RMM rose moderately high. In other cases – when the RMM is slightly higher than the current ratio, although workers are still compensated more than previously, since they spend only a portion of additional incomes, δ, their consumptions are much the same hence collectively could not trigger above process and fail to boost the economy substantially. Nonetheless, it is important to state that an increment in the minimum wage did no harm to the economy.

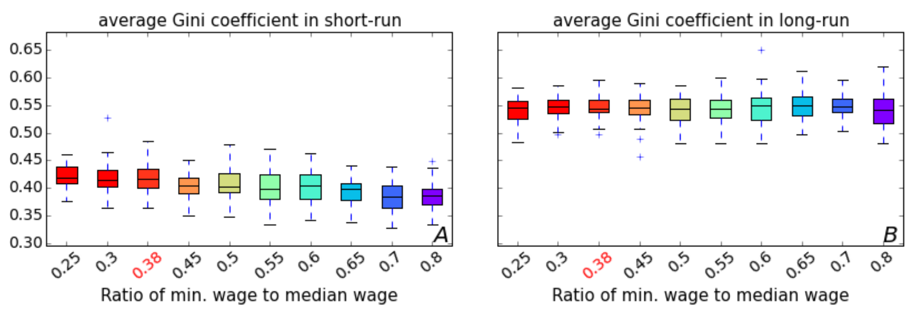

Figure 2.10: Sensitivity analysis – the minimum wage ratio and inequality
A and **B** demonstrate that box-plots of the average level of inequality over different minimum wage ratios, ranged from 0.25 to 0.8, in the short and long run respectively. It is shown that average level of inequality is decreased as the ratio rises in the short-run whereas it is pretty much the same in the long-run. It is noteworthy that the presumed current ratio is 0.38 and the range of y-axis in panel A and B are the same.

When it comes to inequality, of course, the indirect income redistribution program has a sound effect on reducing inequality. As individuals are paid the minimum wage or more and CEOs as a result receive less than before, the wage gap is reduced. Moreover, its magnitude becomes greater as the minimum wage is increased; it is dropped from a little above 0.4 to around 0.35 when the RMM was raised from 0.38, which is the current ratio, to 0.8 in Figure 2.10 panel A.

In the long run, all firms are merged into one large giant firm, or in other words, only one firm survives through the process explained above and in section 2.4, its compensation is always higher than the minimum wage unless the RMM becomes greater than 1.[11] Thus, the magnitude of the effect on growth and inequality was diminished as time went by. Moreover, once the economy reaches this state, It eventually collapsed regardless of the RMM. Nonetheless, due to the strong positive effect in short run, an economy with a higher minimum wage ratio was more likely to prosper longer. In Figure 2.11, it is demonstrated that the average period that an economy last before the fall rose as the RMM was increased.

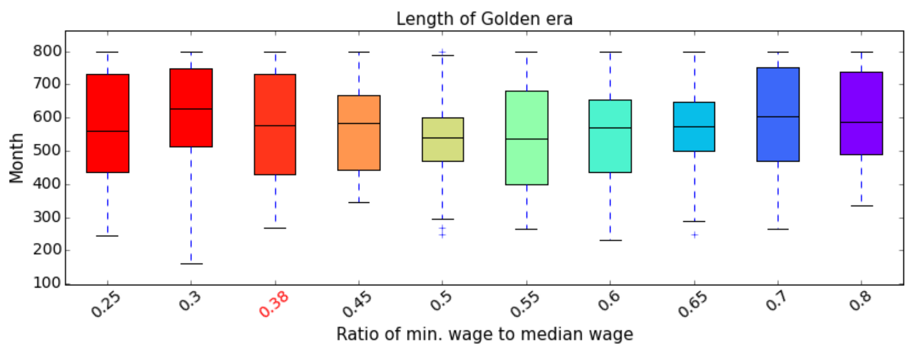

Figure 2.11: Sensitivity analysis – the minimum wage ratio and duration of subsistence of an economy

The Box-plot of average duration of an economy was able to survive given a minimum wage ratio while holding other variables constant is depicted. It is demonstrated that the higher the ratio is, the longer an economy can thrive. It is noteworthy that the presumed current ratio is 0.38.

The result suggests that an increase in minimum wage maybe more efficient and effective than the direct subsidy program in the short run given its performance on growth and inequality. However, this program also only works in the short-run. Yet, it does so not because its impact diminishes over time but because this again could not fix the underlying problem which is a CEO-biased compensation system. This must be considered that an increase in minimum wage can effectively mitigate the fundamental issue in the short run hence deter the collapse of an economy.

[11]In this case, since the mean and median wage are equal to the wage the firm offers, the firm's wage is always greater than the minimum wage.

2.6 Conclusion

In this chapter, I have developed a stylized multi-level and multi-market ABM upon critical traditional assumptions. Yet unlike to the traditional models, individuals' strategic decision making processes are not deliberately designed from top down but evolve endogenously from bottom up through the interactions of agents in micro level. This model, therefore, allows the analysis on the relationship between inequality and growth beyond the conventional scope and is able to investigate and compare different institutional settings. Moreover, despite its simple design, the calibrated model is able to reproduce some stylized facts related to the subject of this research: increasing inequality, severe income concentration on the richest 1%, and so on.

The simulation output confirms that if the transfer of wealth from the poor and middle class to the rich persisted through an unfair compensation mechanism, even if its magnitude is mild, a whole economy soon falls in to the inequality trap followed by a severe recession. In order to mitigate such issues, I conducted rigorous analysis on the impact and direction of two policies such as taxation and minimum wage. It is suggested that when the tax rate is increased moderately, up to 40%, or the ratio of minimum to median wage is raised high beyond 0.5, both policies have a positive effect on the average income per capita and inequality slightly in the short run. Yet, an increase in minimum wage is more efficient than taxation since it does not generate any negative shock in the supply side.

However, in the long run, neither of them is able to prevent the collapse of an economy. Nonetheless, All the negativities of both programs that traditional theories have speculated are either not found or negligible. The primary reason is the neither of those policies is the solution for the underlying cause – CEO-favored compensation system. In the long run, regardless of any policy changes, a wealth in the economy is concentrated in the hands of a few more and more over time, which causes the fall of the economy at the end. This result proposes that unless the distribution is reformed fundamentally thus more competitively, the break down of the economy may not be avoided even though it could be delayed by implementing income redistribution policies suggested above.

Chapter 3: General Equilibrium and Inequality with Lancaster preference

3.1 Introduction

Suppose there are a number of people who live in a garden with finitely many apples and bananas. The trees of those fruits are randomly distributed in the garden and so are the people. Due to the random distribution of trees and individuals, some residents live in the areas where there are more bananas than apples and others in the places with more apples. Let's further assume that some of the former group prefer apple to banana and some others in the latter group like banana more; so they are not satisfied with the current allocation of resources. Somehow – it is discussed in following sections in detail – they figure the way out of sorting this inefficient resource – fruits – allocations and more importantly, they are able to carry out the plan. Upon the execution of such a plan, everyone becomes happier.

This is how the story ends according to traditional theories of supply and demand. In this simple barter economy with only two goods – apple and banana, the auctioneer – let's assume that there is one – announces the price of apple and banana to everyone in the very beginning (Walras, 1954). Those who have excess supplies and demands come to the auctioneer and report that the prices are too low or high. The auctioneer then adjusts the price level until it clears the markets. Through this market clearing process, in Walras (1954)'s term, *tâtonnement*, no one has neither excessive supply nor demand eventually, and they live happily ever after.

