

A SYSTEM DYNAMIC MACROECONOMIC MODEL FOR  
AN INQUIRY OF INCOME INEQUALITY AND ENVIRONMENTAL IMPACT

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2019

A SYSTEM DYNAMIC MACROECONOMIC MODEL FOR  
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Thesis submitted to the  
Institute for Graduate Studies in Social Sciences  
in partial fulfillment of the requirements for the degree of

Master of Arts  
in  
Economics

by  
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Boğaziçi University  
2019

## DECLARATION OF ORIGINALITY

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## ABSTRACT

### A System Dynamic Macroeconomic Model for an Inquiry of Income Inequality and Environmental Impact

Ending hunger, reducing poverty and inequalities, and climate action are the main objectives of the political agenda in the recent years. However, these objectives may be in conflict. Economic growth is promoted to end hunger and reduce poverty; however, a growing economy may well increase human impact on the environment. It is also true that an income redistribution scheme may increase aggregate demand—hence, the economic activity and subsequently the environmental impact. In this thesis, we build a system dynamic macroeconomic model to cope with the intricate relationships among income distribution, economic growth, and human impact on the environment. The model is based on macroeconomic accounting principles, and represents a closed economy with a representative firm, three heterogeneous households, and a simple banking sector. We argue that an aggressive income redistribution scheme can achieve the whole objectives in the policy agenda, while a mild redistribution scheme may worsen the environmental problems. This thesis contributes to the recent Ecological Macroeconomics literature by examining the relationship between income distribution and environmental impact of the human activity by relying on a system dynamics approach.

## ÖZET

### Gelir Eşitsizliği ve Çevresel Etkiyi İncelemek İçin Makroekonomik Sistem Dinamiği Modeli

Son yıllarda siyasi ajandayı açlığın sonlandırılması, yoksulluğun ve eşitsizliklerin azaltılması, ve çevre sorunlarıyla mücadele oluşturuyor. Ancak bu hedefler birbiriyle çelişiyor olabilir. Ekonomik büyüme, açlığın sonlandırılması ve yoksulluğun ortadan kaldırılması amacıyla destekleniyor. Ancak, büyüyen bir ekonomi daha fazla doğal kaynak kullanımı ve daha fazla atık üretimi anlamına geliyor. Öte yandan, gelirin yeniden dağıtım politikası ekonomideki toplam talebi artırarak ekonomik büyümeyi tetikleyebilir. Bu tezde, gelir dağılımı, ekonomik büyüme ve çevresel etki arasındaki karmaşık ilişkinin daha iyi ele alınabilmesi için bir makroekonomik sistem dinamiği modeli inşa ettik. Makroekonomik muhasebe ilkeleri üzerine bina edilen model, temsili bir firmanın, üç farklı hane halkının ve basit bir bankacılığın olduğu kapalı bir ekonomiyi temsil ediyor. Bu tezde, ılımlı bir gelirin yeniden dağıtım politikasının çevre sorunlarını artıracığı, ancak daha radikal bir yeniden dağıtım politikasının hem sosyal hem de çevresel hedefleri aynı anda gerçekleştirebileceği tartışılıyor. Gelir dağılımı ve çevresel etki ilişkisini sistem dinamiği metoduyla inceleyerek Ekolojik Makroekonomi yazınına katkı yapmayı umuyoruz.

## ACKNOWLEDGMENTS

Foremost, I would like to thank my thesis advisor Prof. Dr. Fikret Adaman for his continuous support, patience and guidance throughout the process. I am, also, grateful to Prof. Dr. Ali Kerem Saysel for his valuable ideas and patience. Without them, this thesis would not have been achievable.

I thank Assistant Prof. Ozan Ekin Kurt for his illuminating advices and his valuable time.

I would like to express my gratitude to all the faculty of Economics Department of Boğaziçi University. Also, I would like to thank the Scientific and Technological Research Council of Turkey (TÜBİTAK) BİDEB for the financial support through the 2210-A Masters Scholarship Program.

I would like to express my gratitude to my dear fiancée Hande Önel. Throughout the process, her love and support lessened my stress. Her patience has been immense, and her joy has given me strength. Lastly, I thank my mother and my brother for their unconditional love.

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## CHAPTER 1

### INTRODUCTION

Ecological problems are ever increasing. Climate change is the most severe challenge the humankind faces in recent decades. According to IPCC (2018), climate change will cause sea-level rise, long-lasting droughts and heatwaves, more severe hurricanes, and loss of some ecosystems which cannot be regained. At the end, coastal lands will be lost to the seas and oceans, and people will migrate due to extreme weather conditions. Let us not forget that climate change is not the only anthropogenic environmental problem. Ocean acidification intensifies (IPCC, 2018), land degradation and water depletion continues (UNEP, 2019), and world fishery stocks continue to decrease (FAO, 2018)—to list a few from a long list.

Not only public awareness and ecological activism increase exponentially, but scholarly interest and research on environmental problems are accumulating as well. People from every field of study search for solutions to the environmental issues we face. Recent decades have witnessed a considerable policy focus on environmental problems as well. We largely observe that both international and national policy-making bodies have more than one objective: they promote economic growth, more equitable income distribution, fewer carbon emissions at the same time. However, the question of potential conflict among these objectives has not been properly considered, despite some solid academic studies.

Policymakers desire growing economies because they think that a growing economy will end hunger and reduce poverty. A more prosperous economy will generate more tax revenue for the government, which can be used for social programs to reduce economic inequalities as well. However, a growing economy also means an increase in the resource usage and waste generation. Some other policymakers are in favor of a more equal society. An income redistribution policy, on the other hand, may increase aggregate demand. An increase in the aggregate demand will likely increase economic activity; hence, a redistribution scheme may harm the

environment. Even if the aggregate demand remains intact, income redistribution may increase the human impact on the environment because low-income people's consumption pattern is argued to be more carbon intensive. Thus, policies may well have unintended consequences. It is therefore of interest to analyze the interconnectedness among different policies.

We build a system dynamic macroeconomic model to better comprehend the intricate relationships among income distribution, economic growth, and environmental impact. The model is based on macroeconomic accounting principles, and contains a representative firm, a simple banking sector, and three heterogeneous households. We will show that a mild income redistribution scheme can worsen the environmental problem. The model will indicate that a more radical income redistribution policy is needed to satisfy both socio-economic and environmental ends. The thesis is structured as follows: In the following chapter, we define the problem and the objective of this study. Chapter three reviews the relevant literature. In chapter four, we present the fundamental concepts of the system dynamics methodology. The following chapter describes the dynamic simulation model. Chapter six analyzes the model's standard run. In chapter seven, we present the results of the formal validity tests. Chapter eight discusses different scenarios and different income distribution schemes. Finally, the main findings of this study are summarized and discussed.

## CHAPTER 2

### SETTING OUT THE OBJECTIVE OF THE RESEARCH

As known, the United Nations Development Program has recently suggested a total of seventeen goals to achieve a sustainable development path for nations (UNDP, 2015).

Of these, perhaps the most important ones are the following three goals:

Environmental sustainability, poverty reduction and ending the hunger, and reducing inequalities. The obvious question that follows is whether these three challenges can be addressed at the same time in a successful manner, or is there any trade-off between them.

Policymakers try to confront environmental problems by promoting green technologies, stricter regulations and implementing environmental taxes. However, environmental taxes can be regressive. Regressive taxes may well increase income inequality, and at the same time create social unrest as recently observed in France with the *Gilets Jaunes* Movement. On the other hand, the favorite policy to address poverty reduction and ending hunger is to promote economic growth. An expanding economy is likely to create more jobs especially for the poor as well as generates more tax revenue which can be used among other aims in governments' social programs. To reduce inequalities, the economic growth should also be inclusive. The UN uses the "inclusive growth" term to indicate economic growth which benefits all groups of people in the society. However, growing economies consume more resources and create more wastes. Although economic growth may alleviate extreme poverty, hunger, and even inequalities; it hurts the environment.

It is, of course, possible to consider policies addressing income redistribution (through various wealth/income taxes, transfers, etc.) directly. However, more equitable income distribution may well create more consumption demand at the aggregate level, with an increase in economic output and the ecological impact of the economy. Once poor segments are made richer, they will tend to purchase material products which are harmful to the environment (such as electronics, automobiles etc.)

with the redistributed extra income. On the other hand, more equitable income distribution makes it possible for poor people to reach education services. More educated people are known to concern about environmental problems more. Also, more equitable income distribution eases the consumption competition, which relieves some environmental stress of the economy.

Apart from the direct relationships among income distribution, economic growth, and environmental impact, there are also dynamic feedback loops among them that need to be taken into account. For example, economic growth affects income distribution and is affected by income distribution. More consumption increases the profits, which in turn affects investment. Investment, also, raises employment which increases wage bill; and as a result, consumption. The presence of certain dynamic feedback loops and complicated interdependence of income distribution, economic growth, and environmental impact make it necessary to employ a conceptual model and an analytical approach that is capable of capturing the said relationships. In our project, we will be developing a complex dynamic model to evaluate the impacts of redistribution policies.

## CHAPTER 3

### LITERATURE REVIEW

The problem of interest of this study is characterized by dynamic feedback loops and complicated relationships among the income distribution, the output of the economy, and the environmental impact. As Figure 1 shows, we need to review the literature on i) the relationship between the output of the economy and the environmental impact, ii) the relationship between the output of the economy and the income distribution, and iii) direct linkages between the income distribution and the environmental impact to fully comprehend the scope of the problem.<sup>1</sup>

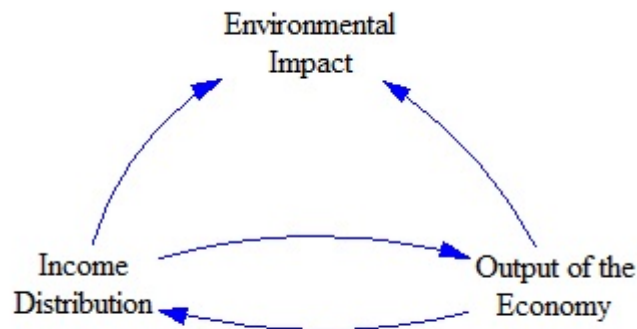


Figure 1. Main relationships among income distribution, environmental impact and the output of the economy

The holistic approach that is embraced in this study makes it necessary to represent supporting and opposing perspectives on each relationship. There is accumulated literature behind each arrow depicted in Figure 1. As a result, the scope of the literature review section is quite broad. Hence, the literature review is divided into four subsections to provide ease to the reader. In the subsection 3.1, the literature on the relationship between GDP growth and environmental impact is explained. In

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<sup>1</sup>Environmental degradation may impede economic growth and affect income distribution as well. However, the challenge that the society is facing now seems to be halting the environmental degradation before such catastrophes happen. Hence, in this study, we ignore the effects of environmental problems on growth and income distribution.

3.2, we review the literature on GDP growth and income distribution. Subsection 3.3 is reserved for the relationship between income distribution and environmental impact. Finally, in 3.4, we present some recent studies which have holistic approaches to the environmental problems by explicitly modeling the macroeconomic variables. In that respect, these studies closely resemble the model we build.

### 3.1 The relationship between GDP growth and environmental degradation

There are two opposing views on whether GDP growth is good or bad to the environment. One of the two is the *Limits to Growth* (hereafter LTG) literature along with the Ecological Economics which point out the embeddedness of the economy within the ecology and focus on the “limits” of the economy. The other one can be called as “Growth Paradigm,” which gained momentum with the Environmental Kuznets Curve at the mid-90s. The Growth Paradigm argues that a prosperous economy deals better with environmental problems than an impoverished one.

One of the earliest studies on GDP growth and environmental degradation is *Limits to Growth* (Meadows, D. H. & Club of Rome, 1974). The economy is embedded within the broader ecological system because the economy takes resources from the ecosystem and then produce waste which is thrown into it. LTG points to the finitude of the ecosystem, specifically the finitude of resource inflows to the economy and the waste outflow to the ecosystem. By this observation, LTG concludes that the economy cannot grow more than its finite boundaries (Meadows, D. H. & Club of Rome, 1974). Resources can be recycled to some extent, and this limit can be enlarged by technological improvements; however, by the entropy law, the economy cannot recycle waste with 100% without energy usage. The energy as a resource, on the other hand, is limited as well. Nuclear power seems to be limitless; however, it creates thermal pollution by the laws of thermodynamics, which state that every energy used will create heat. Even solar power is limited because it flows with limited terms, and we cannot take more than a specific amount of it without disturbing the ecosystem services. As for the wastes, the ecosystem can absorb a certain amount

above which cripples vital ecosystem services (Meadows, D. H. & Club of Rome, 1974). LTG builds an earth system model using system dynamics and studies certain scenarios. The authors start with the standard scenario in which no major policy change happens. The result is the growth and collapse of population and industrialization. In this base scenario, when resources start to be depleted by the large population, then the massive food demand drives down remaining resources and the world population goes down to zero. Their best scenario assumes unlimited resources, pollution control policy, land yields doubling, and perfect birth control. Even with these assumptions, the model simulation results with a collapse behavior for the human population. Their solution is stabilizing population growth by 1975 along with capital stabilization, recycling, pollution reduction policies, and increased durability and productivity of capital. If all these measures are implemented by the year 2000 the model suggests a collapse behavior even under suitable assumptions (Meadows, D. H. & Club of Rome, 1974). <sup>2</sup>

On the other hand, the Environmental Kuznets Curve (hereafter EKC) argument is suggesting just the reverse relation between economic growth and the environment: Economic growth can be the cure of the environmental degradation (Grossman & Krueger, 1995). Grossman and Krueger's joint paper is a broader assessment of the effect of GDP per capita and pollution which is studied by World Bank Development Report (1992), Selden and Song (1994) and Holtz-Eakin and Selden (1995) which also found an inverted U-shaped relationship between the two variables. In their study Grossman and Krueger employ several water and air pollution indicators such as sulfur dioxide and smoke for the air; nitrates, lead, and arsenic in the river basins (Grossman & Krueger, 1995). They specify the following regression:

$$Y_{it} = \beta_1 G_{it} + \beta_2 G_{it}^2 + \beta_3 G_{it}^3 + \beta_4 \bar{G}_{it-} + \beta_5 \bar{G}_{it-}^2 + \beta_6 \bar{G}_{it-}^3 + \beta_7 X_{it} + \epsilon_{it}$$

<sup>2</sup>The doom scenario that LTG warns about has not happened yet. Unfortunately, the lack of evidence is not an evidence, since it is still possible to see events which proves otherwise in the very future. On the other hand, system dynamics method is not designed for point forecasting; but, it is designed for pattern prediction (Barlas, 1996). Hence, we should see LTG accordingly.

where  $Y_{it}$  is pollution indicator,  $G_{it}$  is GDP per capita in year  $t$ ,  $\bar{G}_{it-}$  is the average GDP per capita over the prior three years, and  $X_{it}$  is a vector of other covariates. Their result is the inverted U-shaped curve between GDP per capita and environmental pollution (Grossman & Krueger, 1995). The explanation by the authors is that at the early phases of the industrialization the pollution level rises quickly. At that stage, citizens have more pressing concerns than environmental quality. Beyond a certain income level, the society values the environment more, the regulatory authorities tend to have stricter standards about it, society has high-level technology to confront environmental problems, and economies' composition changes from dirty industries to clean service industry (Grossman & Krueger, 1995; Dasgupta, Laplante, Wang, & Wheeler, 2002; Dinda, 2004).

There are both theoretical and empirical criticisms to EKC literature. The first critique is that EKC can be the result of outsourcing dirty industries to emerging countries (Arrow et al., 1995; Stern, Common, & Barbier 1996). This criticism is also known as the *Displacement Hypothesis* and argued by several other studies (Dinda, 2004). Hence, it might be the case that EKC shows not the reduction of pollution at the global scale, but it shows a displacement of the polluting industries from high income to low-income countries. The main mechanism of Displacement Hypothesis is that developed economies have more regulation regarding pollution (specifically local pollution) and firms switch dirty industries to less regulated areas. Less developed countries have no choice but to ignore the polluting effects of such industries; since, if their governments regulate more strictly, the business will fly to other unregulated areas (Dinda, 2004). Secondly, the argument of "poor people are too poor to care about the environment" could be too simplistic. *Environmentalism of the Poor* (Martinez-Alier, 2002) gives many examples of environmental conflicts which arise by the destruction of the livelihoods of various less-developed and developing countries' poor and indigenous people who are defending nature as it means livelihood for them. On the other hand, Dasgupta et al. (2002) and Stern (2004) test the EKC hypothesis on CO<sub>2</sub> emissions rather than local pollution

indicators, and they found CO<sub>2</sub> emission has either a monotonic or N-shaped (first increasing, then decreasing and then increasing again) relationship with per capita income. Stern (2004) proposes to use total pollution indicators rather than individual ones. In addition to Dasgupta et al. (2002) and Stern (2004), Torras and Boyce (1998) test EKC by introducing Gini and political and civil rights as explanatory variables to standard EKC regression and find that pollution variables first display an inverted U-shaped curve as EKC suggests; however, they find a statistically significant positive relationship between pollution and per capita income cubed implying an increase in the pollution after a certain per capita income level. There are also several criticisms to the EKC based on the inappropriate use of Econometrics. Perman and Stern (2003) and Stern (2004) criticize EKC studies claiming the estimates have omitted variable bias. Also, there are unresolved issues of serial dependence and stochastic trends in the estimation processes, which lead to erroneous results regarding the coefficients of the regression <sup>3</sup> (Perman and Stern 2003, Stern 2004).

We believe that GDP growth harms the environment. Hence, we are close to LTG and Ecological Economics on the economic growth. Confronted by grounded empirical studies; EKC, as a reduced form relationship between GDP growth and the environment, is thought to be wrong. Having stated our final position on the matter, the relationship between GDP growth and income inequality is presented below.

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<sup>3</sup>The role and importance of the technological developments have always been a part of the discussion of the relationship between GDP growth and the environmental impact. Indeed, LTG and Ecological Economics school do not see that the technological developments will be the solution to the environmental problems while academics in favor of growth have seen otherwise. The first academic tradition argues that the efficiency gains with the technological developments may partly or fully rebounded by the increasing use of the resources (Jevons, 1866; Khazzoom, 1980). Secondly, the technological developments have certain delay structures from the idea to the implementation; hence, they may well come late and inadequate (Sterman, 2012). Thirdly, the Laws of Thermodynamics assure that the energy is limited, and resources travel from low entropy to high entropy through our economy and recycling them requires energy which is limited (Daly, 2013). There is no technology which is free from the Laws of Thermodynamics. On the other hand, academics in favor of GDP growth argue that the market economy creates incentives to develop resource saving technologies when the resources get depleted. They point out the capability and ingenuity of the people when facing a challenge.

### 3.2 GDP growth and income inequality

The relationship between per capita GDP growth and income inequality is two-sided. While per capita GDP growth has effects on income distribution, income distribution has effects on per capita GDP growth as well. The question concerning the relationship between the two is a fundamental and one of the oldest questions in Economics. Following subsections divide and elaborate the relationships between the two. The first subsection examines the effects of per capita GDP growth on income distribution, and the other subsection deals with the effects of income inequality on per capita GDP growth.