However, what if some individuals prefer apple to banana not just because they like apple more but because it is chewy and juicy – the characteristics of apple? What if the same individuals are indifference between two goods as long as they are chewy and juicy? In fact, these are not some hypesthetic but realistic assumptions which traditional theories have overlooked over decades. People buy goods not because they like goods itself but because they like properties – or characteristics – of those goods. This is why people choose one good over another although their functionalities are fundamentally the same.

Moreover, the traditional theory could not explain how different perceptions of individuals on the same goods would affect the allocation of resources – inequality. In the traditional perspective, inequality is an indicator of variance in the value of goods and services members of a society have acquired given the assumption that they prefer a certain combination of goods to others. Instead, if individuals prefer a certain combination of characteristics which can be obtained from different goods not one, the traditional theory is limited to elucidate further.

Traditional demand theories, therefore, are very useful yet limited to describe how given resources, or goods, should be distributed to the point where there is no single individual would gain additional benefit without hurting others – Pareto efficiency when people prefer one good to another because they like the one itself more. However, first, it could not explain how such an allocation can be achieved without the auctioneer because it failed to justify the existence of such an auctioneer and her role in a real economy. In this regard, previous studies on decentralized market systems (Albin and Foley, 1992; Axtell, 2005; Crockett et al., 2008; Farmer et al., 2005; Gode and Sunder, 1993) verified that Pareto efficiency can be achieved without the auctioneer at least asymptotically. Second, which is the main concern of this chapter, it is failed to describe the efficiency and equality of resource allocations after trades if individuals prefer characteristics of goods instead of goods itself.

Lancaster (1966a, 1971, 1966b) criticized that economists has long concentrated on the preference side of consumer demand hence often taken another side of consumer demand lightly, which is information about goods. As a result, the existing demand theory make no use of information about things, in other words, properties of goods. "Goods, as such, are not the immediate objects of preference or utility or welfare but have associated with them characteristics which are directly relevant to the consumer" (Lancaster, 1966a).

One could argue that the properties of goods are already weighed in an individual's utility function, hence, the preference among goods represents the preference among objective properties possessed by those goods indirectly. However, if there are individuals whose preferences over goods happen to be identical but their preferences over properties of goods are not, it is very hard to identify the radical difference with the traditional approach which have faced limitations explained above.

In other words, once a manufacturer makes specific changes in one or more properties of a good, or introduces a new good to reflect the needs of unsatisfied consumers hence serve them better, which occurs frequently in the real world, the traditional analysis cannot provide any clues that how individual and the aggregate demand would be affected. Lancaster (1971) said, "any change in any property of any good implies that we have a new preference pattern for every individual; we must throw away any information derived from observing behavior in the previous situation and begin again form scratch." Conventional approach can demonstrate what the optimal allocation of goods would be but it cannot predict that of goods if there more more or less number of goods and why so.

The concept of characteristics and properties of goods is not new but introduced by several economists including Lancaster in mid-1900s (Chamberlin, 1949; Hicks, 1986; Menger, 1981). Moreover, it has been used in environmental economics to measure the true price of a commodity such as house because it is affected by various environmental factors, e.g., air pollution, traffics, neighborhood and so on (Can, 1992; Harrison and Rubinfeld, 1978; Rosen, 1974). However, these studies are restricted and limited to explore environmental cost and benefit related to certain type of commodities on the empirical basis. Few papers that adopted this hypothesis – goods are valued for their utility-bearing properties or characteristics – in order to understand dynamics of consumer behaviors and how a society evolves by itself. Moreover, the research on this subject has not been advanced further hence remained on the highly abstract and theoretical level due to following technical and analytical difficulties.

First, individuals must be heterogeneous – some individuals recognize the same good in fundamentally different ways.The behavior of the representative consumer is limited to represent many individuals' different consumption behaviors. Second, there must be multiple number of goods and characteristics hence it is very difficult to find implicit prices, or "hedonic price indexes", of goods for each agent analytically. Third, since individuals are heterogenous and goods are perceived differently to different individuals, it is very difficult to coordinate the allocation of resources or goods with the traditional approach – Walrasian Auctioneer.

Hence, in this chapter, I built a barter-based economy where heterogeneous individuals independently evaluate goods for their utility-bearing *characteristics* in order to scrutinize (i) whether the convergence of price of each good takes place at the end of a simulation, (ii) how efficiently resources are distributed among agents in the society, (ii) and emergence of inequality. For the comparison purpose, I examined the same affairs by replicating Albin and Foley (1992)'s work, where individuals earn utilities directly from goods rather than its characteristics, in an otherwise identical economy to confirm the traditional belief.

If the convergence in price is observed, i.e., equilibrium exists, only in the latter economy, not in the former, it can argued that individuals could be motivated to invent or discover a new good whose combination of characteristics is different from existing goods in the former type of economy. Hence, a whole economic system evolves endogenously with newly emerged goods. In addition, such a result may suggest that there may be no long-run equilibrium since individuals continue to find a way of improving their well-beings through above *tâtonnement* without making at least one individual worse off.

This chapter is organized as follows. In Section 3.2, it is explained the methodology; how an artificial economy works and individuals behave. The results are presented and discussed in Section 3.3 and . Section 3.5 concludes this chapter.

3.2 Methodology

3.2.1 General features

It is noteworthy that the existence of equilibrium is not explicitly assumed in this research. An equilibrium is just a simple result emerged after things have been settled down.(Schelling, 2006). Since the primary goal of this research is understanding *tâtonnement* – how heterogeneous consumers adjust their behaviors as pursuing self-interested goals – rather than what an economy would look like in the long run, the equilibrium analysis which is built upon such an assumption has little to speak about along with technical difficulties explained above.

Therefore, instead of building a system of equations, I implemented an Agent-based model (hereafter, ABM) in order to create a society whose complexity is emerged through interactions of the members of the society in a decentralized way. ABM does not have an ex-ante assumption of the existence of equilibrium hence does not have a set of aggregate behavior rules which is used to believed through which individuals behaviors can be represented. Instead, it allows individuals to interact with each other and exchange information through which macro phenomena emerge endogenously. Moreover, it is very important to build such an artificial economy to resemble the real economy which is believed is a self-organizing system; even when it starts from an almost homogeneous or almost random state, it forms large-scale patterns spontaneously. (Krugman, 1996)

An artificial economic system I built in this chapter is a closed economy where individuals who are heterogeneous. Furthermore, in such an economy, all individuals are bounded rational so that it is neither for them to know the market-clearing prices for goods and any macro-level information is nor available for them. Many studies including Tolman (1948, 1951)'s work proposed that that an individual learns from her past experience adaptively and adjusts her behaviors to be more effective and efficient given environment rather than behaves rationally.

Moreover, in this economy, it is no longer assumed to have (Walras, 1954)'s auctioneer whose existence and practical function is unknown. As an alternative, I proposed that the markets are local and decentralized. Individuals can only interact with their neighbors to barter. It is verified in many previous studies that the decentralized market system is almost as much efficient as the market with Walrasian auctioneer (Albin and Foley, 1992; Axtell, 2005; Crockett et al., 2008; Farmer et al., 2005; Gode and Sunder, 1993), and has gained strong empirical support recently.

Last but not least, in order to measure the resource allocation efficiency, I employed the coefficient of resource utilization (hereafter CRU), introduced by Debreu (1951) and utilized in many other studies (Albin and Foley, 1992; Arrow et al., 1971; Coelli et al., 2005; Farrell, 1957). It indicates the ratio of how much resources are required at least to meet individuals' current utilities to how much resources they have in a society. It ranges 0 to 1; the higher CRU is, the more efficiently resources are allocated.

3.2.2 Consumption Technology

Likewise Lancaster (1971), it is operationally assumed that all characteristics are quantitative, objectively measurable and operationally distinguishable; $b_{i,j}$ is the quantity of the ith characteristic possessed by a unit amount of the jth good. In addition, given z_i and x_j, which represent quantities of the ith characteristic and jth good respectively, following properties are assumed as well.

Linearity: $z_i = b_{i,j}x_j,\ \forall\ i, j \in \mathbb{R}$. An unit of the jth good possesses $b_{i,j}$ amount of the ith characteristic, hence, the total amount of the characteristic is $b_{i,j}x_j$.

Additivity: $z_i = b_{i,j}x_j + b_{i,k}x_k,\ \forall\ i, j, k \in \mathbb{R}$. A total amount of ith characteristic owned by a collection of goods x_j and x_k is the sum of the amount of the characteristic possessed by x_j and x_k, respectively.

Suppose there are 'r' number of characteristics and 'n' number of goods. It is, then, derived along with above assumptions that the total quantity of ith characteristic held by a vector of goods is expressed as follows. $z_i = \sum_{j=1}^{n} b_{i,j}x_j,\ i = 1, ..., r.$

In a matrix formation, which is frequently used in following analysis in this chapter,

$$z = Bx \tag{3.1}$$

where $z = [z_1, ..., z_r]$ is a vector of characteristics, $x = [x_1, ..., x_n]$ is that of goods, and $B = [[b_{11}, ..., b_{1n}]...[b_{r1}, ..., b_{rn}]]$ is a $r \times n$ matrix of coefficients which maps goods onto characteristics. Noted that $z = Bx$ explicitly defines a unique set of characteristics associated a given vector of goods, but, not the other way around. It is also important to state that equation 3.1 does not suggest any relationships between the number of characteristics (r) and that of goods (n); it is possible that one can be greater than or equal to another. However, assuming practically, it is likely that r is less than or equal to n[1], thus, in this chapter, it is only considered situations where $r \leq n$.

3.2.3 Agents

It is explicitly assumed that all axioms of Von Neumann-Morgenstern utility theorem hold in this economy. Therefore, individuals have well-defined preferences for collections of characteristics, expressible in terms of preference map with indifference curves convex toward the origin (Lancaster, 1971). Each agent h is given a random amount of each good, $x_{h,j}$ and a sum of given goods, $x_h = \sum_{j=1}^{n} x_{h,j}, \ \forall \ h \ \in \mathbb{R}$, is individual i's total endowment initially. Given amount of goods, x_h, each individual maximizes her utility, presented in a Cobb-Douglas function, with respect to characteristics she can attain from goods she possesses and a set of her preference(α_h) over characteristics.

$$U_h = U(z_h; \alpha_h) = \prod_{i=1}^{r} (z_{h,i})^{\alpha_{h,i}} \tag{3.2}$$

$$st. \ \ z_h = B_h x_h$$

[1]If n is greater than r, it means that each good is very uniquely defined by its characteristics in a way that it is unlikely substituted by any other goods for all agents, which is unrealistic

Thus, the individual is long to find z_h^*,

$$z_h^*(\alpha_h) = \arg\max_{z_h} U_h(z_h; \alpha_h)$$

However, even though characteristics are quantifiable, it cannot be traded among people because it is not an entity that an individual can acquire directly but indirectly by consuming commodities. Even if it could be, more to the point, it is not exchangeable because it is simply priceless; its values are different to different individuals. Therefore, an individual must delineate her utility indirectly in terms of goods given a matrix of coefficients so that each individual can measure the value of characteristics in terms of goods that is comparable to others. Goods in this case, play a role of a medium of exchange. Had substituted the equation 3.1 for z in above equation, indirect utility function can be derived with respect to B and x as follows.

$$V_h = U(z_h(B_h, x_h)) = V(B_h, x_h) = \prod_{i=1}^{r} (B_{h,i} \cdot x_i)^{\alpha_{h,i}} \tag{3.3}$$

$$\text{where } B_{h,i} = [b_{i1}, ..., b_{ir}]$$

The agent is now looking for x_h^* adaptively instead of z_h^* i.e.,

$$x_h^*(\alpha_h) = \arg\max_{x_h} V(x_h; \alpha_h, B_h)$$

It is noteworthy that $B_{h,i}$ is the ith row of the coefficient matrix. Given indirect utility function (V_h), an individual h can compute her marginal rate of substitution (hereafter MRS) according to equation 3.4, simply a ratio of subjective value of one good to that of another, and compare it with her trade partner's.

$$MRS_{v,w}^h = \frac{MU_v^h}{MU_w^h} = \frac{\frac{\partial U(z_h)}{\partial z_h} \cdot \frac{\partial z_h}{\partial x_{h,v}}}{\frac{\partial U(z_h)}{\partial z_h} \cdot \frac{\partial z_h}{\partial x_{h,w}}} = \frac{\frac{\partial VB_{h,x_h}}{\partial x_{h,v}}}{\frac{\partial VB_{h,x_h}}{\partial x_{h,w}}} \tag{3.4}$$

If there are two goods, x_1 and x_2, and two characteristics, z_1 and z_2, for example,

$$MRS_{x_1,x_2}^h = \frac{MU_{x_1}^h}{MU_{x_2}^h} = \frac{\frac{\partial VB_{h,x_1}}{\partial x_1}}{\frac{\partial VB_{h,x_2}}{\partial x_2}} = \frac{\alpha b_{11} z_2 + (1-\alpha) b_{21} z_1}{\alpha b_{12} z_2 + (1-\alpha) b_{22} z_1} \tag{3.5}$$

$$= \frac{\alpha b_{11}[b_{21}x_1 + b_{22}x_2] + (1-\alpha) b_{21}[b_{11}x_1 + b_{12}x_2]}{\alpha b_{12}[b_{21}x_1 + b_{22}x_2] + (1-\alpha) b_{22}[b_{11}x_1 + b_{12}x_2]}$$

In a special case where z and x have one-to-one relationship – a good possesses only one characteristic, the coefficient matrix becomes an identity matrix – a matrix with ones on the diagonal and zeros elsewhere, an agent's behavior can be represented in a traditional way. Utility now can be a function of either goods or characteristics and individuals can maximize their utilities with respect to x and calculate their MRSs directly. Mathematically speaking,

$$U_h = U(x_h; \alpha_h)$$

$$x_h^*(\alpha_h) = \arg\max_{x_h} U(x_h; \alpha_h)$$

$$MRS_{v,w}^h = \frac{MU_v^h}{MU_w^h} = \frac{\frac{\partial U(x_h)}{\partial x_h}}{\frac{\partial U(z_h)}{\partial z_h}}$$

If there are two goods, for example, the MRS of goods is as follows.

$$MRS_{x_1,x_2}^h = \frac{MU_{x_1}^h}{MU_{x_2}^h} = \frac{\alpha}{(1-\alpha)} \frac{x_2}{x_1}$$

3.2.4 Dynamics

For simplicity, it is only considered when the number of goods and that of characteristics are limited by 2, respectively. Since it is assumed that individuals can only do barter, the trade activity can be represented in an Edgeworth box. Suppose there are two individuals, O and A and O's MRS of good v and w is larger than A's MRS, which means O is willing to buy x_v and sell x_w and A is vice versa. Since MRSs are not equal, they are willing to initiate a trade to improve their well-beings to the point where their post-exchange MRSs become identical or close to each other hence an additional trade could not make them happier – accomplishing (bounded) optimal allocations.