#### 3.2.1 The effects of per capita GDP growth on income distribution

One of the oldest observations on the effect of per capita GDP growth on income distribution is Kuznets' Curve (Kuznets, 1955). As very well known in Economics discipline, Simon Kuznets observes an inverted U-shaped relationship between per capita GDP and income inequality. Kuznets speculates on the causality of this observation and comes up with several explanations: Entrepreneurship, professional service jobs, and most importantly the switch from agriculture to industry (Kuznets, 1955). Firstly, with the increasing innovation and technologies, an entrepreneur with no wealth could become rich. Secondly, there are now more jobs which do not require wealth or capital and still provide a handsome salary such as engineering, advocacy. Thirdly, Kuznets argues that if average per capita earnings of the industry sector is higher than the agricultural sector and industry sector has a more inequitable distribution of income within the sector than agricultural sector, then workers switching from agriculture to industry has an effect that first increases then decreases the income inequality (Kuznets, 1955). For Kuznets these two assumptions are plausible (Kuznets, 1955). Hence, this third explanation gives rise to the idea that a developing economy inherently produces the inverted U-shaped curve, since the main development path is a switch from agriculture to industry.

There is vast empirical literature after Kuznets' works, which elaborates the matter in several contexts and different data sets. Paukert (1973), Chenery, Ahluwalia, Bell, Dulloy, and Jolly (1974), Ahluwalia (1976), Ahluwalia, Carter and Chenery (1979), Bacha (1979), Papanek and Kyn (1986) are some of the empirical studies that test Kuznets' Curve and find supporting results (as cited in Adelman & Robinson, 1988). On the other hand, Adelman and Morris (1973) find mixed results because they consider that after a development point income inequality is a policy choice (as cited in Adelman & Robinson, 1988). All these works conclude that income inequality is rising in the early stage of economic growth. However, these empirical studies rely on cross country data sets rather than actually observing countries' development path, and they regress reduced form equations between per capita income growth and income inequality. There is a possibility that Kuznets' Curve is not a natural development path, and some country-specific effects cause its shape. Hence, there may be no causal link between income inequality and economic growth (Ray, 1998). Indeed, when countries are grouped by using dummies such as Latin America, Africa, and Asia in the regressions, then the inverted U hypothesis does not hold (Deininger & Squire, 1998).

Thomas Piketty arrives a similar conclusion in his work *Capital in the Twenty-First Century* (2013/2014). Piketty starts his analysis with a rewritten accounting identity:

$$\alpha = r \beta$$

where  $\alpha$  is the share of capital income,  $r$  is rate of return on capital, and  $\beta$  is total capital over national income i.e.  $K/Y$  which is, for Piketty, an indicator for income inequality (Piketty, 2013/2014).<sup>4</sup> Then, Piketty states that in the long run:

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<sup>4</sup>To see why this equation is an identity we should plug  $K/Y$  instead of  $\beta$  and rewrite to  $\alpha Y = r K$ .

$$\beta \rightarrow s/g \text{ as } t \rightarrow \infty$$

where  $s$  is the savings rate and  $g$  is the growth rate of the economy. This implies that:

$$\alpha \rightarrow r(s/g) \text{ as } t \rightarrow \infty$$

From this point, Piketty arrives at his main conclusion: If growth declines with a given saving structure, then inequality increases in the long run (Piketty, 2013/2014). As Jackson and Victor see this result as a fundamental challenge to the Limits Thinking and Ecological Economics, they respond this argument by a Stock-Flow Consistent (SFC) macroeconomic model and find that Piketty's result is a particular case over savings rates of capital owners and workers (Jackson & Victor, 2016). The fundamental flaw in Piketty's arguments is that Piketty uses interdependent variables such as GDP growth, savings and capital's share of income; however, his arguments are based on changing the growth rates while keeping savings rate constant (Acemoglu & Robinson, 2014). Besides, Jackson and Victor propose that with progressive income taxes what Piketty suggests can be altered; and hence, Jackson and Victor point out that income inequality is instead a policy choice (Jackson & Victor, 2016).

The effect of the GDP growth on income distribution depends on the aggregate production function's characteristics, the openness of the economy, and institutional settings (specifically the strengths of the unions). In this study, we assume a closed economy with a Cobb-Douglas production function and the wage rate is determined by the supply and demand of the labor. Under these assumptions, a growing economy creates an income distribution according to the marginal productivity of the factors of

production. The effect of economic downturn on income distribution is more significant than a growing economy.

### 3.2.2 The effects of income inequality on per capita GDP growth

A direct economic relationship between income inequality and per capita GDP growth is based on the fact that low-income people consume more of their income compared to the rich. Altering existing income distribution towards a more equitable distribution can increase the societies' overall demand, which increases the aggregate demand. Stronger demand structure leads to more sales and production, which increases per capita GDP growth (Bhaduri & Marglin, 1990; Bhaduri, 2008; Lavoie, 2014; Lavoie & Stockhammer, 2013). Post Keynesians make this argument by referring to factor incomes, namely wages and profits. They believe wage earners consume almost all their income while profit earners tend to save. Higher wages increase the aggregate demand; hence, wages are not just a cost item to the firms but also a revenue source for them. <sup>5</sup>

On the other hand, the reasoning of differential spending and saving behavior of different income groups gives rise to Kaldor (1957) to think that more inequitable distribution of income creates more savings, which foster economic growth. This perspective is elaborated by Stiglitz (1969) when he employs the Solow growth model and finds that income distribution is irrelevant to economic growth if the saving function is linear to income. There are other models which support the idea of higher inequality (income and/or wealth) creates higher growth by considering convex saving function with AK production function (as cited in, Aghion, Caroli & García-Peñalosa, 1999) and risk aversion of employees (as cited in, Aghion et al., 1999).

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<sup>5</sup>6 It is possible that the higher wages contract the economy. Thus, Post-Keynesians make a distinction between wage-led growth and profit-led growth regime (Bhaduri & Marglin, 1990). If higher wages stimulate the economy than there is wage-led growth while the reverse situation is called profit-led growth (Lavoie, 2014). Lavoie and Stockhammer (2013) conduct an empirical research and they find that bigger and more closed economies have wage-led growth characteristics (Lavoie & Stockhammer, 2016).

In the 1990s, a new theoretical and empirical literature emerged, arguing that income inequality impedes growth. Benabou (1996) makes an astonishing survey of this empirical literature and lists twenty-three studies which establish empirical regularities.<sup>6</sup> The main reduced-form empirical estimation is to regress long-period (generally twenty years) of average growth on initial income or wealth distribution with several controls (human capital, initial national income, country grouping dummies, etc.). Some of the cornerstone studies of this literature are Perotti (1992, 1994, 1996), Persson and Tabellini (1992, 1994), Alesina and Rodrik (1994), Alesina and Perotti (1996), Alesina (1996) and Barro (1996) (as cited in Benabou, 1996). All these studies show that initial income and/or wealth inequality is harming the long-run growth of the economy (Benabou, 1996). The theories and models explaining this empirical regularity were developed in the same decade as well. Galor and Zeira (1993) point out imperfect capital markets where people with low income or low wealth cannot access to credits. Capital market imperfection reduces poor people's investment opportunities. People who cannot access credit lines would increase their productivity more than the people who already obtained credit and accumulated capital (Galor & Zeira, 1993). Alesina and Rodrik (1994); and Persson and Tabellini (1994) come up with a political economy argument referring to median voter theorem. With increasing inequality, society demands more redistribution (especially when mean income is greater than median income) and the government, at the request of the society, imposes higher taxes. The result is higher taxes, which reduces incentives to invest; hence, reduces the growth. Also, Barro (2000) states that greater inequality creates social and political unrest which inflates crime and riots. Private property may be threatened, and uncertainties arise.

Another possible channel through which income inequality affects growth is creating consumption competition. There is a necessary consumption a person should meet. Beyond the necessary consumption, there is the consumption that is determined by complex parameters such as personal choice, status-seeking, and advertisement,

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<sup>6</sup>For a more recent survey: Bagchi and Svejnar (2015).

etc. The presence of consumption competition can affect the growth in two contrasting ways: i) it increases aggregate demand and enhance growth, ii) it reduces savings and impedes growth. There is no consensus among economists whether an increase in consumption demand fosters or impedes growth. One of the first economists who theorize the status consumption is Veblen (1899/1991) who argues that with an increasing price of a commodity, some people demand more of it, which is contradictory to the law of demand. Unlike Giffen goods, such goods exhibit this reverse demand pattern not out of poverty but out of affluence (Veblen, 1899/1991). After Veblen, Frank (1985), Hirsch (1976), Galbraith (1958) developed the idea of relative consumption. There is also literature on the issue of consumption competition through psychological arguments. Easterlin (1974), for example, argues that the share of the population stating they are very happy is quite stable throughout the time while average income increases (as cited in Clark, Frijters, & Shields, 2008). This observation is argued to be a supporting point of consumption competition do exist. However, the answer to the happiness question is itself affected by social average; hence, casting doubt on the validity of such survey data as well (Clark, Frijters, & Shields, 2008). There is, nevertheless, supporting evidence on the consumption competition <sup>7</sup> (Solnick & Hemenway, 1998; Johansson-Stenman, Carlsson & Daruvala, 2002; Luttmer, 2005; Kapteyn, Van Praag & Van Herwaarden, 1978; Schor 1998).

In this study, we assume that there is consumption competition behavior among households. More equitable income distribution schemes have opposing effects on the GDP growth under this assumption. When the income is distributed more equitably the low-income households spend more of the distributed income compared to high-income households. As a result, aggregate demand tends to increase. This is the same reasoning of the several Post-Keynesian scholars as reviewed. However, when income distribution is more equitable, then households compete less on consumption. Less consumption competition decreases aggregate demand. Changes in aggregate

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<sup>7</sup>For an extensive survey: Clark, Frijters and Shields (2008).

demand affect the GDP growth. In our model we build the latter effect of the income redistribution along with the former.

### 3.3 Inequality and environmental degradation

Apart from growth and income inequality cycle, there are studies on the direct effects of income inequality on environmental degradation. However, there is no consensus among economists on the sign of the net effect. Hence, we will cover the arguments from both sides.

Ravallion, Heil, and Jalan (2000) state that more equitably distributed income damages the environment more. They conducted an econometric study where they regress carbon emissions on GDP per capita, squared GDP per capita, population, time trend, Gini index, and interactions of GDP-Gini, squared GDP-Gini, population-Gini, and time trend-Gini. They found a statistically significant negative coefficient for Gini index (Ravallion et al., 2000). If we think CO<sub>2</sub> emissions as a function of income, then Ravallion et al.'s result means that the shape of this function is concave. Hence, the marginal propensity to emit is diminishing with income (Ravallion et al., 2000). They suggest that people consume CO<sub>2</sub> intensive goods at lower stages of income, and beyond a certain income level, they consume this extra income on cleaner services (Ravallion et al., 2000). Hence, a redistribution of income would create more emissions.

There are two other empirical studies which show the relationship between income distribution and environmental performance. These two studies' results are contradictory to Ravallion et al.'s (2000) findings. Mikkelsen, Gonzalez, and Peterson (2007) regress biodiversity loss to population, GDP per capita (PPP adjusted), GDP per capita square, and Gini ratio for cross country data set. They conclude a positive and significant coefficient for Gini ratio. Holland, Peterson, and Gonzalez (2009) regress biodiversity loss on GDP per capita, population density, Gini ratio, environmental governance, and proportion of endemic vertebrates. They find a positive and statistically significant result for Gini ratio. Holland et al. (2009) think

that inequality makes people less able to build institutions for collective actions to use the resources sustainably.

The relationship between income inequality and willingness to pay (hereafter WTP) for the environment/environmental protection projects is argued to be a decreasing function. Economists use WTP to measure how people value non-market goods in monetary terms. Hence, if WTP is rising while income inequality is falling, then more equitable income decreases environmental degradation. Many studies state that a more equitable income distribution leads to more social WTP (Frank & Schlenker, 2016; Cai, Cameron & Gerdes, 2010; Drupp, Meya, Baumgärtner, & Quaas, 2018; Ebert, 2003; Baumgärtner, Drupp, Meya, Munz & Quaas, 2017). The essential logic is that environment is a normal good; hence, with increasing income people tend to value more to the environment but in a decreasing manner (Boyce, 2002; Frank & Schlenker, 2016). If we distribute income more equitably, then WTP gains from lower-income people compensate WTP losses from the high-income people.

When we consider Ostrom's arguments with Baland, Bardhan, and Bowles (2007) on common pool resources and common good provisions, one can argue that income inequality harms the environment by hindering the conditions of cooperation of the society. Cooperation of the society is critical for governing common pool resources and common goods without government, market mechanisms or private property rights. Baland et al. (2007) give many examples on inequality's (both income and wealth) negative effects on cooperation. Inequality means, most of the time, conflicting interests (Baland et al., 2007). The level and the public anticipation of the conflict increase when income inequality rises.

As we know, education increases environmental awareness if the environmental topics are placed in the curriculum. WTP is increasing with education level. Adaman et al. (2011) find that primary and secondary school diploma have a positive effect on WTP, while college degree does not. Stigka, Paravantis, and Mihalakakou (2014) and Wisser (2007) find similar results. Hence, income inequality can make some members

of the society not to reach educational services, and an increase in the poorly educated people in the society reduces WTP.

In this study, we consider that Ravallion et al. (2000) are right in the sense that marginal propensity to emit is decreasing with consumption level. However, we conduct some experiments with different functional forms of the CO<sub>2</sub> emission function with respect to consumption. The other aspects, such as cooperation and environmental awareness, are not included in the model.

### 3.4 Recent ecological macroeconomics studies

There are recent studies which have a holistic macroeconomic approach to the environmental problems similar to this study. Some of these works also examine the relationship between income distribution and the environmental impact as this study tries to do.<sup>8</sup>

Dafermos, Nikolaidi, and Galanis (2017) build an SFC model to analyze the effects of financial leverage of the firms and green finance policies on the environmental variables. Dafermos et al. (2017) explicitly model the material cycle, energy consumption, green technology, and climate indicators along with the macroeconomic variables such as the output, a representative firm, household, and commercial bank. In a similar way, Naqvi (2015) builds an SFC model which includes non-renewable energy and renewable energy sectors along with the representative firm, household, and bank. While Naqvi (2015) is interested in functional income distribution, Dafermos et al. (2017) are not. Naqvi and Stockhammer (2018), in an SFC model, investigate the effects of R&D investment on the environment while income distribution is not included in their model.

The SFC models and system dynamics are close modeling approaches in some respects. They are both built on the stock-flow structure. SFC models often use identities which equate stocks to another variable. Equating stock variables to another

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<sup>8</sup>The Ecological Macroeconomic Models generally employ the SFC method. SFC modeling is developed and used by the Post-Keynesians. Hence, SFC Ecological Macroeconomic Models do not violate the standard assumptions of Post-Keynesian school.

variable is a fundamental error in the system dynamics method since a stock changes only with its flows. Dafermos et al. (2017), for example, define demolished material stock as DEM and then write:

$$DEM = \mu(\delta K_{-1} + \xi DC_{-1})$$

Where  $\mu$  is the material intensity in the output produced,  $\delta$  is the depreciation rate of the capital,  $\xi$  is the proportion of durable goods discarded every year,  $K$  is the capital, and  $DC$  is the durable consumption goods. Notice that the right-hand side of the equation is only the inflow of the stock DEM and DEM at time  $t$  is the accumulation of the past flows. Naqvi (2015) also writes similar equations, such as:

$$\Delta inventory = \gamma(\sigma sales_{t-1} - inventory_{t-1})$$

Where  $\gamma$  is the fraction of the gap between target inventories,  $\sigma$  is the fraction of past sales. Inventory is a stock; hence, its past values cannot affect its present value directly. Besides, there is a clear unit inconsistency in this equation.  $\Delta inventory$  and sales are flow variables, while  $inventory_{t-1}$  is a stock.  $\gamma$  and  $\sigma$  are fractions and they are unitless. Thus, the right hand side of the equation subtracts a stock variable from a flow variable. The model presented by Naqvi and Stockhammer (2018) is the most compatible SFC model among the three with the system dynamics methodology in terms of its equations. Due to the said equation structure of the SFC models, the same variables modeled in the system dynamics method will entail significantly different results.

This study contributes to the Ecological Macroeconomic literature by employing system dynamics and by explicitly modeling the income distribution. One of the main shortcomings of the model presented in this work is that it does not model

the environmental variables directly. There is no energy sector, no green technology sector and no material cycle compared to the recent models.

## CHAPTER 4

### METHODOLOGY

System dynamics is a useful modeling method when analyzing complex structures that cannot or should not be separated. Also, system dynamics should be employed to dynamic problems which are endogenous and have feedback nature. All relations in a system dynamics model are causal. The whole causal relations within a system dynamics model is called the structure of the system. The structure of the model is rich in feedback loops. A system dynamic model is not used for point forecasting because the feedback rich structure makes it hard to estimate the behavior of the model. Hence, system dynamic models are used for pattern prediction and design improvement. A valid and credible structure creates the real-life dynamics of the system. Hence, by implementing policies, system dynamics models try to catch desired behaviors.

To handle the complexity of the problem that we are interested in, we put different economic models and theories together into the model. Although the technical methodology we employ is system dynamics, the overall approach in the thesis is quite pragmatic and eclectic. We pursue an adequate level of realism in the formulations, and we test, albeit in a simple manner, the realism of the model behavior. We do not calibrate our model. We check whether the main variables of the model are in accordance with the real data; hence, the reader should not expect a developed empirics in the model as well.

Two main building blocks exist in system dynamics. The first one is stocks. Stocks are the memory/inertia of the system. They can only be changed by its flows. Without the stocks, no dynamic behavior is possible because stocks decouple inflows and outflows. The primary goal in system dynamics models is to manage them. The second building block is flows. Flows change stocks by flowing in and out. Flows should have the same unit per time (Sterman, 2000; Barlas, 2002). Another important concept of system dynamics is converters. Converters are either constants given to the

model or functions of stocks and/or flows. In the model map stocks are represented as rectangular boxes while flows represented as arrows with a valve. Converters, on the other hand, displayed as circles. The variables with the dashed lines are copied forms of the variables with solid lines. A simple example will explain system dynamics method better:

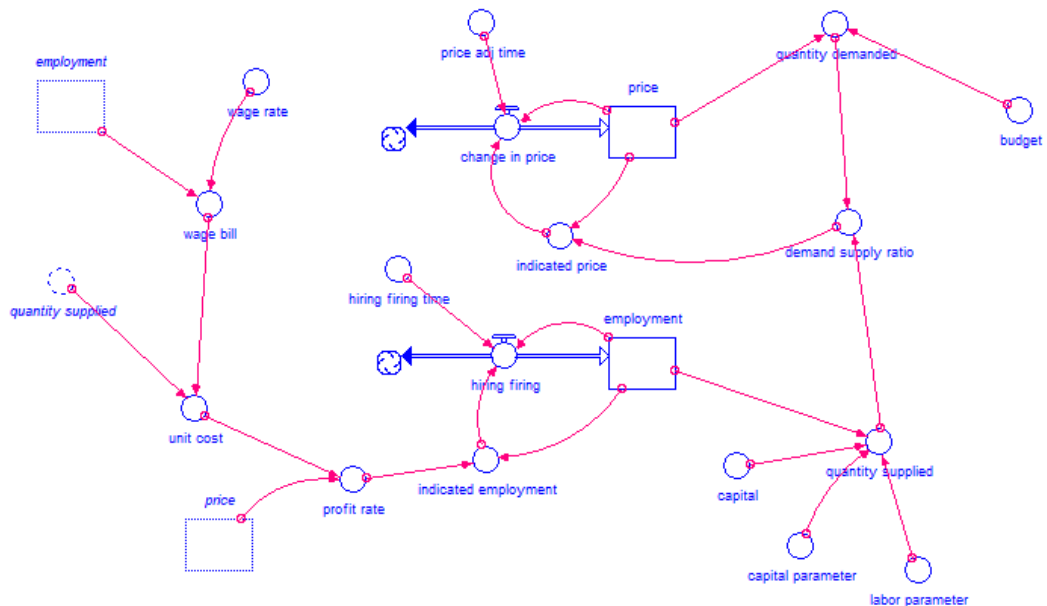


Figure 2. An example of stock-flow modeling

$$price(t) = price(t - dt) + change\ in\ price * dt$$

$$employment(t) = employment(t - dt) + hiring\ firing * dt$$

$$supply(t) = capital(t)^{capital\ parameter} * employment(t)^{labor\ parameter}$$

$$demand(t) = budget(t)/price(t)$$

$$\text{demand supply ratio}(t) = \text{demand}(t)/\text{supply}(t)$$

$$\text{indicated price}(t) = \text{price}(t) * \text{demand supply ratio}(t)$$

$$\text{change in price}(t) = (\text{indicated price}(t) - \text{price}(t))/\text{price adjustment time}(t)$$

The example in Figure 2 is an illustration of a simple supply-demand model. When price increases, then demand decreases and supply increases. An increase in supply and a reduction in demand reduce demand-supply ratio, which has a positive effect on the indicated price. In time, price converges to the indicated price. The stock variables in this model are "price" and "employment" while flow variables are "change in price" and "hiring firing". "Demand", "supply", "demand-supply ratio", "indicated price", and "price adjustment time" are examples of the use of converters. The red arrows show the causal links between variables in the model map.