Table 3.1: Baseline model attributes

Parameters	**Values**
preference coefficient, α_i[2], $\forall\, i$	uniform(0.2,0.8)
characteristic coefficient, $b_{i.j}$[3]	uniform(0.0,1.0)
endowments, ω	uniform(50,200)
number of neighbors	uniform(2,4)
agent activation order	random
time calibration, t	one month
number of characteristics, r	2
number of goods, n	2
number of agents, H	1,000
number of simulations	20
total run time, T	20

The sequence is as follows. At the beginning of the simulation, all agents receive a random amount of each good, $x_{h,j}$ and the sum could be as large as up to 200. At every time, t, all individuals are activated sequentially but in a random order. Upon activation, each individual contacts her neighbors to exchange goods in pair if they are willing to do so. Once all agents complete their tasks, statistics are calculated, and the simulation starts

[2] $\sum_{i=1}^{r} \alpha_i = 1$

[3] $\sum_{j=1}^{n} b_{i,n} = 1$

over – another round of exchange – until the end of the simulation. Model attributes can be found in Table 3.1.

3.3 The Complexity of Equilibrium

3.3.1 Special case

When a good has only one characteristic and each good has a different characteristic – $B = I = \begin{bmatrix} 1.0 & 0.0 \\ 0.0 & 1.0 \end{bmatrix}$ – hence considered as a immediate object of preference – a special case of Lancaster's theory and a typical case of the traditional supply and demand theory – it is found that asymptotic convergence in average MRS of goods toward the optimal level, 1.0 – where the marginal utility of consuming additional unit of good 1 and 2 become equal – in Figure 3.1 panel A[4]. Moreover, the standard deviation of MRSs, grey color bar in panel A, is decreased monotonically and becomes very small and negligible.

Panel B and C in Figure 3.1 demonstrate what the convergence would look like in another angle – individual level. In this figure, individuals' MRSs at the beginning (panel B) and the end (panel C) of a simulation are portrayed for comparison. At the beginning, a majority of agents have one good more than they desired and another less than they want; individuals' MRSs are very different from one another.

Because most agents if not all, are not satisfied with what they have, they are motivated to barter with their neighbors in order to increase their utilities as much as possible. Over a handful number of trades, individuals continue to have more balanced endowments which bring more joy to them; the difference in MRSs once large in panel A is reduced significantly in panel B and the average level of MRS is diminished accordingly in the early stage of the simulation.

Eventually, individuals' MRSs are asymptotically converged to 1.0 and so is the average

[4]The simulation results replicate Albin and Foley (1992)'s work very closely although a few modifications were made.

MRS, which is strong enough conclude that the markets are cleared almost perfectly – Pareto efficiency is achieved. In other words, micro-motivated behaviors in decentralized markets collectively could achieve close-to-perfect efficient resource allocations hence stabilize an economy and leads it into equilibrium in the long-run.

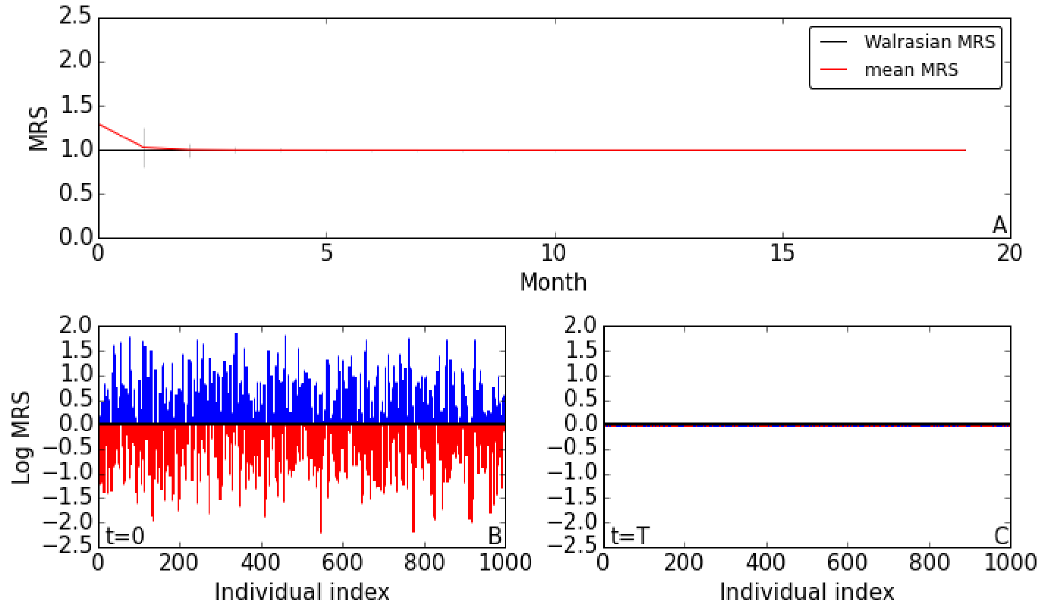

Figure 3.1: [MRS, utility and CRU in a special case]
Graphical representation of the average level of MRS throughout the simulation period (top) and individuals' MRS at the beginning of a simulation (bottom left) and the end (bottom right) in the special case of Lancaster's theory. The solid red line represents the mean value and solid grey line for the standard deviation of MRS in panel **A**. In panel **B** and **C**, blue lines represents those whose MRSs are higher than 1 and red for those whose MRSs are lower than 1 at the beginning. Figures exhibit how MRSs are changed in micro and macro level over time; the convergence of (implicit) price in micro level toward equilibrium leads to that in aggregate level.

Moreover, it is found that self-interested behaviors collectively produces an improvement in the social welfare and the usage – or allocation – of given endowments through trade in Figure 3.2 panel A and B, respectively. Since individuals constantly barter and become better off, so does the overall well-being. The average utility rises, from 45 to 60. In addition, resources – endowments in this experiment, are very efficiently allocated among individuals through trade. The CRU is increased from 0.7 to little less than 1.0 which is very close to the perfect efficiency level[5]. In other words, as goods are transferred to those who need it most throughout trades, individuals have less excessive supply and demand of goods and make better use of given goods all together.

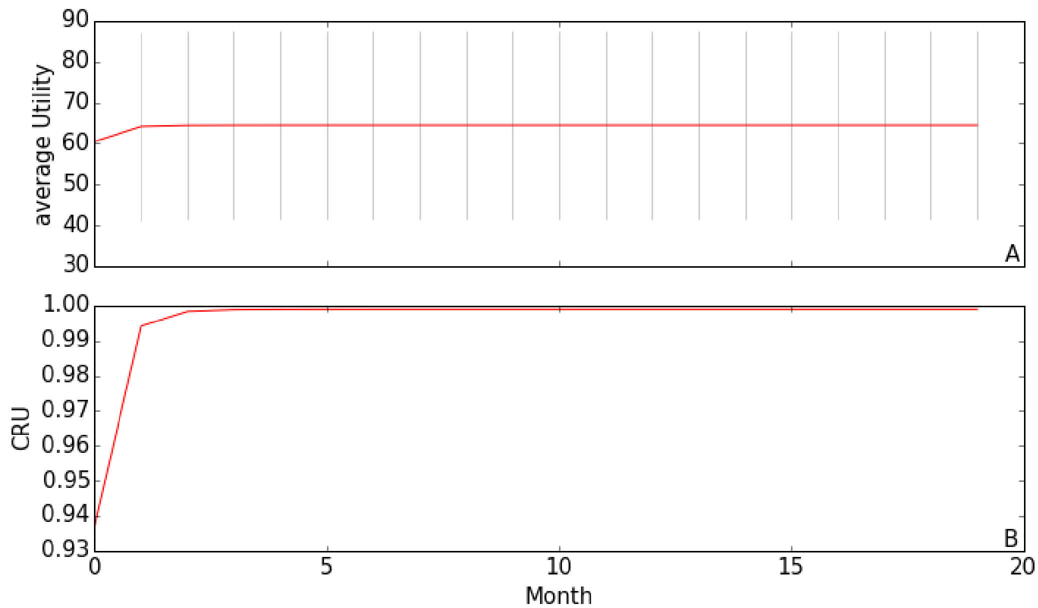

Figure 3.2: Comparison of MRS in a special case
Graphical representation of average level of utility and CRU in a special case of Lancaster's theory. In panel **A**, the solid red line represents the average utility and the grey the standard deviation. In panel **B**, the solid red line indicates the level of CRU over the simulation. Graphs demonstrate that both average utility and CRU are increased significantly through trades.