In this thesis we employ *Accounting System Dynamics* (hereafter ASD) developed by Yamaguchi (2013). Yamaguchi builds a general economic model which includes a representative firm, a representative household, an extensive banking, demography, government, and external world models. His main aim is to show several contradictions within the Neoclassical theory. However, his framework is a solid base to analyze economic problems, and we take his ASD framework as a building block for the thesis. Yamaguchi's ASD method satisfies stock flow consistency in monetary transactions, and we believe, in that respect ASD method is crucial for realistic economic models. We start to model a closed economy with heterogeneous households from scratch in accordance with ASD. Hence, the model in this thesis substantially differs from Yamaguchi's model, except the ASD approach.

## CHAPTER 5

### MODEL

#### 5.1 Model overview

The time unit of the model is year, and the model is run for thirty years. The time step for numeric simulation is picked as 1/16.

In this model we put many economic theories and models (both verbal and mathematical) together. A careful reader would notice the eclectic feature of the model. For example, the model is a stock flow consistent model (a modeling approach mostly used by Post Keynesians), while we formulate the aggregate production function as a Cobb-Douglas function. Also, we define consumer behavior as a mixture of the Keynesian consumption function and the conspicuous consumption approach. We will further explain the different theories behind the formulations when the model is explained sector by sector.

The model in this study is a dynamic and demand-driven macroeconomic model which consists of a firm, a simple financial sector, and three households with different factor incomes. Households supply labor to the firm and in return, the firm pays wages. Households' consumption goes as revenue to the firm while their savings are loaned to the firm if demanded. The firm pays dividends to shareholders. The firm also pays interest for its debts as well as due debts.

The model in this study does not contain all the relations between income inequality and environmental damage as the literature review part covers. The task of covering all the relationships between the two carries the risk of building an uncontrollably colossal model. Considering the time limit, it is also needed to make simplifying assumptions. The model follows some entirely economic relationships between income inequality and economic growth and relates the output of the economy to environmental damage by using footprint calculations. The model's main assumptions are:

Assumption 1: There is no outside world, i.e., the economy is closed

Assumption 2: There is no government

Assumption 3: There is one product which is used both in consumption and investment

Assumption 4: Population and labor force are constant. Labor supply is not affected by the wage rate level.

Assumption 5: There are three kinds of households: Firm Owners, High Skilled Wage Earners, Low Skilled Wage Earners. These different households have different population sizes, and firm ownership does not change.

Assumption 6: There is one representative firm which is owned by the firm owner households.

Assumption 7: The firm is fully leveraged by the commercial banks, and commercial banks can easily borrow from the central bank when necessary.

Assumption 8: Households have conspicuous consumption behavior.

The building block of the model is ASD as developed by Yamaguchi (2013). ASD follows macroeconomic accounting identities and constructs appropriate stocks and flows compatible with accounting principles. In a closed economy with a representative household and a representative firm, Figure 3 and Figure 4 show how stock and flow diagrams are used to represent accounting relationships. For example, household consumption spending goes to the firm as revenue while wages, dividends, and interest paid by the firm goes to household as income. With different assumptions the ASD framework differs. For example, Yamaguchi (2013) assumes in his MacroSystem3 model that consumers can hold shares, and government securities; hence, there are government securities and shares stocks and related flows for consumers. Since we do not model government and we assume that there is no direct financing we do not have these stocks and flows.

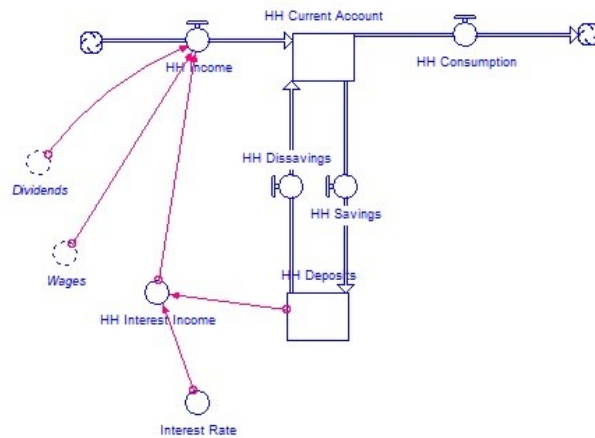


Figure 3. An example of household accounting

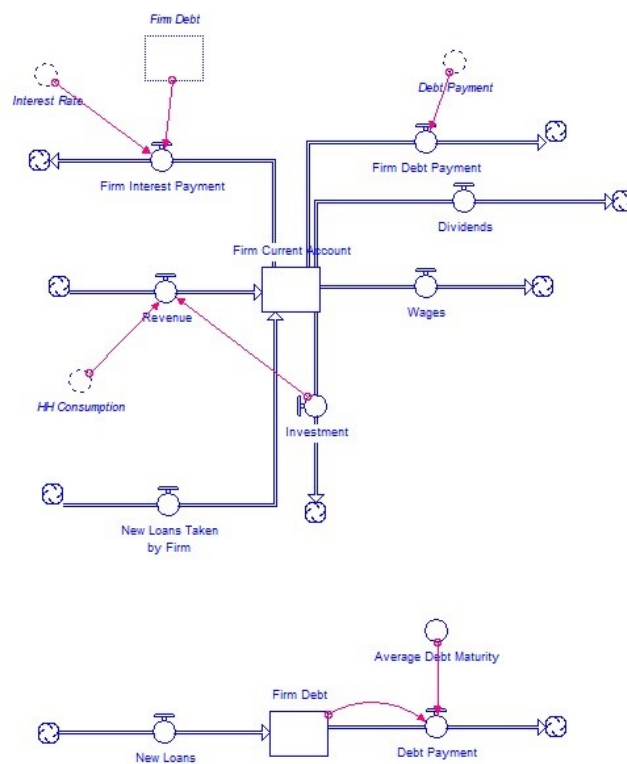


Figure 4. An example of firm accounting

There are eight main sectors in the model. Three of them are accounting sectors of different households: Firm Owners, High Skilled Wage Earners, Low Skilled Wage Earners. One of them is the accounting sector for the single firm. Production and



What Figure 6 presents is familiar to us from Economics textbooks. There are three similar loops created by aggregate demand. When aggregate demand increases, then the revenue and the profit of the firm increase. When revenue and profit increase, then the firm pays more dividends, invests in the capital, and employs more labor. The employment increases because the firm increases its capital stock when it is more profitable and an increase in the capital stock increases the marginal productivity of labor. Hence, hiring more labor is now profitable with the new marginal productivity and real wage rates. This process creates more income for people, which increases consumption; hence, aggregate demand. This virtuous cycle can turn to a vicious cycle as well. When aggregate demand decreases, then the reverse process follows.

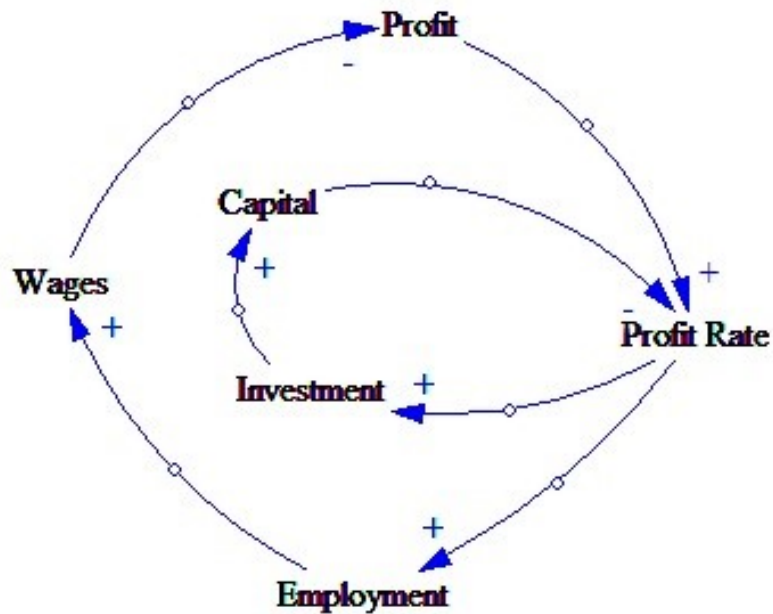


Figure 7. Wage cost and profit rate decline cycles

Figure 7 presents two balancing loops. Without these balancing loops, the vicious and virtuous cycles of aggregate demand can create either an endless boom or a bust for the economy. When the economy grows, the firm invests to capital. Investment continues until all the economic profit goes to zero, and profit rate tends to go back to its natural level. With economic growth, rising employment creates a cost

to the firm. An increase in the cost item of the firm reduces its profits. A less profitable firm invests less than a profitable one. Hence, increasing wage bill impedes economic growth.

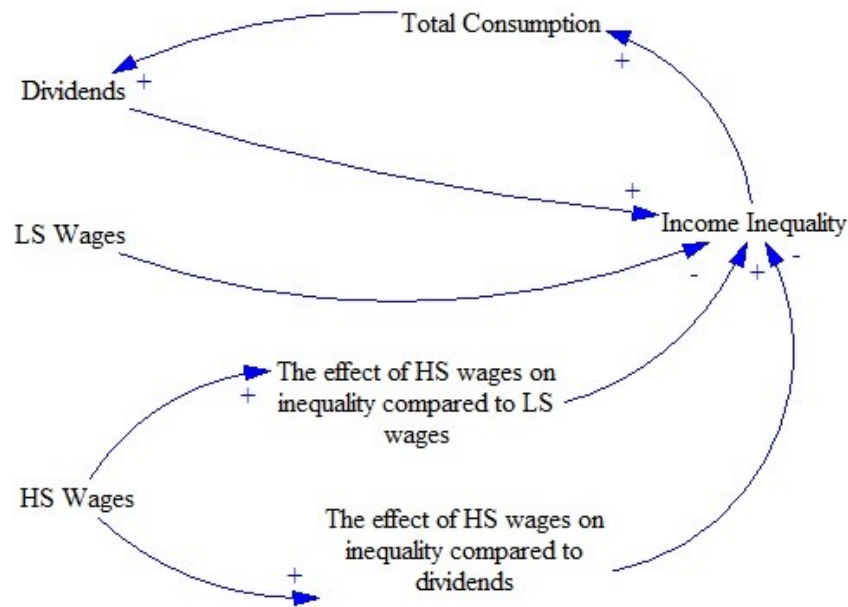


Figure 8. Inequality loop

Figure 8 presents the inequality loop. Dividends and low skilled wages have clear effects on income distribution, while high skilled wages have mixed effects. Income inequality has an increasing effect on aggregate demand when there is consumption competition. An increase in aggregate demand will increase dividends, which further deteriorates income distribution. An increase in aggregate demand will increase wage rates as well since there will be more labor demand by the firm. This last process has a negative effect on income inequality.

## 5.2 Model sectors description

In this section, sectors of the model and main equations are presented and discussed. The full equations are given in the Appendix A: Model Equations.

### 5.2.1 Household accounting sectors

Figure 9 presents Firm Owner Household Accounting. There are three stocks. FO HH Current Account is the stock of current money/liquidity of the household. FO Deposits are the stock of money which is saved by the household, and this money earns interest. FO HH Debt is the stock of debt. FO HH Current Account is there for accounting reasons. It should always be zero since we assume the household has zero liquidity preference. FO Deposits and FO HH Debt, on the other hand, affect how much the household earns and pays interest. Any income of the household is an inflow to FO HH Current Account stock while any expenditure is outflow. Although savings of the household is not an expenditure, it is modeled as an outflow from FO HH Current Account stock, since we track the flows of money here. Similar reasoning leads to dissaving and new loans to be modeled as inflows to the stock. Savings and dissaving are flows of FO Deposits; savings increase deposits while dissaving decreases. FO HH Debt increases with new loans while it decreases with debt payment, which depends on average maturity and the debt level. There are two other household accounting sectors which are the same as the the one presented here, except that income sources differ with different households. The household accounting stocks and flows are based on ASD developed by Yamaguchi (2013).

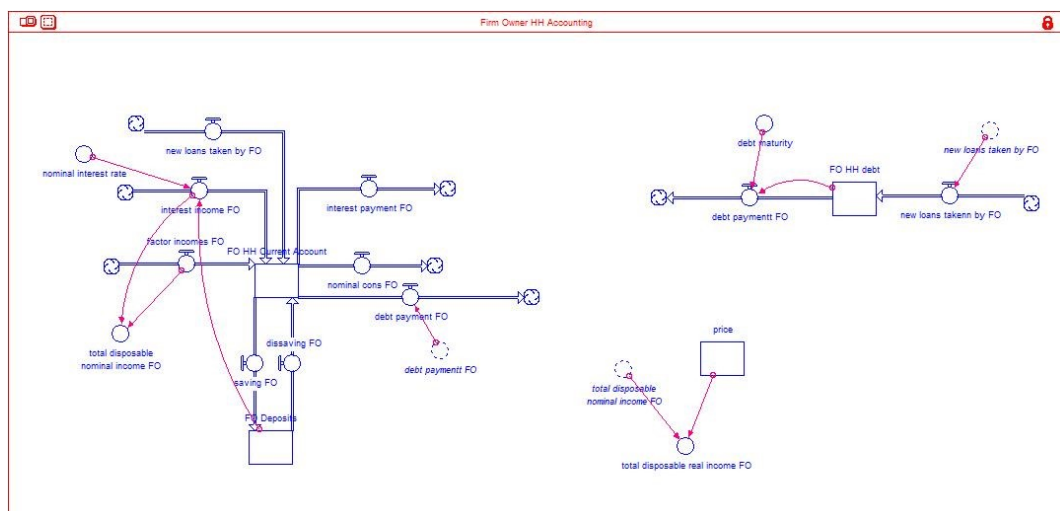


Figure 9. Simplified firm owner household accounting

Some important equations for this sector are:

$$FO\ HH\ Current\ Account(t) = FO\ HH\ Current\ Account(t - dt) + \\ [factor\ incomes\ FO + interest\ income\ FO + bank\ dividends\ FO + \\ dissaving\ FO + new\ loans\ taken\ by\ FO + transfers\ FO - nominal\ cons\ FO - \\ interest\ payment\ FO - saving\ FO - debt\ payment\ FO - income\ tax\ FO] * dt$$

$$FO\ Deposits(t) = FO\ Deposits(t - dt) + (saving\ FO - dissaving\ FO) * dt$$

$$FO\ HH\ debt(t) = FO\ HH\ debt(t - dt) + (new\ loans\ taken - debt\ payment\ FO) * dt$$

$$saving\ FO(t) =$$

$$\max(total\ disposable\ nominal\ income(t) - nominal\ cons\ FO(t), 0)$$

$$dissaving\ FO(t) =$$

$$\min(nominal\ cons(t) - total\ disposable\ income(t), possible\ dissaving(t))$$

$$desired\ new\ loans(t) =$$

$$nominal\ cons(t) + savings(t) - dissaving\ FO(t) - total\ disposable\ income(t)$$

The stocks in this sector are given zero value initially. The reason is setting up a “clean page” for the agents of the economy. In a closed economy, one agent’s savings should be countered as another agent’s debt. Hence, putting positive deposit values should be balanced by putting debts. Initial values for deposits and debts can be calculated by the banking data. However, country-level data can have positive or negative net deposits since financial capital is free to float all around the world now. Household Current Account stock’s initial value is zero as well since we assume the household has zero liquidity preference, as discussed above.

## 5.2.2 Firm accounting sector

Figure 10 presents Firm Accounting Sector, which is similar to household accounting. There are four stocks. Any money flow received by the firm is represented as an inflow to Firm Current Account, and any payment made by the firm represented as an outflow from it. Firm Debt increases with new loans and decreases with debt payments. The firm is assumed not to retain any earnings and not to save as well. All the profit the firm makes goes as dividends. Hence, there is no firm deposits. Profits and dividends are calculated with Firm Retained Earnings stock and its flows. Nominal capital stock, on the other hand, increases with nominal investment and decreases with nominal depreciation. The stocks and flows in the firm accounting sector are, also, in accordance with ASD (Yamaguchi, 2013).

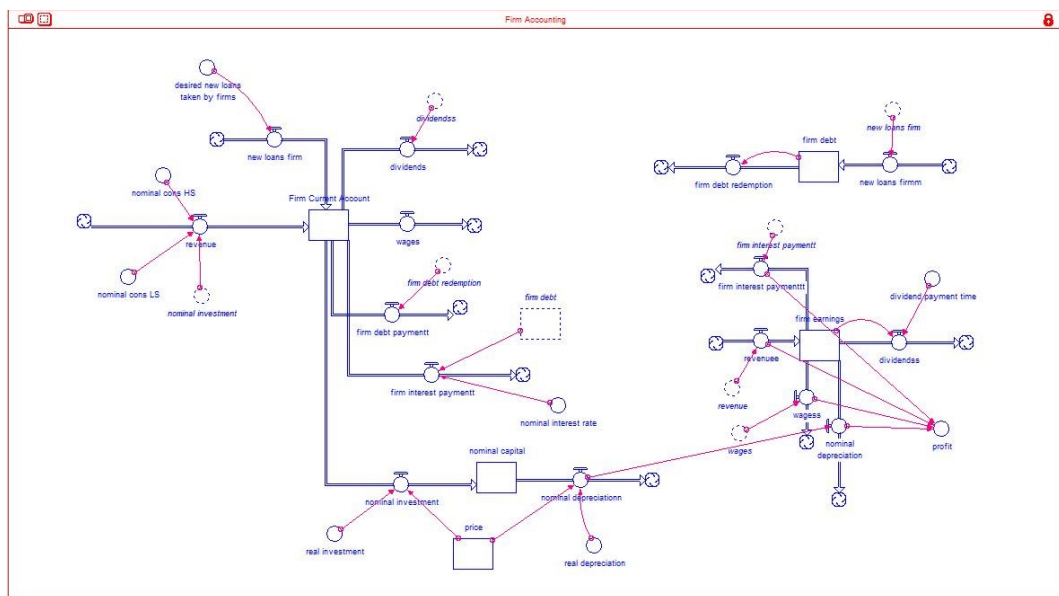


Figure 10. Simplified firm accounting sector

Some important equations in this sector are:

$$Firm\ Current\ Account(t) = Firm\ Current\ Account(t - dt) + (revenue + new\ loans\ firm - wages - firm\ debt\ payment - firm\ interest\ payment - dividends - nominal\ investment) * dt$$

$$\text{firm debt}(t) = \text{firm debt}(t - dt) + (\text{new loans firm} - \text{firm debt redemption}) * dt$$

$$\text{firm earnings}(t) = \text{firm earnings}(t - dt) + (\text{revenue} - \text{wages} - \text{nominal depreciation} - \text{firm interest payment} - \text{dividends}) * dt$$

$$\text{nominal capital}(t) = \text{nominal capital}(t - dt) + (\text{nominal investment} - \text{nominal depreciation}) * dt$$

$$\text{desired new loans taken by firms} = \text{wages} + \text{nominal investment} + \text{firm interest payment} + \text{firm debt payment} + \text{dividends} - \text{revenue}$$

$$\text{profit} = \text{revenue} - \text{firm interest payment} - \text{nominal depreciation} - \text{wages}$$

$$\text{dividends} = \max(\text{firm earnings} / \text{dividend payment time}, 0)$$

The debt stock's initial value is zero in accordance with the household accounting sector. Retained earnings is initially set to 350, which is close to initial profit level in the model. The initial value of nominal capital is simply the initial value of the real capital times the initial price.

### 5.2.3 Investment decision and real capital sector

As depicted in Figure 11, there are two stocks in this sector. Real capital stock increases with investment and decreases with depreciation. Perceived profit rate stock is adjusted to profit rate with two-year lag, meaning that perceived profit rate is two year moving average of the profit rate. Perceived profit rate is the sole indicator of the firm when taking investment decisions. When perceived profit rate is greater than nominal interest rate, then desired capital increases. An increase in desired capital increases desired investment; hence, investment rises. Depreciation rate is taken constant as 0.05 which means that the average life of capital is twenty years.

Here the implicit assumption is that there is competition among firms that we model as one representative firm. When there is economic profit, then more firms enter into the business. Hence, in this sector we take a Neoclassical position.

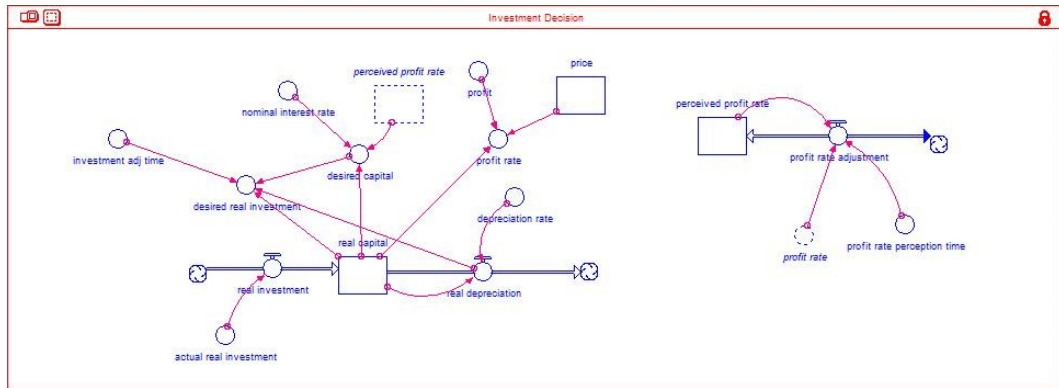


Figure 11. Investment decision and real capital sector

Some important equations of this sector are:

$$\text{perceived profit rate}(t) =$$

$$\text{perceived profit rate}(t - dt) + (\text{profit rate adjustment}) * dt$$

$$\text{real capital}(t) = \text{real capital}(t - dt) + (\text{real investment} - \text{real depreciation}) * dt$$

$$\text{desired capital} = (1 + \text{perceived profit rate} - \text{nominal interest rate}) * \text{real capital}$$

The perceived profit rate is initially set to initial marginal productivity of capital. We set the capital stock 4500 initially. This value is calculated by comparing real national income and real national capital based on the same year's prices. One can calculate real capital stock over real GDP ratio. The US capital is close to 3.8 times of the national output.<sup>9</sup> Please note that we set the initial values of the stock variables according to the US macroeconomic data, as far as possible. We will compare the

<sup>9</sup><https://fred.stlouisfed.org/series/RKNANPUSA666NRUG>

model behavior to the US data in the behavioral validation part as well because we try to emulate the behavior of the US economy. Hence, Equation (1) gives us the initial capital value when we choose labor first.

$$Labor^{LaborCoefficient} * Capital^{CapitalCoefficient} = 3.8 * Capital. \quad (1)$$

#### 5.2.4 Labor market sector

Figure 12 shows the stocks and flows of the labor force, while Figure 13 depicts the determination and adjustment process of the nominal wage rates. As mentioned earlier, there are two types of labor: Low skilled and high skilled. It is assumed that high skill workers can work in both high skilled jobs and low skilled jobs while low skilled workers are only able to work in low skilled jobs. Hence, high skilled workers switch sectors by comparing real wage rates of both sectors. Labor demand is determined by the firm according to a Cobb-Douglas production function. In other words, the firm demands labor by comparing the real wage rate and marginal productivity of the labor. Workers are assumed to work when the firm demands; hence, there is no reservation wage.

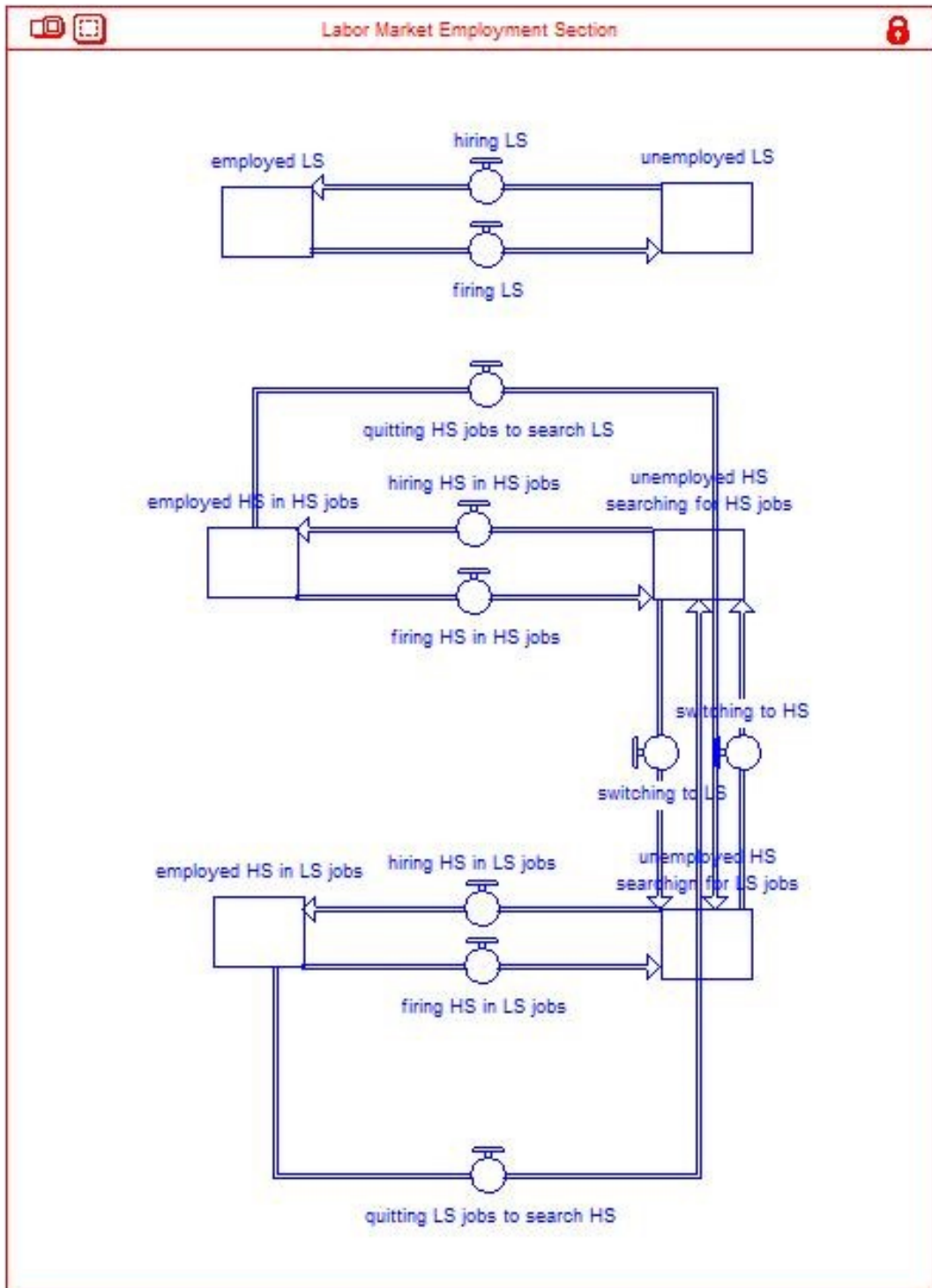


Figure 12. Labor market sector employment section

Nominal wages are determined by supply and demand of the labor. The labor supply is assumed to be constant while the firm demands labor by comparing real wage rate and marginal productivity of the labor.

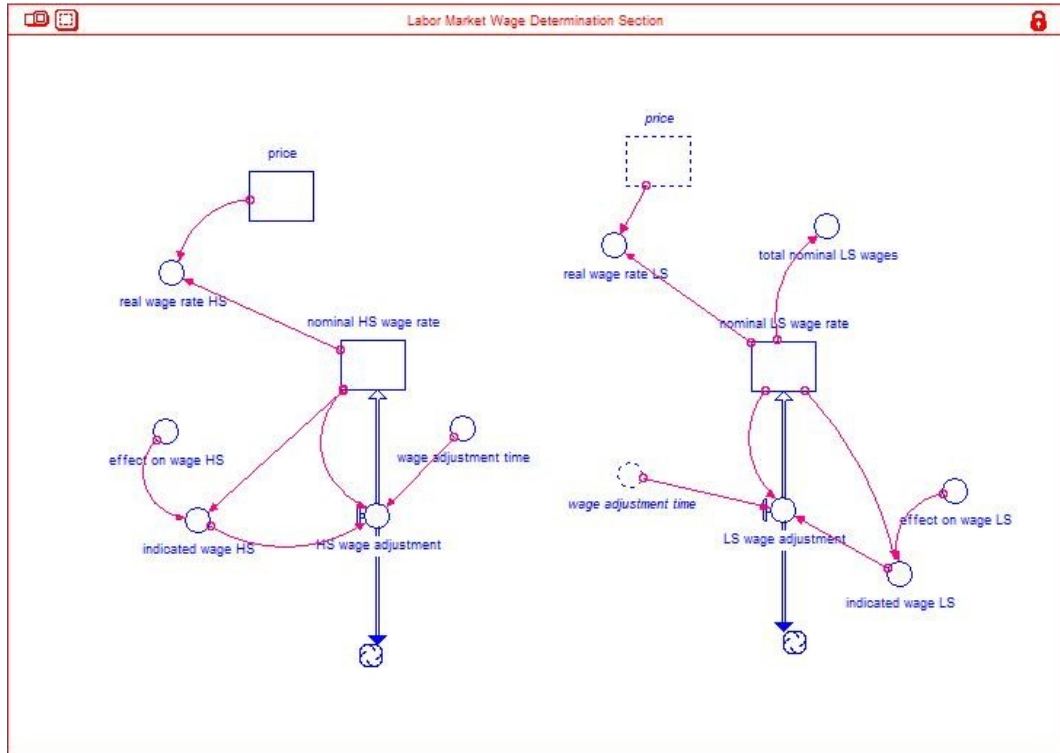


Figure 13. Labor market sector wage determination section

Some important equations of this sector are:

$$\text{employed HS in HS jobs}(t) =$$

$$\text{employed HS in HS jobs}(t - dt) + (\text{hiring HS in HS jobs} - \text{firing HS in HS jobs} - \text{quitting HS jobs to search LS}) * dt$$

$$\text{employed HS in LS jobs}(t) =$$

$$\text{employed HS in LS jobs}(t - dt) + (\text{hiring HS in LS jobs} - \text{firing HS in LS jobs} - \text{quitting LS jobs to search HS}) * dt$$

$$\text{employed LS}(t) = \text{employed LS}(t - dt) + (\text{hiring LS} - \text{firing LS}) * dt$$

$$\begin{aligned} \text{nominal HS wage rate}(t) &= \\ \text{nominal HS wage rate}(t - dt) &+ (\text{HS wage adjustment}) * dt \end{aligned}$$

$$\begin{aligned} \text{nominal LS wage rate}(t) &= \\ \text{nominal LS wage rate}(t - dt) &+ (\text{LS wage adjustment}) * dt \end{aligned}$$

$$\begin{aligned} \text{desired HS employment} &= \\ &(\text{real wage rate HS} / (\text{HS coefficient} * (\text{real capital}^{\text{capital coefficient}}) * \\ &(\text{total LSEmployment}^{\text{LS coefficient}})))^{1/(\text{HS coefficient}-1)} \end{aligned}$$

$$\begin{aligned} \text{desired LS employment} &= \\ &(\text{real wage rate LS} / (\text{LS coefficient} * (\text{real capital}^{\text{capital coefficient}}) * \\ &(\text{employed HS in HS jobs}^{\text{HS coefficient}})))^{1/(\text{LS coefficient}-1)} \end{aligned}$$

To calculate the initial values for employment and unemployment stocks; firstly, LS labor force is set to 1000. For the US, the share of labor force, which has a diploma for bachelor's degree and higher education is 40% of all labor force.<sup>10</sup> Hence, the HS labor force is calculated as 667. Initial values for the wage rates are initial marginal productivity of labor.

### 5.2.5 Inventory sector

In this sector, there is only one stock: Inventory. Figure 14 shows the stock flow diagram of the "Inventory sector". The existence of the inventory allows us to separate production and consumption. Hence, it is not assumed in the model that the consumption equals to the production. The production function used here is a Cobb-Douglas production function<sup>11</sup> with three inputs: High skilled labor, low

<sup>10</sup> <https://www.bls.gov/cps/tables.htm#empstat>

<sup>11</sup> Cobb-Douglas production function and other neoclassical production functions are heavily criticized by heterodox economists. Shaikh (1974) and McCombie (2001) show that Cobb-Douglas function simply reflects the national income accounts. Post-Keynesians and Sraffians also criticized Cobb-

skilled labor, and capital. The coefficients are selected as 0.35 for high skilled labor, 0.25 for low skilled labor, and 0.4 for capital. By employing a Cobb-Douglas production function we take a Neoclassical position in this sector, as well.

Households' desired consumption in real terms and desired real investment are added together. This aggregation forms total desired consumption. Total desired consumption may or may not be met. It depends on whether the inventory contains enough products. If there are fewer products than demanded, possible consumption is split between different competing ends by their share in the total desired consumption. The desired inventory is calculated as a proportion of total desired consumption. The logic here is the firm wants to keep some inventory for unexpected demand conditions as a buffer.

When desired inventory is higher than the inventory, then the price increases, as Figure 15 explains the stock flow dynamics of the price. The ratio of desired inventory over inventory measures how strong the demand structure is and how much room there is to increase the price. Effect on price times price gives us indicated price to which the price converges.

---

Douglas production function; since heterogeneous capital usage by different sectors create a severe aggregation problem even if production functions of different sectors are Cobb-Douglas type (Lavoie, 2014; Pasinetti 1966). The re-switching argument also casts doubt on the claim that individual firms' capital demand is inversely related to interest rates; thus, sector or firms' production functions are not Cobb-Douglas type individually yet alone in the aggregate economy. This study employs Cobb-Douglas type production function not because these criticisms are considered to be invalid. The first reason is that using a Leontieff production function sets a maximum value for the aggregate production, because labor force is assumed not to change. Second, using a Kaleckian production function (Production = Labor Productivity x Employment) with constant labor productivity creates this upper limit as well. Then, the productivity parameters should be changed for both types. However, if productivity of labor depends on the capital level, then these functions become something very similar to Cobb-Douglas.

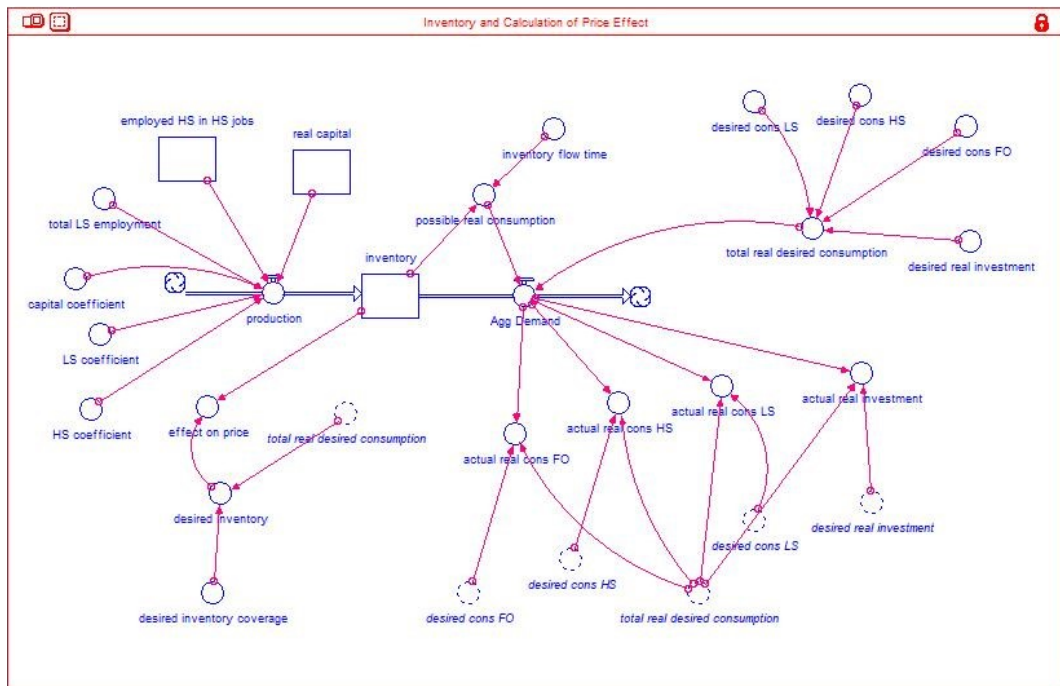


Figure 14. Inventory sector

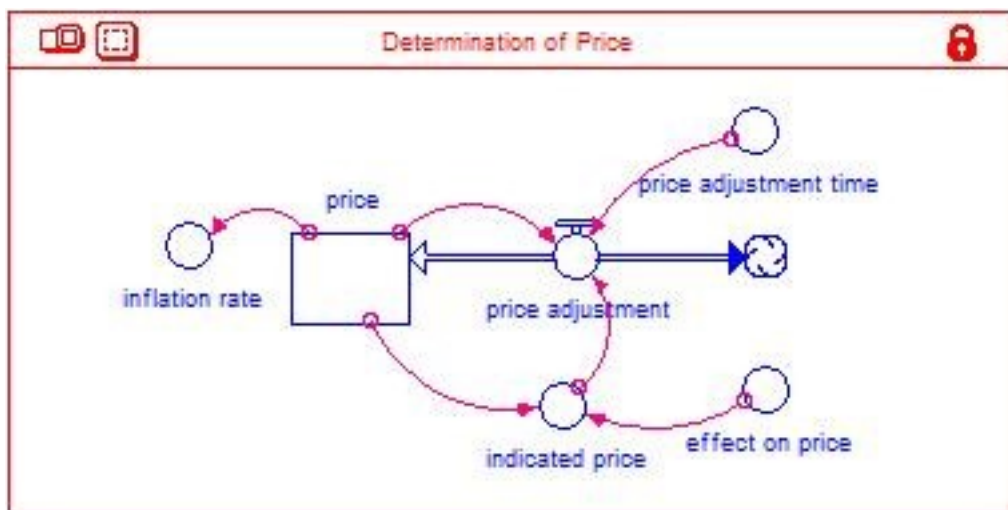


Figure 15. Price sector

Some important equations of this sector are:

$$inventory(t) = inventory(t - dt) + (production - Agg Demand) * dt$$

$$production = (total\ LS\ employment^{LS\ coefficient}) * (real\ capital^{capital\ coefficient}) * (employed\ HS\ in\ HS\ jobs^{HS\ coefficient})$$

$desired\ inventory = total\ real\ desired\ consumption * desired\ inventory\ coverage$

$effect\ on\ price = (desired\ inventory / inventory) - 1$

$price(t) = price(t - dt) + (price\ adjustment) * dt$

$indicated\ price = price * (1 + effect\ on\ price)$

The initial value for the inventory is the initial desired inventory. The initial price can be set arbitrarily since it does not change anything.