This simulation results suggest that when one good has only one characteristic, regardless of the initial resource distribution, individuals maximized their utilities through trades. As a consequence, Individuals' MRSs of goods as well as the average MRS of goods are converged to the optimal level in micro and macro level, and, the resource allocation becomes almost perfectly efficient – Pareto efficiency – and an economy converged to equilibrium.

[5]Since it is very hard to achieve perfect efficiency due to individuals' diverse preference and scarcity of resources, any number close to 1.0 indicates the resources are very much efficiently distributed among agents.

3.3.2 General case with a homogeneous B

When a single good has more than one characteristic and a single characteristic can be obtained from multiple goods,

$$B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} (1-b) & b \\ b & (1-b) \end{bmatrix}$$

the convergence of MRSs may not occur depending on the value non-diagonal element of B. The outcomes in Figure 3.3 are generated when $b_{ii} = b_{jj} = 0.65$ and $b_{ij} = b_{ji} = 0.35$ in an identical economy for the comparison purpose, but, it is qualitatively the same as long as $b_{ij} = b_{ji} > \alpha$.

Another interesting thing is the initial difference in MRSs in the general case is a lot smaller than that in the special case. In the special case, given α, since each good has only one characteristic, the ratio of characteristics individuals possess depends on the ratio of initial endowments individuals are given directly. If individuals have a lot of one good and little of another, their MRSs must be either very high or low. However, in the general case, given the same α, MRSs of goods not only depend on the amounts of goods but also values of non-diagonal elements in B matrix. Thus, even when the ratio of initial endowments is extreme, such an extremeness could be canceled out in calculating the MRS according to Equation 3.5.

Figure 3.3[6] panel A demonstrates that even though the average level of MRS is reduced from around 1.05 to the optimal level, 1.0, the standard variation is not – if it is, it is negligibly small – but remained the same throughout the simulation period. Graphs in panel B and C manifest the reason; some individuals' MRSs are not changed over the period as much as that of others even though they had done many number of trades in order to maximize their utilities. Since individuals are no longer interested in goods itself directly but properties – characteristics – of goods, if the characteristic ratios of existing

[6]It is noteworthy that the range of respective y-axes are the same as in Figure 3.1.

goods do not suit most individuals' interests, individuals could not gain much additional level of utility through trades.

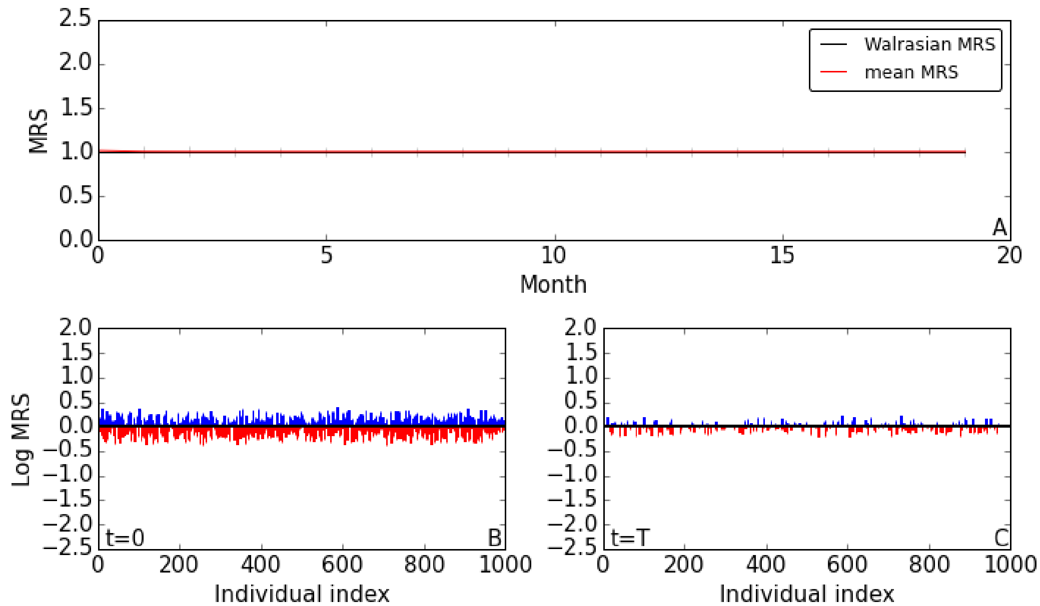

Figure 3.3: MRS, utility and CRU in a general case

Graphical representation of the average level of MRS throughout the simulation period (top) and individuals' MRS at the beginning of a simulation (bottom left) and the end (bottom right) in the general case of Lancaster's theory. The solid red line represents the mean value and solid grey line for the standard deviation of MRS in panel **A**. In panel **B** and **C**, blue lines represents those whose MRSs are higher than 1 and Red for those whose MRSs are lower than 1 at the beginning. Figures exhibit how MRSs are changed in micro and macro level over time. Although the average MRS is converged to the optimal level but its standard deviation is remained high due to the non-convergence in individuals' MRSs over the simulation.

Proposition 1. *Given* $x_1 > 0$ *and* $x_2 > 0$, $MRS_{x_1,x_2} > 1$ *if and only if* $(1-\alpha) = (b-\epsilon) < b < 0.5$.

In order to prove this, suppose $MRS_{x_1,x_2} > 1$.

$$
\begin{aligned}
MRS^h_{x_1,x_2} =& \frac{\alpha(1-b)z_2 + (1-\alpha)bz_1}{\alpha bz_2 + (1-\alpha)(1-b)z_1} > 1 \\
& \frac{(1-b+\epsilon)(1-b)z_2 + (b-\epsilon)bz_1}{(1-b+\epsilon)bz_2 + (b-\epsilon)(1-b)z_1} > 1 \\
& \frac{(1-b+\epsilon)(1-b)z_2 + (b-\epsilon)bz_1}{(1-b+\epsilon)bz_2 + (b-\epsilon)(1-b)z_1} > 1 \\
& (1-b+\epsilon)(1-2b)z_2 + (b-\epsilon)(2b-1)z_1 > 0 \\
& x_1[(1-b+\epsilon)(1-2b)b + (b-\epsilon)(2b-1)(1-b)] \\
& + x_2[(1-b+\epsilon)(1-2b)(1-b) + (b-\epsilon)(2b-1)b] \\
& \frac{x_1}{x_2} > -\frac{(1-b+\epsilon)(1-b) - (b-\epsilon)b}{1-b+\epsilon)b - (b-\epsilon)(1-b)} \\
& \frac{x_1}{x_2} > \frac{2b-\epsilon-1}{1} \\
& \frac{x_1}{x_2} > 0 > \frac{2b-\epsilon-1}{1}
\end{aligned}
$$

Thus, it is true that MRS_{x_1,x_2} is always higher than 1 when b is higher than $(1-\alpha)$. Since B is a symmetric matrix, it also applies when b is above 0.5. Moreover, the very same computation can be applied when b is greater than α.

Proposition 2. *Given* $x_1 > 0$ *and* $x_2 > 0$, $MRS_{x_1,x_2} < 1$ *if and only if* $\alpha = (b-\epsilon) < b < 0.5$.

In above cases, individuals' consumption behaviors become very extreme. They always want to buy one and sell another unless they meet partners whose combined preferences with respect to α and B are more extreme. For example, if $\alpha_i = 0.75$ and $b = 0.35$,

$(1-\alpha_i) < b$, additional consumption of x_1 provides an individual i 0.65 unit of z_1 and 0.35 of z_2 hence the individual i cannot be satisfied because each unit of x_1 provides z_1 less than the individual desire and z_2 more than the one looks for. The ratio has to be 0.75 to 0.25 or similar. The very same logic applies to individuals whose $\alpha_i < b$. Therefore, those agents continues to buy one good and sell another yet no matter how many trades they coordinate with their neighbors, it could not quench their thirsts for greater happiness. Interesting point is, even though they have mild preference on characteristics – α – and perception on goods – B – respectively, their yearning for one good over another became extreme and behave like those who have lexicographic preference in traditional theories[7]. As a result, their MRSs do not converge as much as that of others whose $(1-\alpha) > b$ or $\alpha > b$.

It is well described in Figure 3.4 where $b = 0.35$ and $(1-b) = 0.65$. Those whose αs' are close to or larger than 0.35 and close to or smaller than 0.65 are more likely to have well balanced combination of goods and their MRSs of goods become very close to the optimal level within the margin of ± 0.2 over trades. On the other hand, those whose αs are smaller than 0.35 or greater than 0.65, exhibit lexicographic consumption behaviors and their MRSs of goods do not converge much – it is either below 0.98 or over 1.02. There are some individuals have acquired only one good yet whose MRSs are very close to the optimal level. It is the case where they have extreme preference on goods but they have met, time to time, those whose preference on goods are more extreme hence have to sell what they prefer. Except such uncommon cases, the above explanation holds in most cases.

Of course, agents gain some additional utility through trade regardless of their initial conditions and their extreme trading behaviors. They are willing to trade with their neighbors as long as they can be better-off even by a little because they are rational however bounded. As a consequence, in Figure 3.5, the level of average utility is improved from 60 to 65 as well as CRU from 0.82 to 0.86, in panel A and B respectively. The improvement in welfare and the usage of given resources implies that individuals do what they can do

[7] Technically speaking, they do still have a convex preference yet the slope is either always greater or less than 1 depending on values of α and b

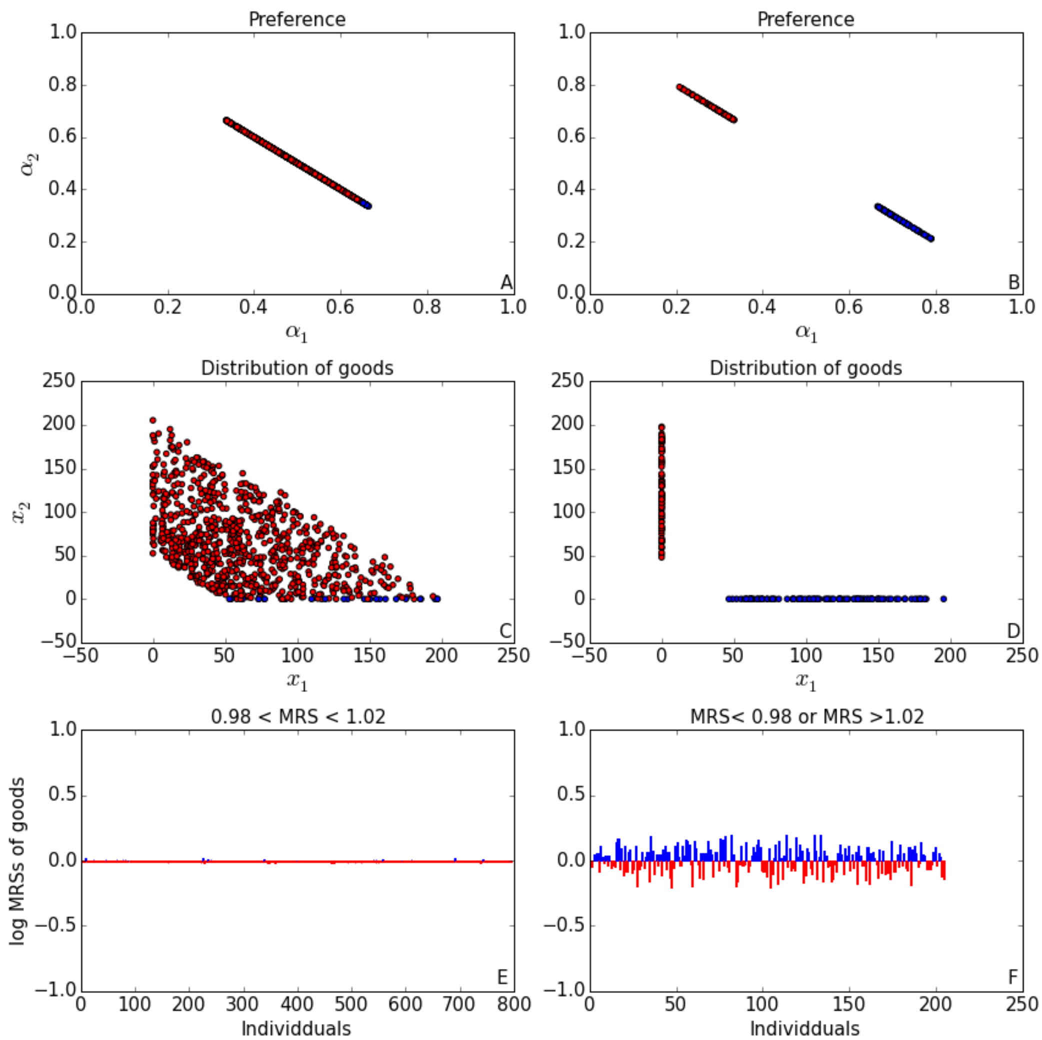

Figure 3.4: Distribution of MRSs, goods and preference in a general case
Graphical representation of individuals' preferences (panel **A** and panel **B**), possession of goods (panel **C** and panel **D**) and distribution of MRSs (panel **E** and panel **F** at the end of the simulation when $b_{ij} = b_{ji} = 0.35$ and $b_{ii} = b_{jj} = 0.65$. Blue color represents those whose MRSs are higher than 1 and red for lower than 1. The figures demonstrate that those whose α ($(1-\alpha)$) is close to or smaller than b_{11} (b_{22}), their MRSs asymptotically are converged to the optimal level, 1.0 and resource allocations are very close to Pareto efficiency level. Whereas MRSs of others do not converge as much as the former, although it becomes closer to the optimal level through trades. Moreover, their resource allocations become very extreme, and eventually they are caught up by budget (or endowment) constraints hence cannot coordinate further trades.

in order to increase their utilities given environment, but, the large dissatisfaction in individual level and yet-inefficient resource allocation indicate that there are still rooms for improvement.