#### 5.2.6 Consumption decision sector

Figure 16 shows the stock flow map of this sector. Households' desired consumption is modeled as a Keynesian consumption function. Households consume first their necessary consumption. If there is remaining income, they consume a part of this extra income. The amount of the extra income consumed is determined by marginal propensity to consume (hereafter MPC). Households stare up when they engage in consumption competition (Schor, 1998; Sterman, 2012). Hence, the firm owner household's MPC is assumed to be constant because the firm owner household has the highest step in the hierarchical setting. Therefore, the high skilled wage earner household emulates the firm owner household, and the low skilled wage earner household emulates the high skilled wage earner household. The high skilled household compares its per capita consumption level with the firm owner household's per capita consumption level. The perceived relative consumption between them affects MPC HS. The effect function is formulated as a graphic function. The same process holds for the low skilled wage earner household.

Here we model conspicuous consumption as an original contribution. As far as we know, there is no previous modeling of conspicuous consumption within system dynamics. There are utility function formulations in Economics literature, which

accounts for conspicuous consumption; however, they are based on optimization rather than heuristics.

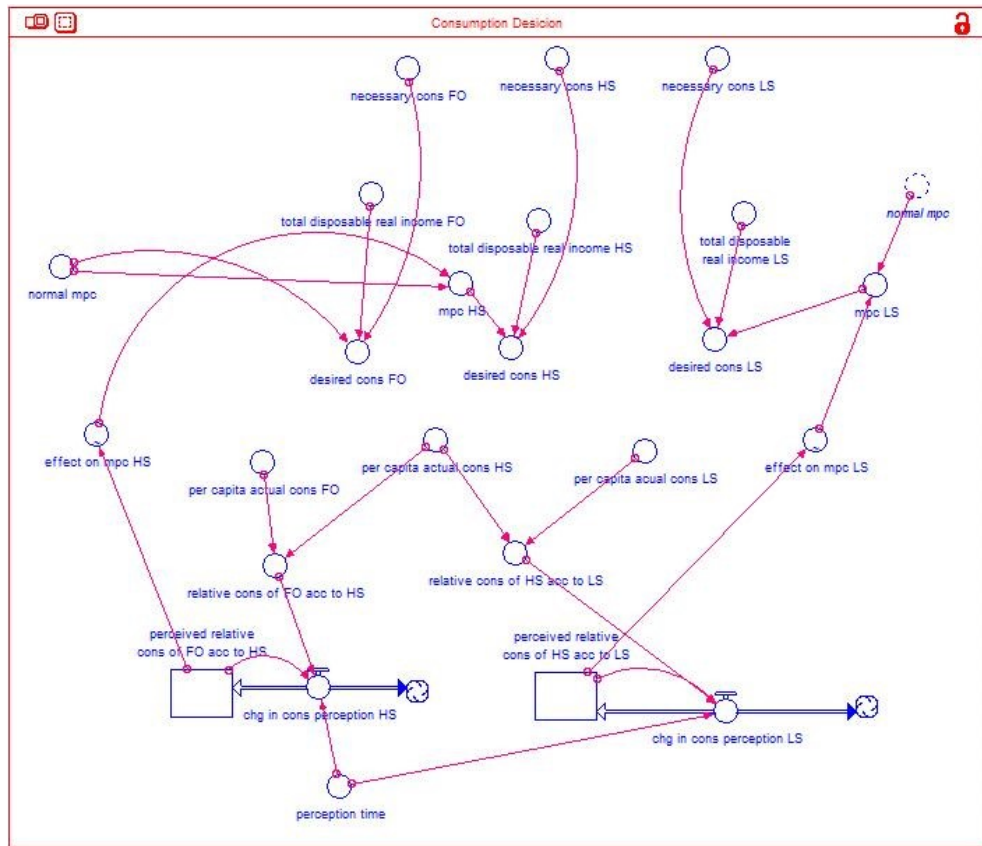


Figure 16. Consumption decision sector

Some important equations for this sector are:

$$\text{perceived relative cons of FO acc to HS}(t) = \text{perceived relative cons of FO acc to HS}(t-dt) + (\text{chng in cons perception HS}) * dt$$

$$\text{desired cons HS} = (\max(\min(\text{necessary cons HS} + (\text{total disposable real income HS} - \text{necessary cons HS}) * \text{mpc HS}, \text{total disposable real income HS}), \text{necessary cons HS}))$$

$$\text{mpc HS} = \text{effect on mpc HS} * \text{normal mpc}$$

*effect on mpc HS =*

*GRAPH(perceived relative cons of FO acc to HS)* (0.00, 0.2), (0.2, 0.25), (0.4, 0.4), (0.6, 0.6), (0.8, 0.8), (1.00, 1.00), (1.20, 1.10), (1.40, 1.15), (1.60, 1.20), (1.80, 1.23), (2.00, 1.25)

Initial values for perceived relative consumption stocks are set to initial relative per capita incomes.

### 5.2.7 Environmental impact and Gini calculation

The environmental impact of the consumption is calculated by putting an exogenous function, which turns consumption to the carbon footprint. The function is calculated by using WWF's footprint calculator available online.<sup>12</sup> The underlying logic of the footprint calculation is that every product a person consumes requires a certain land of production and certain sunk areas for the waste. The theoretical foundation of footprint calculator rests on Wackernagel and Rees (1996).

The function which turns consumption to ecological footprint is assumed to be first linear then increasing in a decreasing way. The underlying reason for this specification is that service consumption is less harmful to the environment, and at some point in income level, the material consumption is saturated (Ravallion et al., 2000). The alternative formulations would be a linear or an S-shaped relationship between consumption and environmental footprint. The shape of this function is a question which should be addressed by detailed empirical research. In this study, the alternative specifications are analyzed in scenario analysis.

Some important equations to calculate the environmental impact are:

$$\text{cumulative footprint}(t) = \text{cumulative footprint}(t - dt) + (\text{yearly footprint}) * dt$$

---

<sup>12</sup><https://footprint.wwf.org.uk>

*per capita footprint FO =*

*GRAPH(per capita actual cons FO)*(0.00, 0.00), (0.25, 0.25), (0.5, 0.5), (0.75, 0.75),  
(1.00, 1.00), (1.25, 1.25), (1.50, 1.50), (1.75, 1.75), (2.00, 2.00), (2.25, 2.25), (2.50,  
2.50), (2.75, 2.75), (3.00, 3.00), (3.25, 3.15), (3.50, 3.30), (3.75, 3.40), (4.00, 3.50),  
(4.25, 3.60), (4.50, 3.70), (4.75, 3.75), (5.00, 3.80)

*per capita footprint HS =*

*GRAPH(per capita actual cons FO)*(0.00, 0.00), (0.25, 0.25), (0.5, 0.5), (0.75, 0.75),  
(1.00, 1.00), (1.25, 1.25), (1.50, 1.50), (1.75, 1.75), (2.00, 2.00), (2.25, 2.25), (2.50,  
2.50), (2.75, 2.75), (3.00, 3.00), (3.25, 3.15), (3.50, 3.30), (3.75, 3.40), (4.00, 3.50),  
(4.25, 3.60), (4.50, 3.70), (4.75, 3.75), (5.00, 3.80)

*per capita footprint LS =*

*GRAPH(per capita actual cons FO)*(0.00, 0.00), (0.25, 0.25), (0.5, 0.5), (0.75, 0.75),  
(1.00, 1.00), (1.25, 1.25), (1.50, 1.50), (1.75, 1.75), (2.00, 2.00), (2.25, 2.25), (2.50,  
2.50), (2.75, 2.75), (3.00, 3.00), (3.25, 3.15), (3.50, 3.30), (3.75, 3.40), (4.00, 3.50),  
(4.25, 3.60), (4.50, 3.70), (4.75, 3.75), (5.00, 3.80)

*total footprint FO = population of FO \* per capita footprint FO*

*total footprint HS = population of HS \* per capita footprint HS*

*total footprint LS = population of LS \* per capita footprint LS*

*total footprint = total footprint FO + total footprint HS + total footprint LS*

In this model, we calculate a Gini index. However, there is no individual level income variable in the model to construct a Gini index. Hence, the three households'

income is assumed to be distributed equally within themselves to calculate the model Gini. As a consequence, the model's Gini underestimates the income inequality.

We calculate the personal income distribution out of functional income distribution in a way that is similar to the Dafermos and Papatheodorou (2015). Dafermos and Papatheodorou (2015) define five different households which earn different income types such as wages, interests and dividends and the same income type in different proportions. They ruled out the differences within the different household groups and they assume there is no transition from high skilled to low skilled, and wage earner households to capital owner household, similar to our income distribution model (Dafermos & Papatheodorou, 2015). Their model focuses mainly on the transformation of functional income distribution to the personal income distribution; hence, their income distribution model is substantially more detailed than the one we employ here.

There are six different ordering of the income distribution. For example, per capita income of the firm owner household is greater than per capita income of high skilled wage earner household, and per capita income of low skilled wage earner household is the lowest. Hence, we define six different Gini indexes. We name them type 1 Gini, type 2 Gini and so on. Then we write a logical function to calculate which of these six different Gini indexes is correct.

$$\begin{aligned} \text{type 1 Gini} = & (0.5 - ((LS \text{ population share} * LS \text{ income share}/2) + \\ & (HS \text{ population share} * HS \text{ income share}/2) + (FO \text{ income share} * \\ & FO \text{ population share}/2) + (LS \text{ income share} * HS \text{ population share}) + \\ & (FO \text{ population share} * (HS \text{ income share} + LS \text{ income share}))))/0.5 \end{aligned}$$

*model Gini = if(income per capita LS < income per capita HS)then( if  
(income per capita HS < income per capita FO) then (type 1 Gini) else  
(if (income per capita FO < income per capita LS) then (type 6 Gini) else  
(type 2 Gini))) else (if (income per capita LS < income per capita FO) then*

*(type 3 Gini) else (if (income per capita HS < income per capita FO) then  
(type 4 Gini) else (type 5 Gini))*

## CHAPTER 6

### VALIDATION

The model in this thesis brings different theories in Economics together. In Economics, these theories are analyzed and discussed partially. Hence, the structural validation process assesses the internal validity of these theories, which interact together in this model. After we establish the structural validity of the model we check whether the model captures the real behavior of an economy, especially the US economy.

The validity tests are carried to ensure that the dynamic model is a good representation of the real system (Barlas, 2002). The validity tests are implemented in two ways. First, the model should pass direct structural tests. If the direct structural tests are satisfied, then the model should pass indirect structural tests. Second, since the model should create the real system's behavior, the behavioral validity test is implemented to the model.

#### 6.1 Structure validity

##### 6.1.1 Direct structural tests

Structure tests are carried to ensure the structure of the model is a meaningful representation of the real-world structure (Barlas, 2002). With the direct structural tests, the modeler tries to assess i) whether the parameters and variables of the model have real-life meaning and ii) whether the model equations yield dimensional consistency. Securing the direct structure tests means that every parameter and variable in the model should have real-life counterpart, and all equations of the model satisfy dimensional consistency.

The direct structure tests are implemented throughout the building phase of the model. Every parameter and variable have real-life meaning and dimensional consistency.

### 6.1.2 Indirect structural tests

There are two indirect structure tests. One of them is extreme condition tests, and the other one is the parameter sensitivity tests.

The extreme condition tests are carried to understand the model behavior under extreme conditions. The model behavior should be logical under extreme conditions. Extreme condition means that parameters and initial values of stocks are given “too high” or “too low” values. Some of the extreme conditions are simulated and explained below.

Parameter sensitivity tests are carried to determine the parameters in which the model is highly sensitive. The question to be asked is whether the real system would exhibit the same sensitivity to those parameters (Barlas, 1996).

#### 6.1.2.1 Extreme condition 1: Low skilled labor force is equal to zero

Figure 17, 18, 19, and 20 depict the behavior of the main variables of the model under the extreme condition 1.

When the low skilled labor force is set to zero the real wage rate of low skilled jobs gets higher. An increase in the real wage rate of the low skilled jobs attracts high skilled workers to low skilled jobs. At first, the production is zero, and then the replacement of the high skilled workers to low skilled jobs creates more production. The production cannot reach the old production level simply because the economy loses a considerable amount of labor force.

The real income of the firm owner household goes to negative values because production is depressed at first. High skilled workers’ wage rate is lower because most of them are laid idle since the firm makes losses and not desire to employ workers.

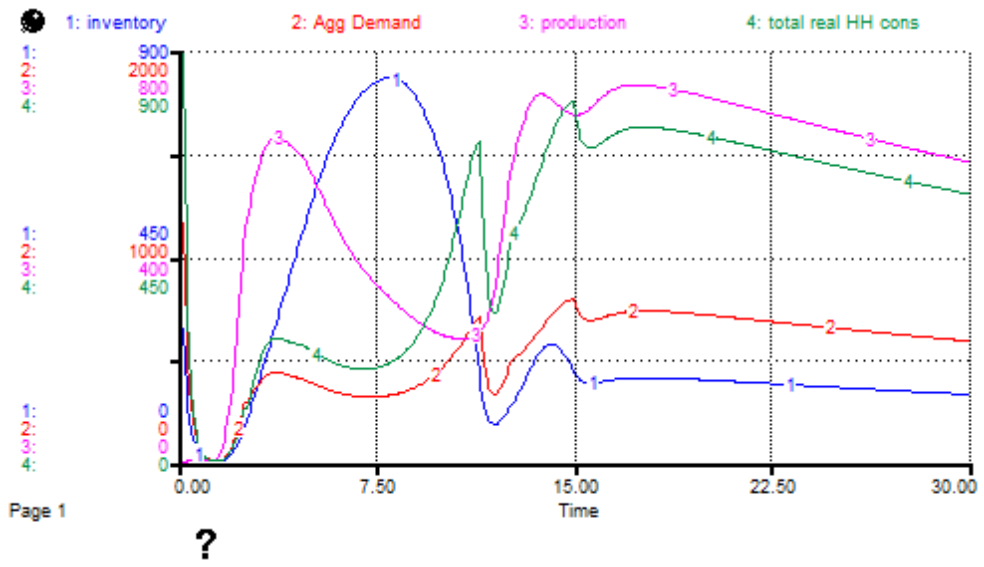


Figure 17. Production, aggregate demand, inventory and the total household consumption under extreme condition 1

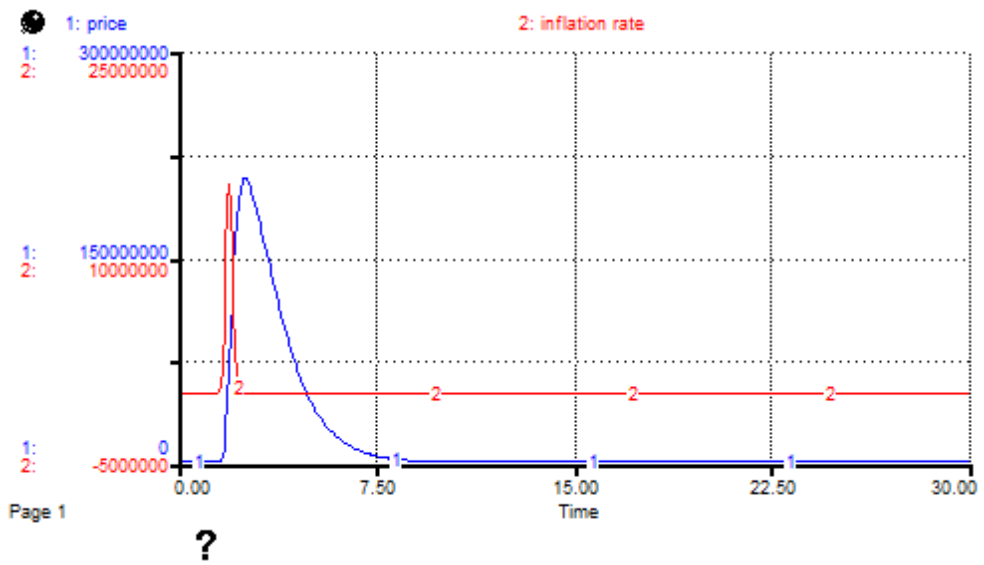


Figure 18. Price and inflation rate under extreme condition 1

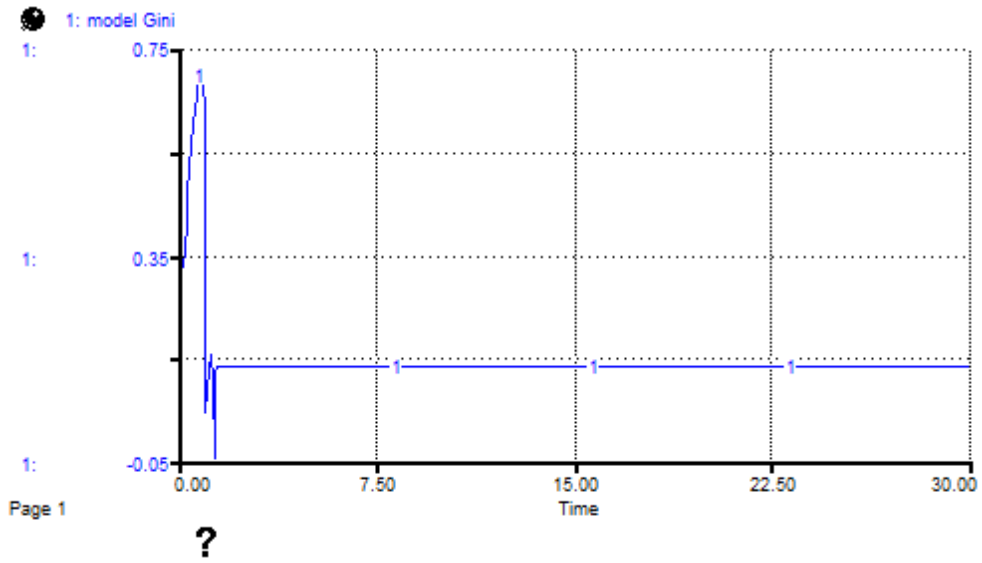


Figure 19. Model Gini under extreme condition 1

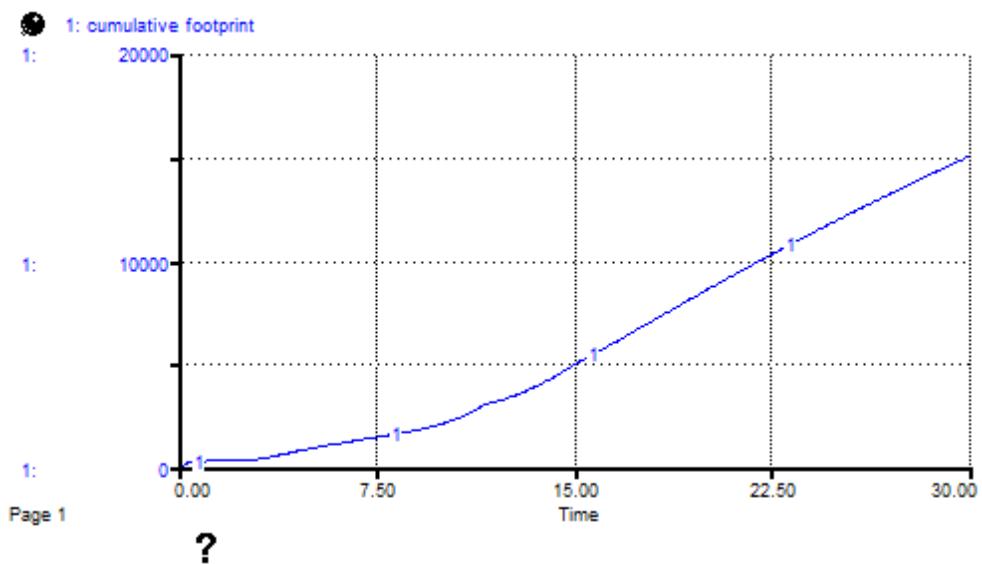


Figure 20. Cumulative footprint under extreme condition 1

#### 6.1.2.2 Extreme condition 2: High skilled labor force is equal to 1

Figure 21, 22, 23, and 24 show how the main variables of the model behave under the extreme condition 2.

The model cannot complete the thirty-year run if the high skilled labor force is set to zero. The reason is that the two out of three factors of production, namely capital and high skilled labor, are both essential factors. One of them being absent would create zero production. The inventory would go down to zero, and the

indicated price goes to infinity since it depends on the ratio of desired inventory/inventory. When the high skilled labor force is set to 1, then the production is substantially low. The low skilled labor cannot replace with the high skilled labor. The production, consumption, and inventory all go down near zero.

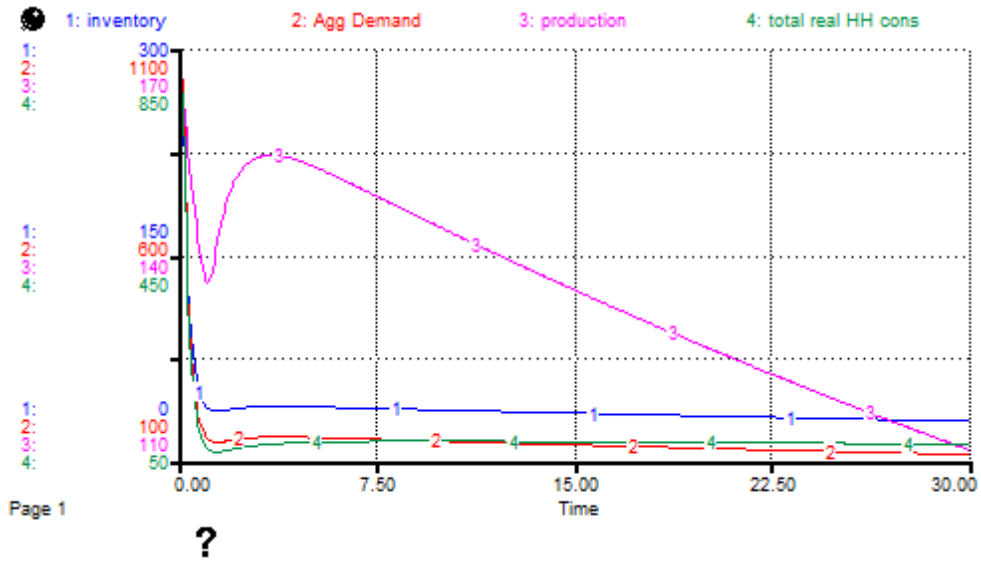


Figure 21. Production, aggregate demand, inventory and the total household consumption under extreme condition 2

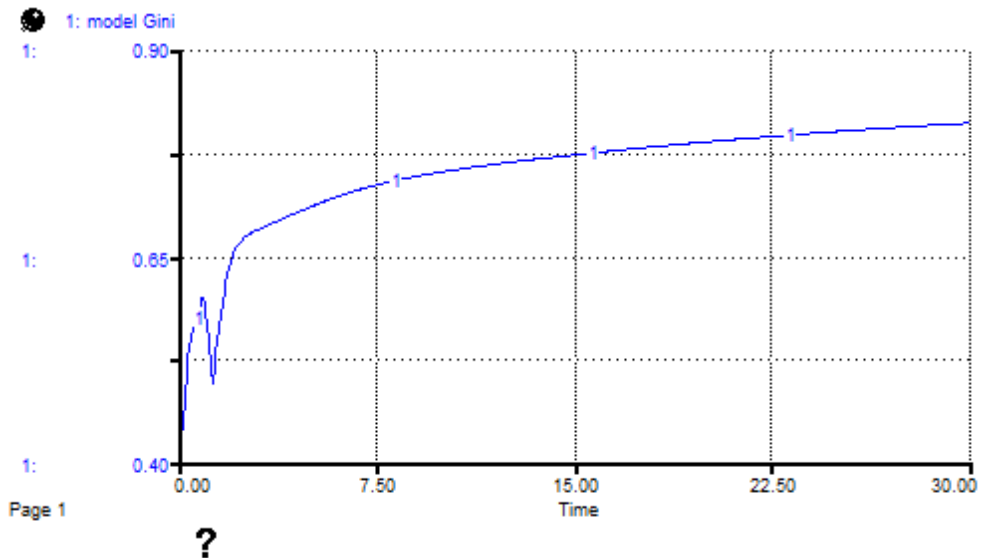


Figure 22. Price and inflation rate under extreme condition 2

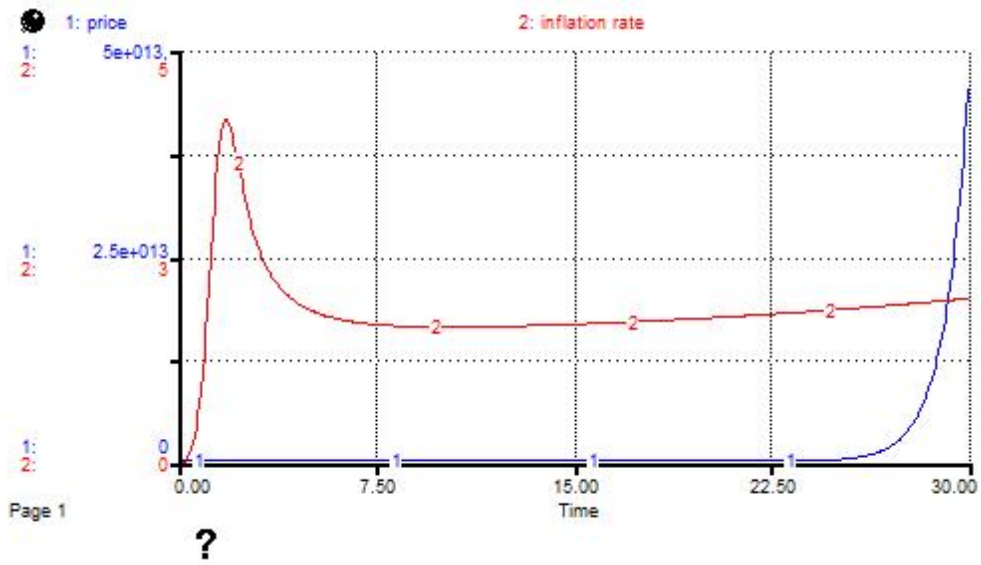


Figure 23. Model Gini under extreme condition 2

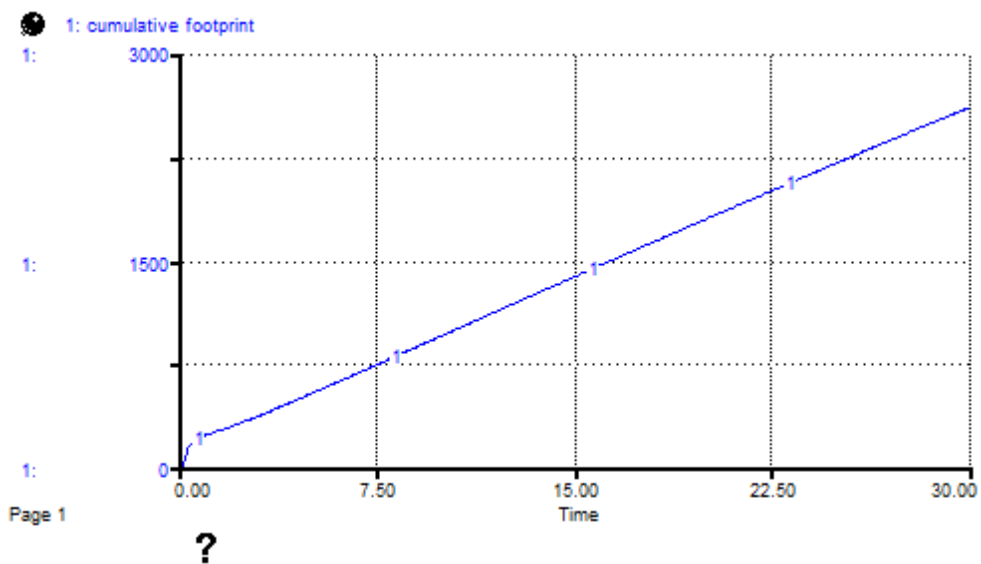


Figure 24. Cumulative footprint under extreme condition 2

### 6.1.2.3 Extreme condition 3: Initial capital is set to zero

As Figure 25, 26, and 27 show; the economic activity is zero, inflation skyrocketed and cumulative footprint is stable at a low rate when the initial capital is set to zero.

When the initial capital is set to zero, then the production, aggregate demand, and total household consumption become zero. The products in the inventory are consumed by the households, and there is no product left for investment to increase the capital stock.

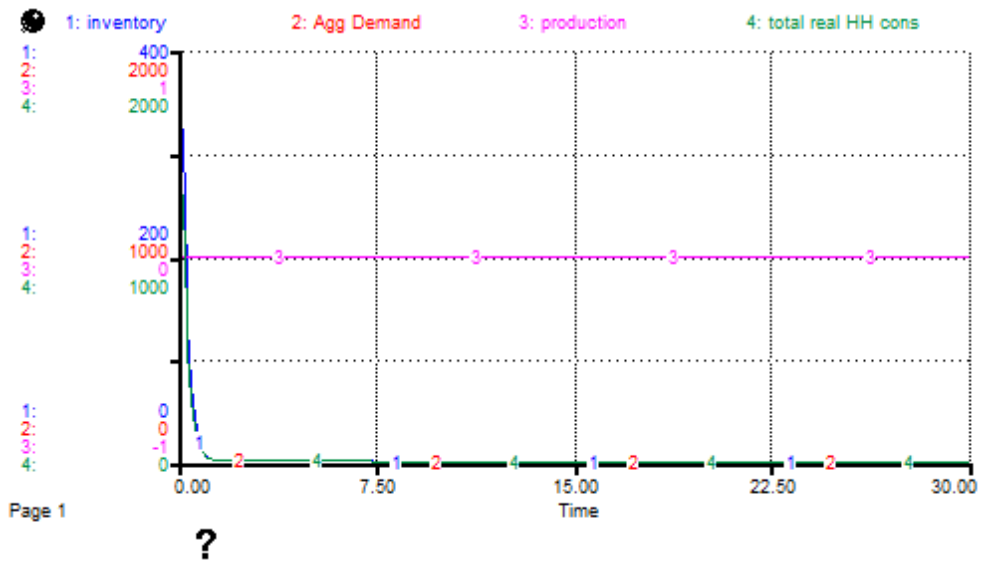


Figure 25. Production, aggregate demand, inventory and the total household consumption under extreme condition 3

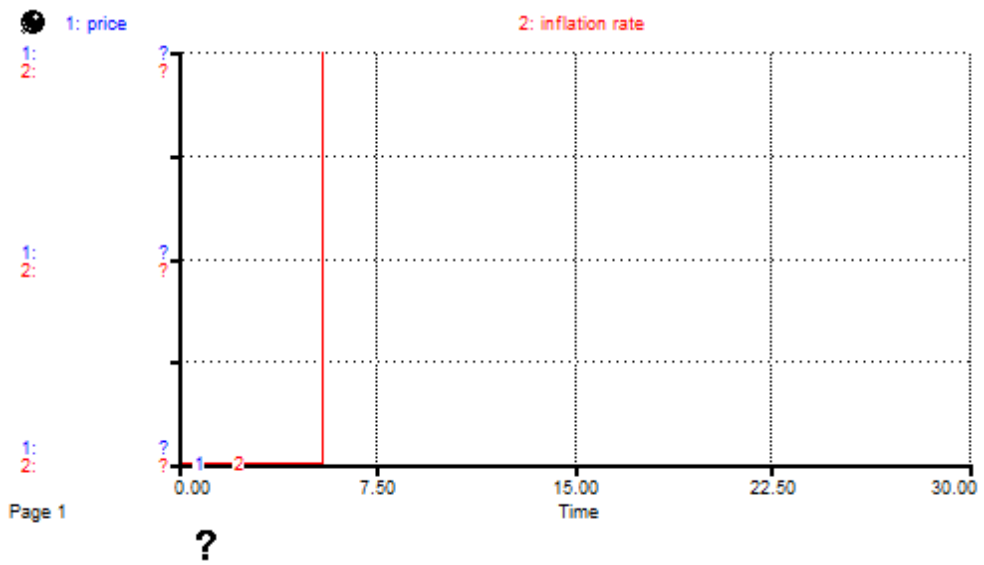


Figure 26. Price and inflation rate under extreme condition 3

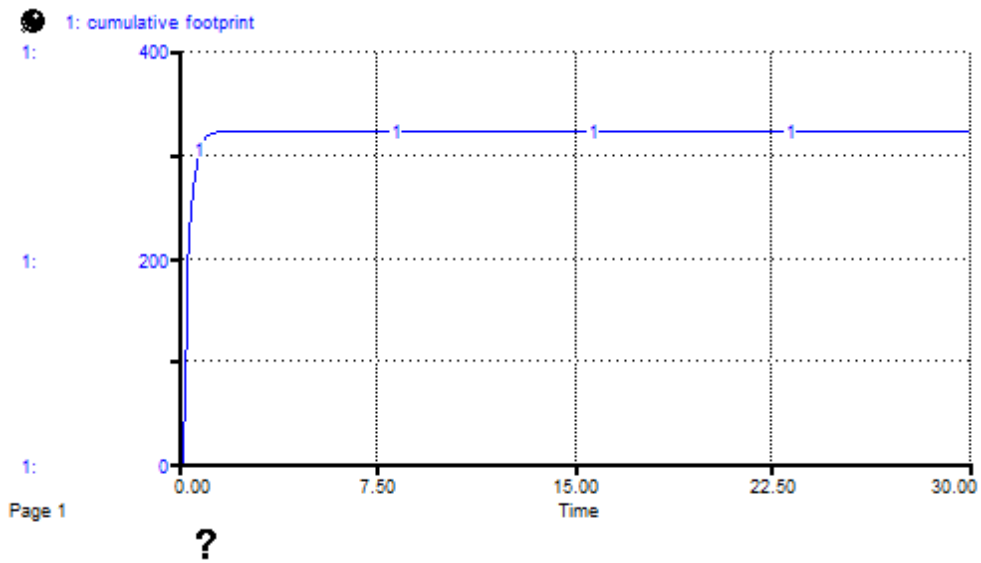


Figure 27. Model Gini under extreme condition 3

#### 6.1.2.4 Extreme condition 4: Nominal interest rate is set to 100% and 0%

Figure 28, 29, 30, and 31 show the behavior of the economy when the nominal interest rate is 100% and Figure 32, 33, 34, and 35 depict it when the nominal interest rate is 0%.

When the nominal interest rate is set to 100%, then the firm has less incentive to invest. The result is less production and less consumption. Cooling of the economy reduces the inflation rate. Income inequality gets higher first. Then it gets lower since the economic downturn makes everyone poorer.

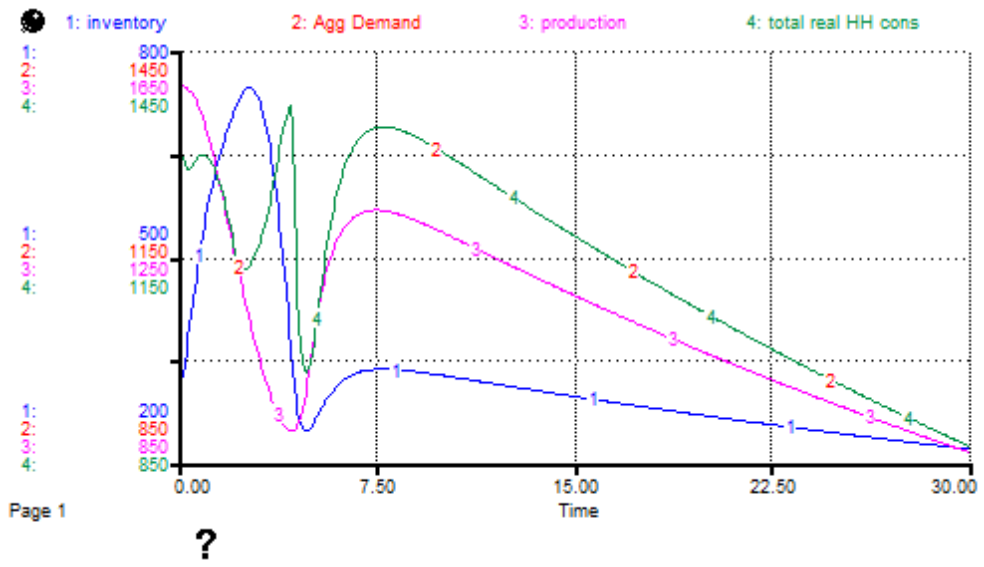


Figure 28. Production, aggregate demand, inventory and the total household consumption when nominal interest rate is 100%