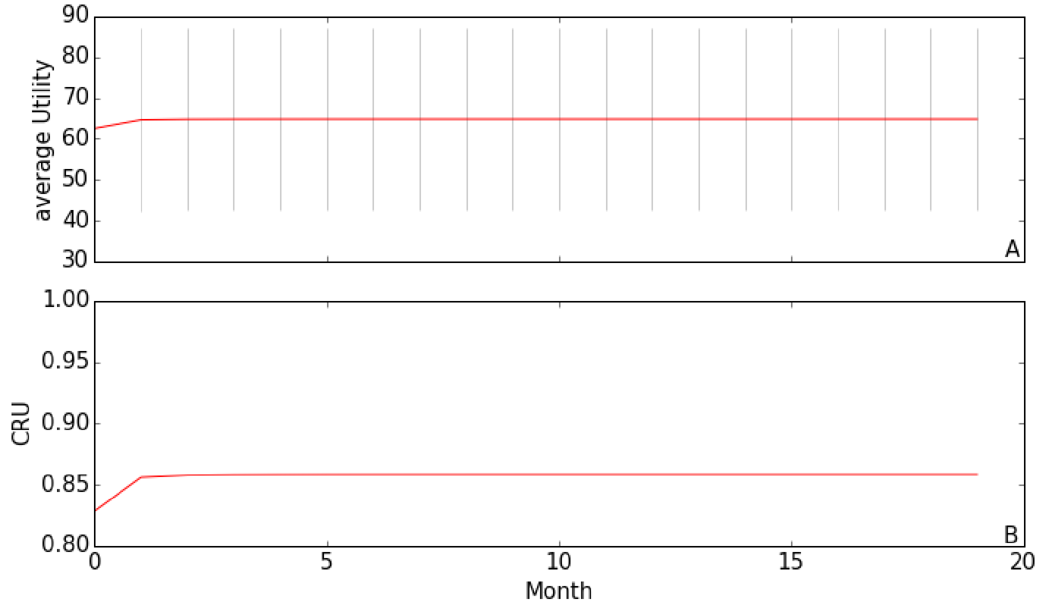

Figure 3.5: Comparison of MRS in a general case

Graphical representation of average level of utility and CRU in a general case of Lancaster's theory. In panel **A**, the solid red line represents the average utility and the grey the standard deviation. In panel **B**, the solid red line indicates the level of CRU over the simulation. Graphs demonstrate that both average utility and CRU are increased through trades.

Based on the simulation results, it is clear that the economy is not in the steady state. Aggregate behaviors of this economy – average MRS and utility and CRU – may look stable because the (implicit) price still converges to equilibrium anyway. However, it is just a temporal macro order – or equilibrium – arises from micro instability and highly unstable. It is like a ball on the inverted U shape surface; it could fall off to either side any time. In terms of traditional analogy, the micro system of this economy is currently at the edge of the boundary hence unstable, and as soon as the boundary is expanded, it is highly likely diverge from the current state.

3.4 Inequality

In this research, inequality is defined as follows. The variance of values of goods individuals possess. Since there is no nominal value for each good, the values of goods are calculated relatively according to the average MRS at time, t. Moreover, inequality is measured by GINI coefficient, which ranges from 0 – perfectly equal – to 1 – perfectly unequal.

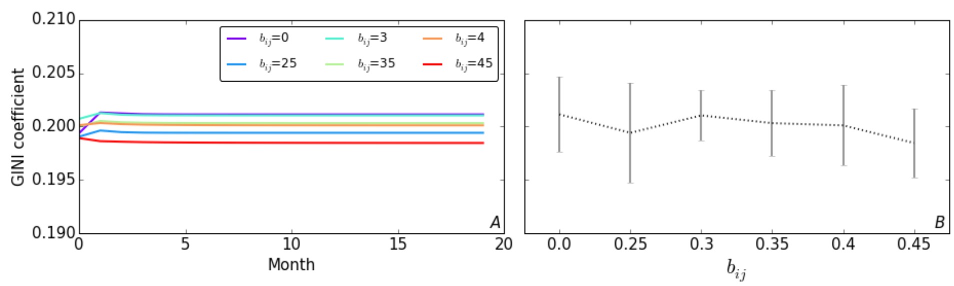

Figure 3.6: Inequality over time given B matrix

Graphical representation of average GINI coefficient over time and at the last period with the standard deviation for each b_{ij}. In panel **A**, each colored line represents the average value of GINI coefficient over time for different b_{ij}s, respectively. In panel **B**, the solid dotted line represents the average utility and the grey the standard deviation at the end of the simulation for each b_{ij}. It is found that inequality is not much affected whether characteristics or goods are the object of preference.

Surprisingly, Figure 3.6 shows that the change in the object of preference – from goods to characteristics, is not much related with the level of inequality. Although the level of after-trade inequality was decreased as the value of b increases, the magnitude is not statistically significant. However, this should not be understood that a change in the preference object does not affect the distribution of resources. Since a lot of trades take place every period in the beginning, yet GINI coefficient only measure the distribution of wealth at the end of each period, in other words, after all trade activities are done, it is very limited hence not useful to capture the dynamics of the change in the wealth distribution over trades within the period.

3.5 Conclusion

The role of information about goods in consumer behaviors is thoroughly examined in this chapter, which has been overlooked by the traditional demand theory. It is also scrutinized that how such a small yet fundamentally important modification in preference in individual level can result in large difference in aggregate behaviors. When individuals perceive goods as direct sources of utility, as the traditional theory has argued, simulation results show that equilibrium is emerged through a handful number of decentralized trades among individuals who are eager to maximize their utilities. The equilibrium, indeed, is stable hence individuals have no incentive of altering their decisions once optimized. Therefore, the traditional approach is useful yet limited to only exploring equilibrium behaviors when the goods are the immediate object of preference but is is no use of understanding of a society where characteristics of goods are the immediate object of preference instead.

If each individual's utility is linked to characteristics of goods rather than goods itself, simulation outcomes suggest that the vary same utility maximization behaviors collectively did not necessarily lead an economy into equilibrium. Some agents show lexicographic consumption behaviors although they have a mild preference on a set of characteristics and perception on a set of goods; MRSs (of goods) of those individuals do not converge. Collectively, MRSs of goods do not converge in micro level. Although it is still possible that the average MRS of goods do converge to the optimal level, since its standard deviation is remained high, it is hard to conclude that the economy, after numerous number of trades, finds itself in the steady state.

When it comes to inequality, it turns out that GINI coefficient, an index for measuring the level of inequality is limited to capture dynamics of the change in wealth over trades within a period. Hence, it is not clear, in this study, that the change in the object of preference, from goods to its characteristics, would affect the evolution of inequality over trades as well as over time.

Appendix A: An Appendix

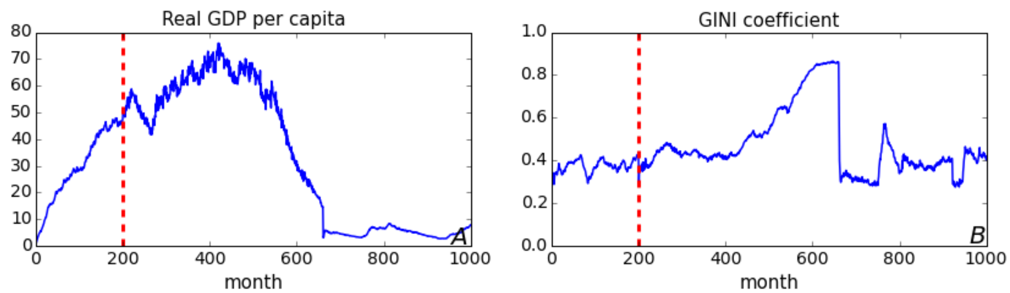

Figure A.1: The calibrated model – real GDP per capita and inequality
A and **B** demonstrate the average level of real GDP per capita and inequality measured by GINI coefficient over the simulation period respectively. It shows that per capita income continued to rise but soon fell once inequality became extremely severe.