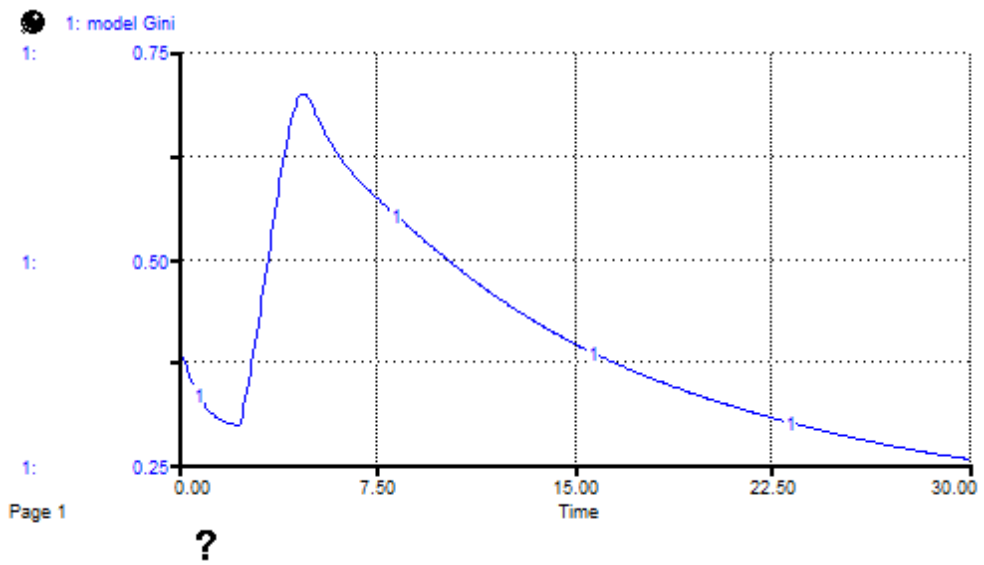


Figure 29. Price and inflation rate when nominal interest rate is 100%

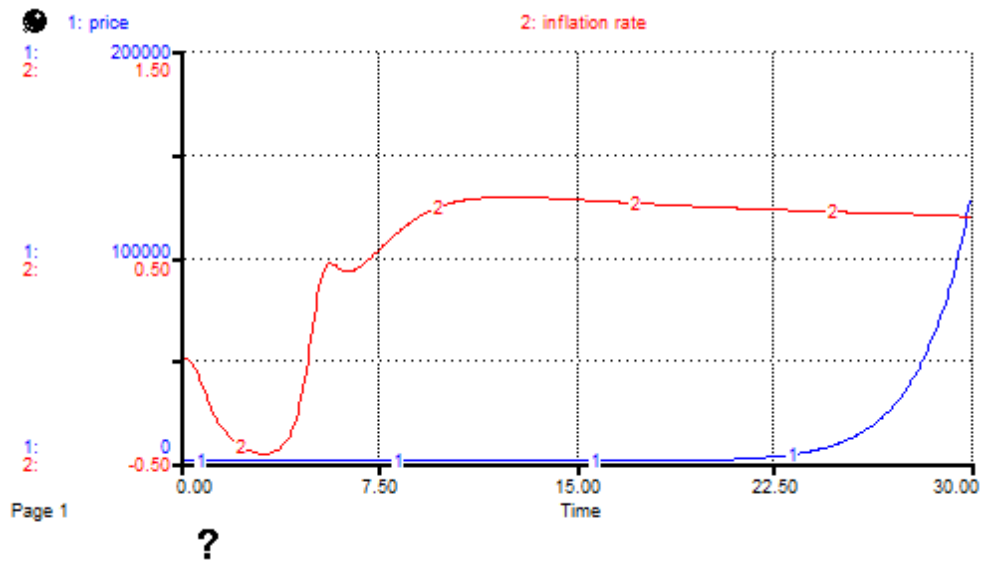


Figure 30. Model Gini when nominal interest rate is 100%

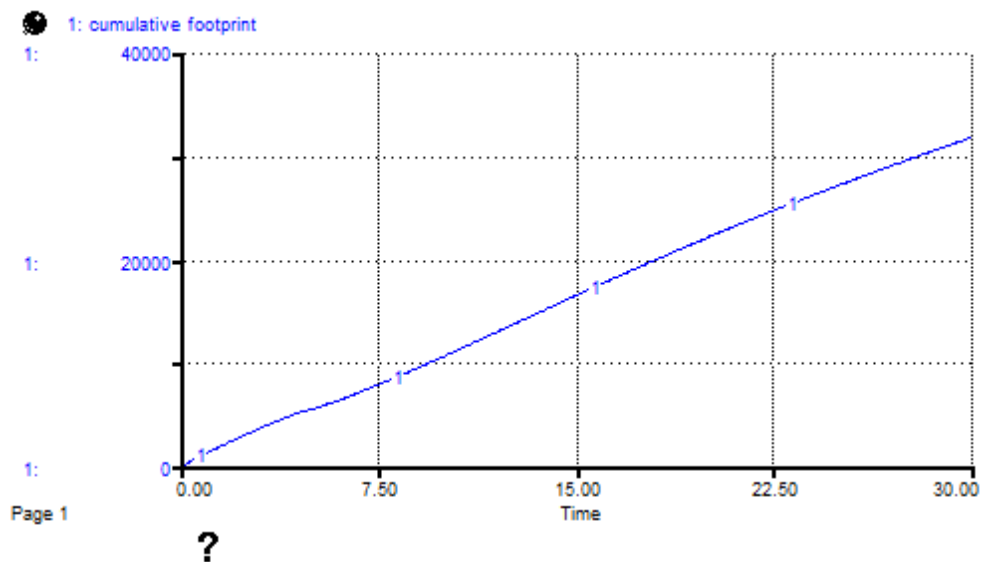


Figure 31. Cumulative footprint when nominal interest rate is 100%

When the nominal interest rate is set to 0%, the reverse process follows. The firm invests more than the base-run and the production and consumption increase. The production and consumption is higher than the base-run. Apart from that, the model behavior is very similar to base-run.

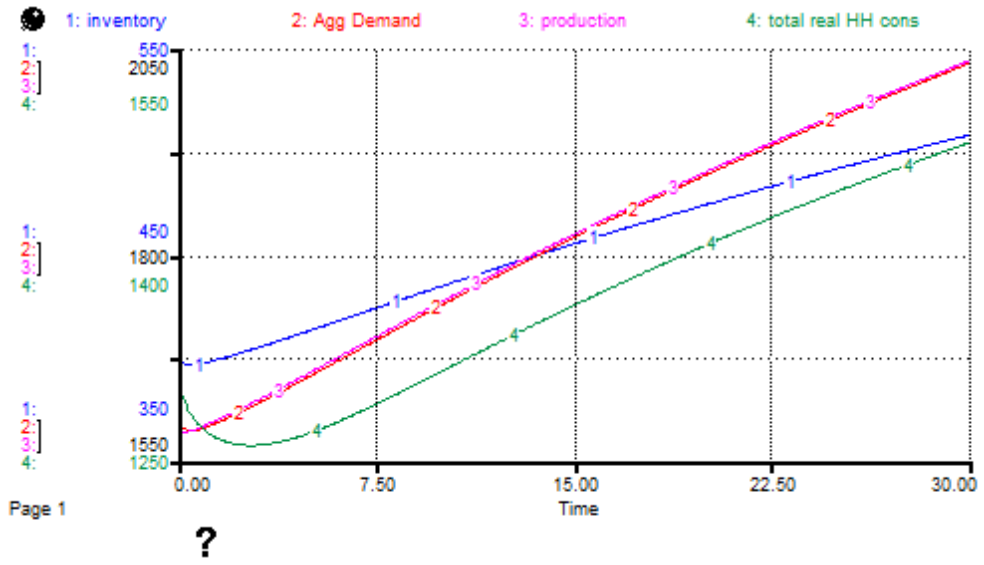


Figure 32. Production, aggregate demand, inventory and the total household consumption when nominal interest rate is 0%

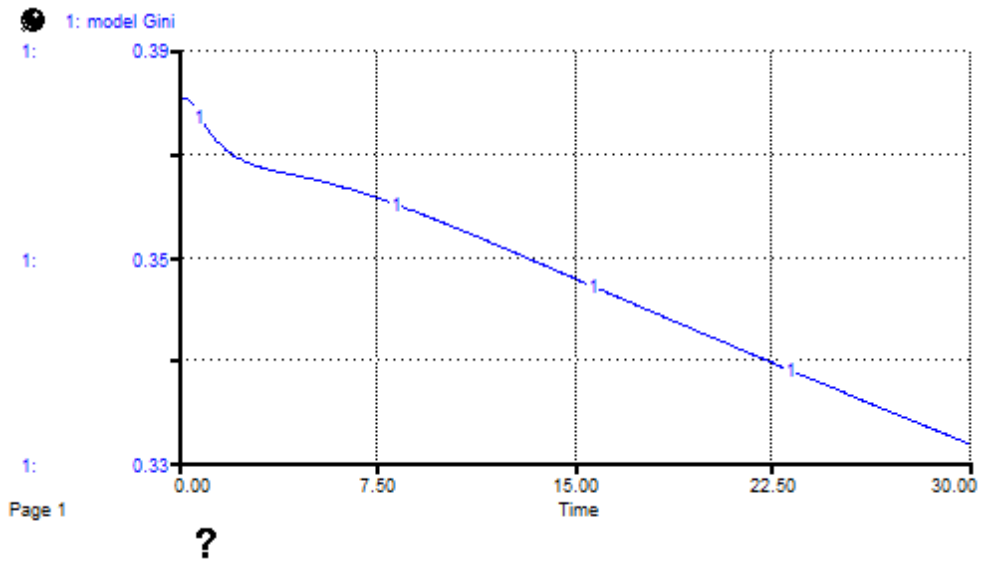


Figure 33. Price and inflation rate when nominal interest rate is 0%

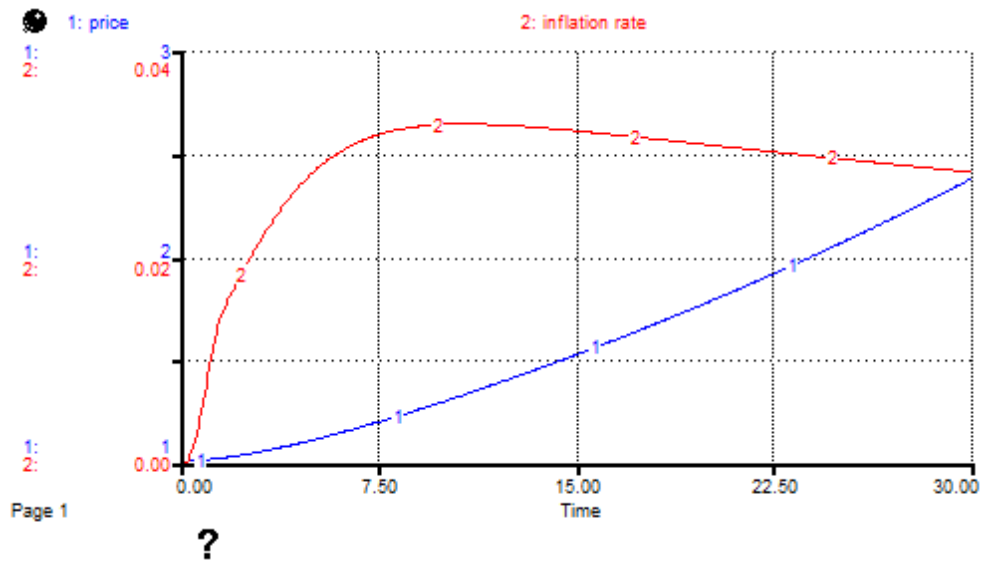


Figure 34. Model Gini when nominal interest rate is 0%

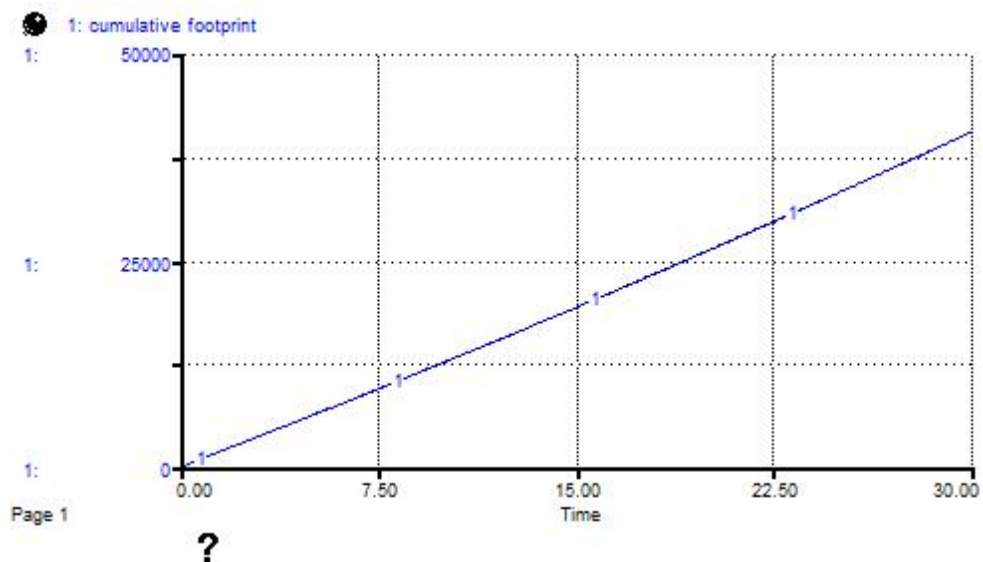


Figure 35. Cumulative footprint when nominal interest rate is 0%

#### 6.1.2.5 Depreciation rate sensitivity test

Figure 36, 37, 38, and 39 show the sensitivity of the main variables of the model to the changes in the depreciation rate.

Depreciation rate is set to 0.025, 0.05 and 0.075 respectively. Depreciation rate determines one of the cost items of the firm. When the depreciation rate is lower, then the firm is more profitable and invests more. As a result, the economy expands more rapidly.

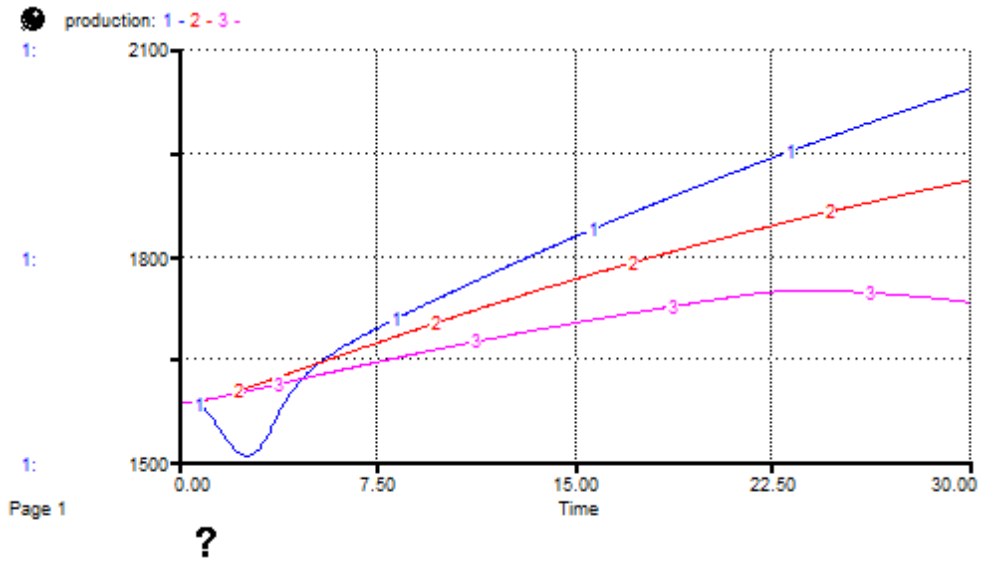


Figure 36. Depreciation sensitivity test: Production

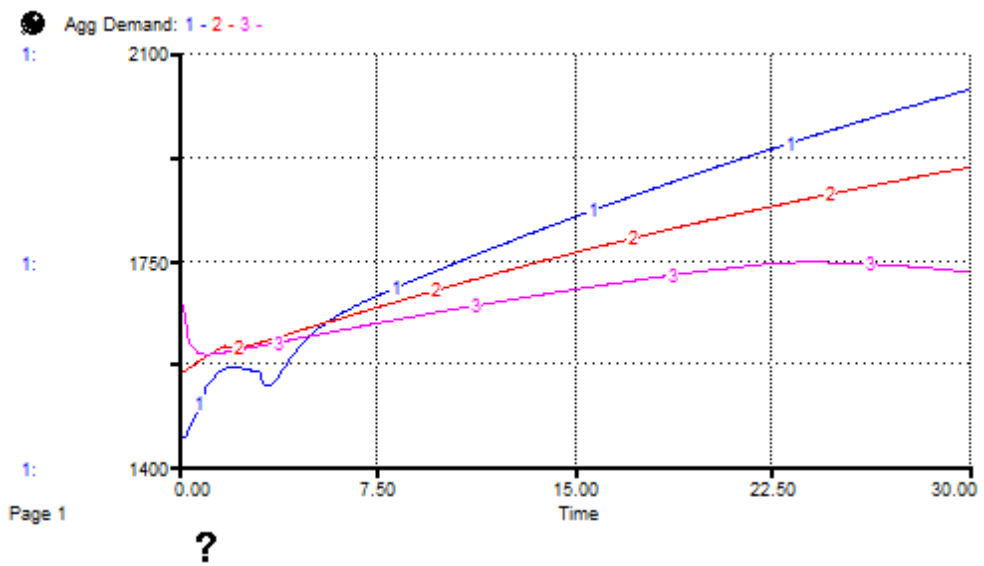


Figure 37. Depreciation sensitivity test: Aggregate demand

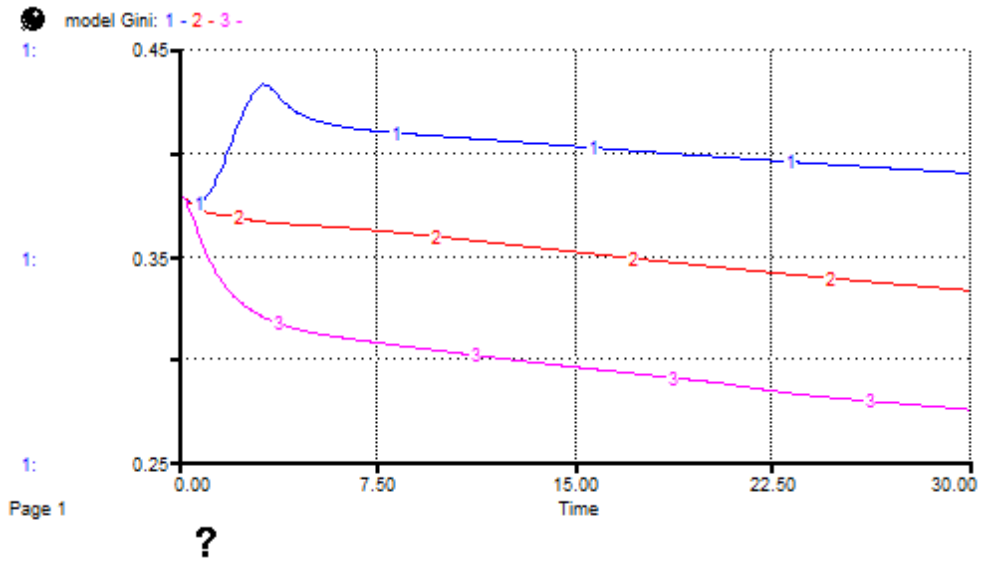


Figure 38. Depreciation sensitivity test: Model Gini

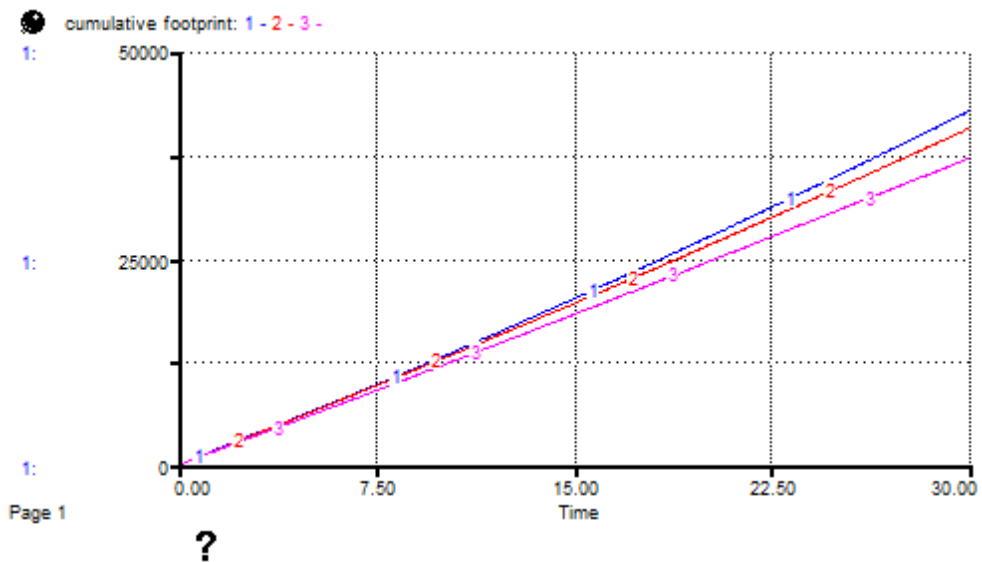


Figure 39. Depreciation sensitivity test: Cumulative footprint

#### 6.1.2.6 Normal MPC sensitivity test

Figure 40, 41, 42, and 43 show how the main variables of the model respond to the changes in normal MPC.