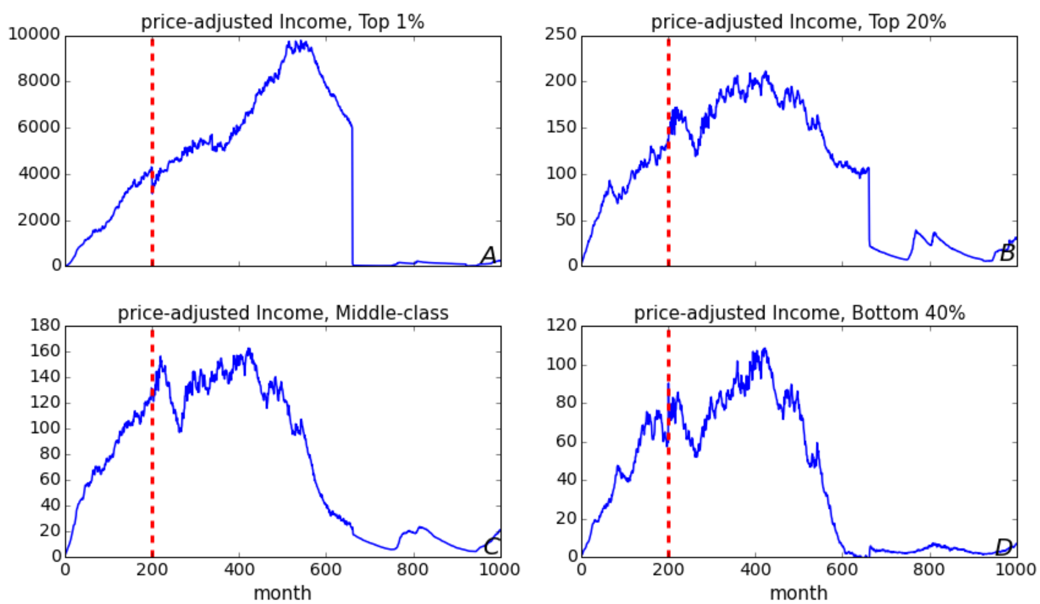

Figure A.2: The calibrated model– average price-adjusted income by class
A, **B**, **C**, and **D** exhibit the mean level of average price-adjusted income by class – top 1%, top 10%, middle-class, and bottom 40% – over the simulation period. The average income of all classes rose and fell cyclically; yet, the poorer the class is, the earlier its income falls. It is noteworthy that scale on y-axis of each panel is different from one another.

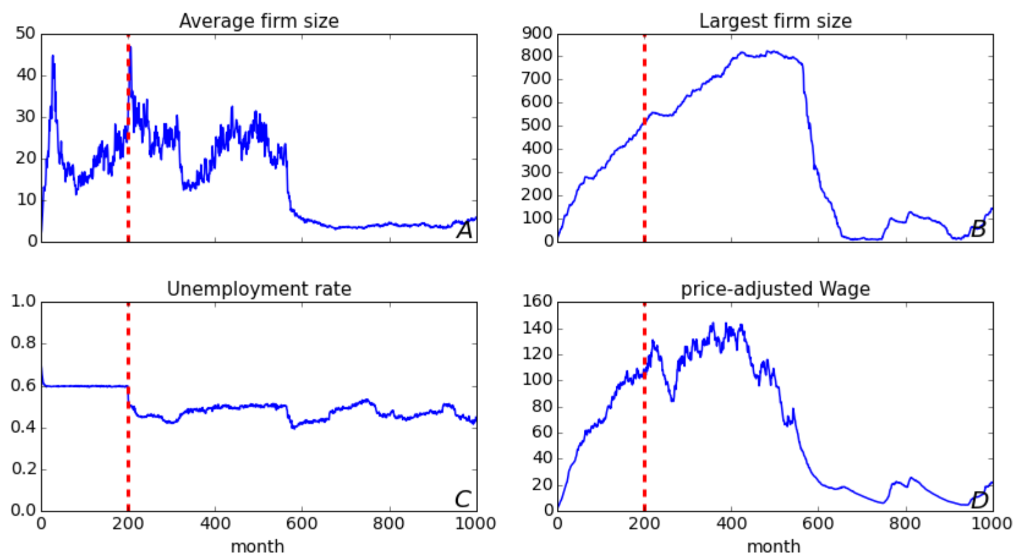

Figure A.3: The calibrated model – labor market indicators

A and **B** illustrate the average firm size and that of the largest firm size over the simulation period respectively. The average firm size repeatedly went up and down and the largest firm grew up slowly gradually but both of them dropped dramatically upon the collapse of the economy. **C** exhibits the unemployment rate and **D** shows the price-adjusted wage over the same period. It is found that the unemployment rate was stable but jumped up upon the collapse of the economy. The average of price adjusted wage was increased and decreased cyclically.

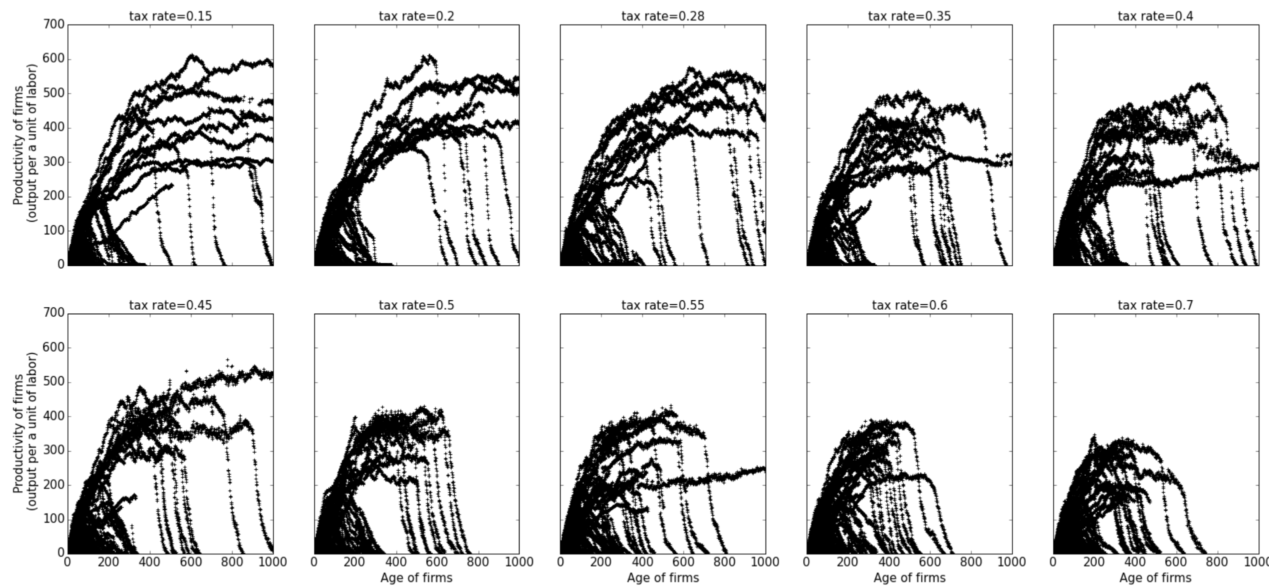

Figure A.4: Sensitivity analysis – age and productivity of firms over tax rates

This scatter-plots illustrate how the age of a firm is related with the level of productivity, measured output per a unit of labor, of the firm given a tax rate from 15% to 70%. respectively. It is noteworthy that the data is collected in each simulation period and the range of y-axis are the same for all figures. It shows that the lower the rate is, the more likely that productive firms live longer holding others constant.

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