Normal MPC parameter is tested by setting it to 0.5, 0.6, 0.7, 0.8, 0.9. Normal MPC determines households' demand. Higher demand implies a more profitable firm which invests more. However, when household consumption demand is getting higher and higher, the effect of Normal MPC vanishes. The reason is that the firm cannot sell

more than the possible consumption, which is determined by the distribution time of the inventory. The inventory limit, in this case, is a supply limit which is created by the fixed labor force.

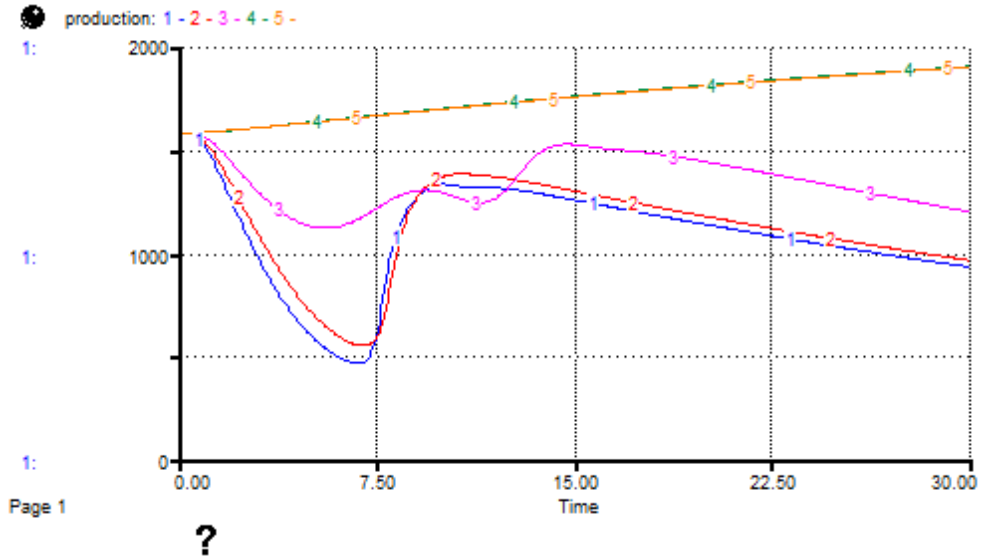


Figure 40. Normal MPC sensitivity test: Production

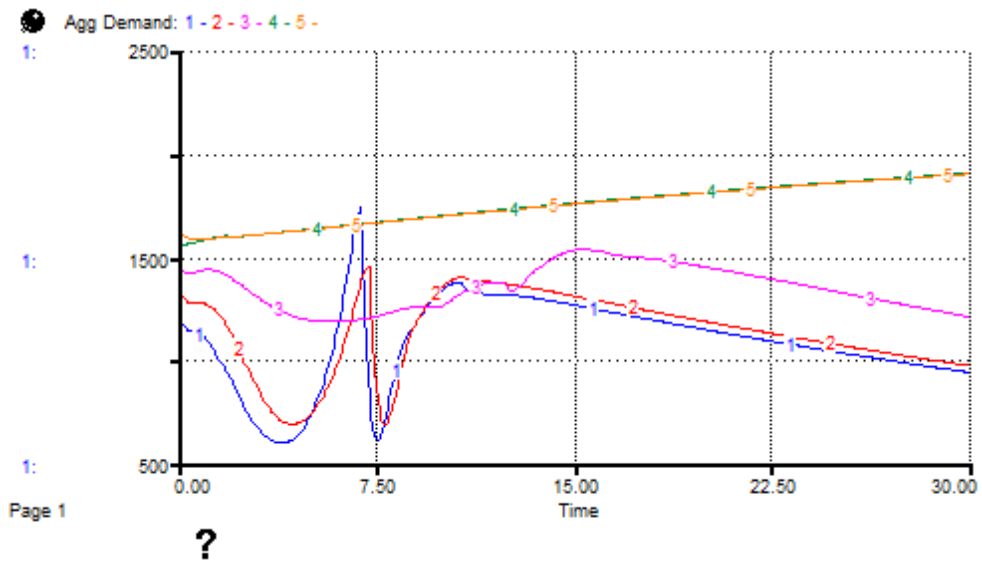


Figure 41. Normal MPC sensitivity test: Aggregate demand

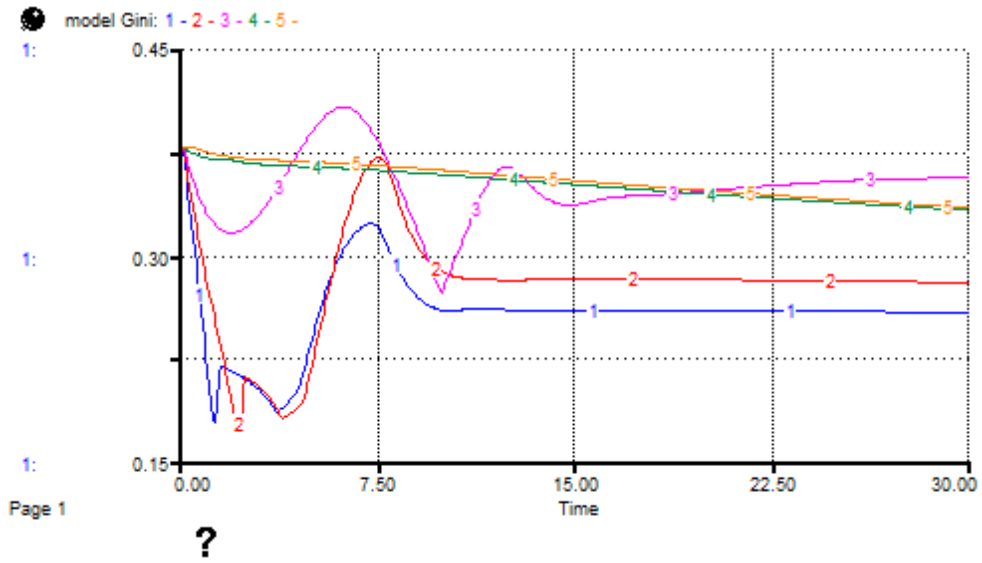


Figure 42. Normal MPC sensitivity test: Model Gini

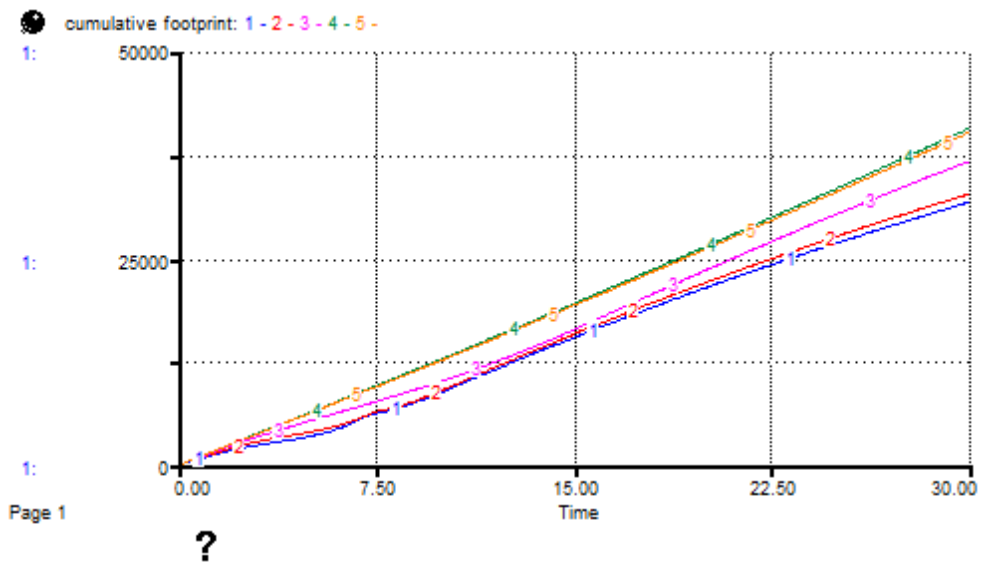


Figure 43. Normal MPC sensitivity test: Cumulative footprint

### 6.1.2.7 Capital productivity sensitivity test

Capital productivity affects the main variables of the model significantly, as Figure 44, 45, 46, and 47 show.

There are three productivity parameters in the model: Capital productivity, LS productivity, and HS productivity. The production function in the model is assumed to be a constant returns to scale function. Constant returns to scale property implies that these three parameters should always add up to 1. Increasing and decreasing capital

productivity parameter changes the HS productivity parameter as well. Capital productivity determines how much the firm owner household takes from the economic output. Hence, increasing capital productivity parameter will increase profits, which fosters the economy. In this experiment, capital productivity parameter is set to 0.2, 0.4, and 0.6 respectively.

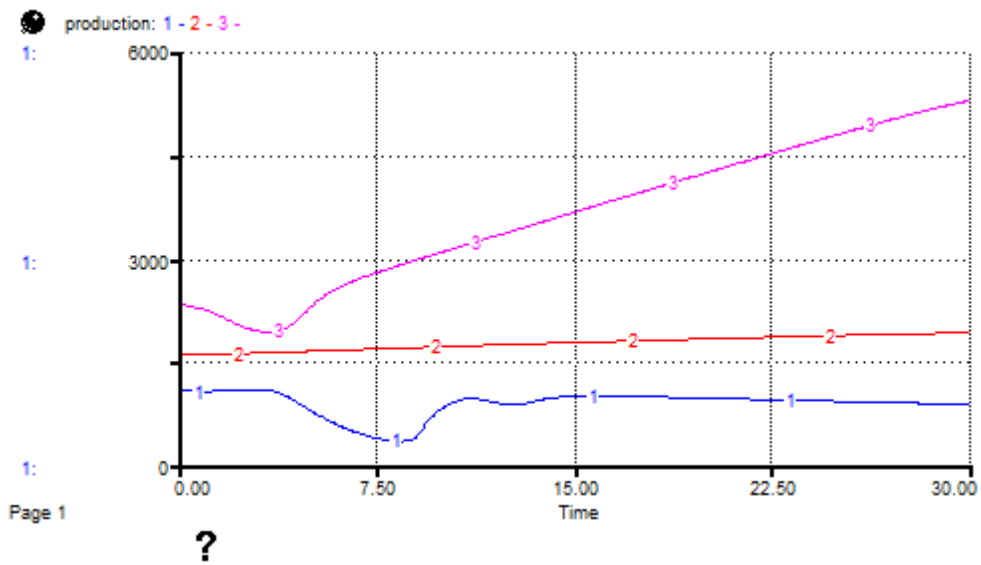


Figure 44. Capital productivity sensitivity test: Production

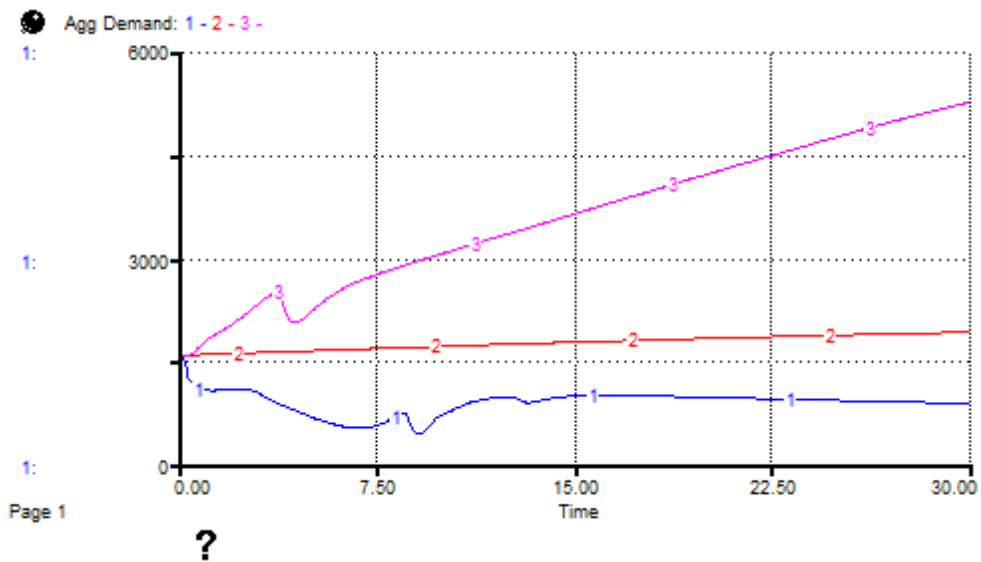


Figure 45. Capital productivity sensitivity test: Aggregate demand

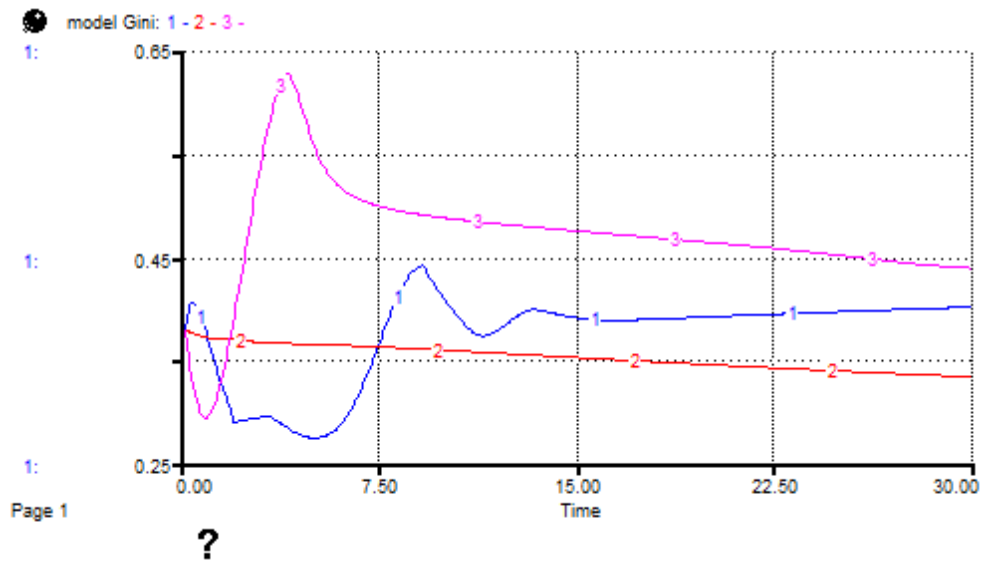


Figure 46. Capital productivity sensitivity test: Model Gini

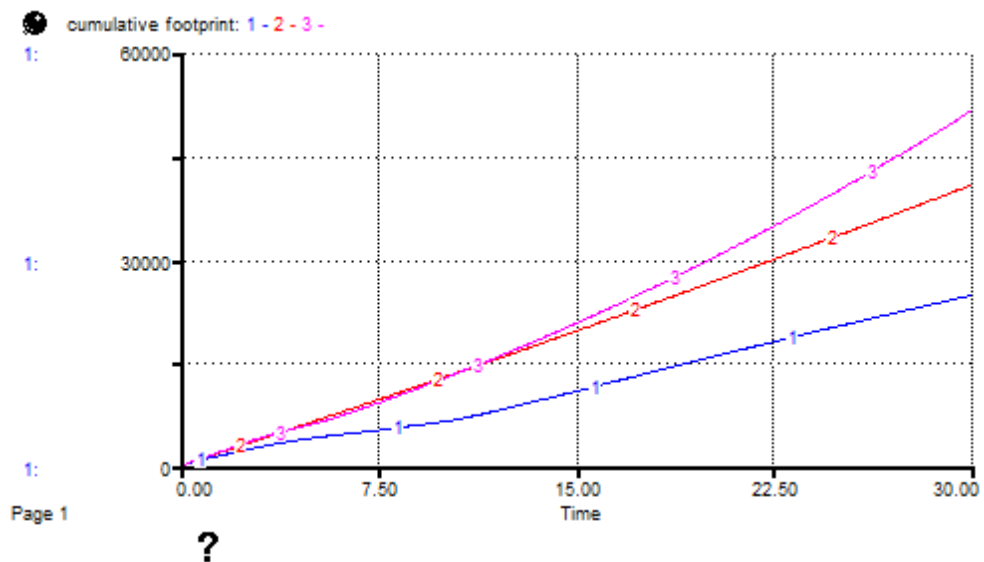


Figure 47. Capital productivity sensitivity test: Cumulative footprint

#### 6.1.2.8 Inventory coverage rate sensitivity test

Inventory coverage rate affects the main variables of the economy in a significant way. The behavioral change of the economy is shown in Figure 48, 49, 50, and 51.

Inventory coverage rate's sensitivity is tested by setting it to 0.1, 0.25, and 0.5, respectively. Smaller numbers for the inventory coverage rate make the firm unable to meet demand. As a result, sales, revenue, and profits decrease. The model is sensitive

to inventory coverage rates, which are lower than the distribution time for the inventory.

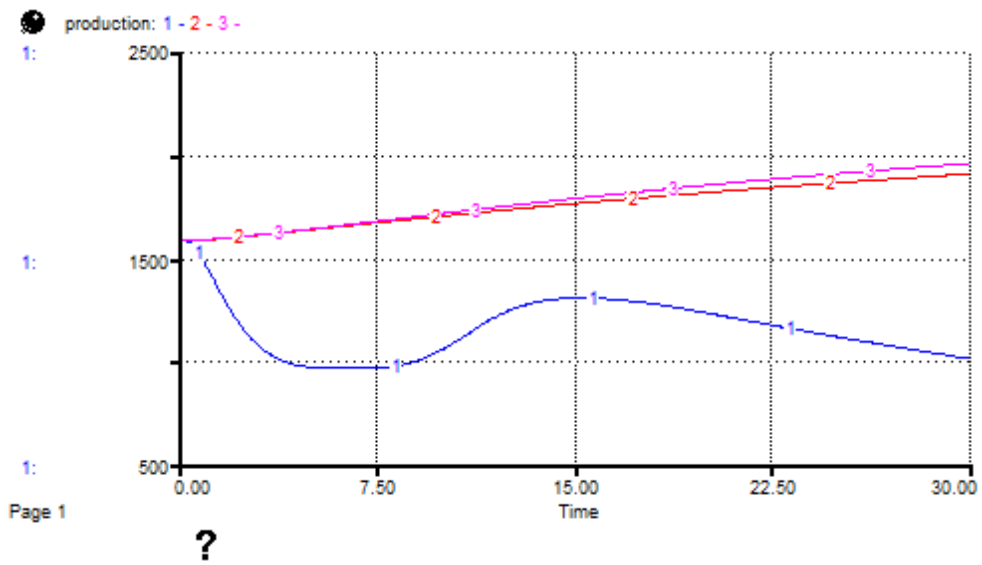


Figure 48. Inventory coverage rate sensitivity test: Production

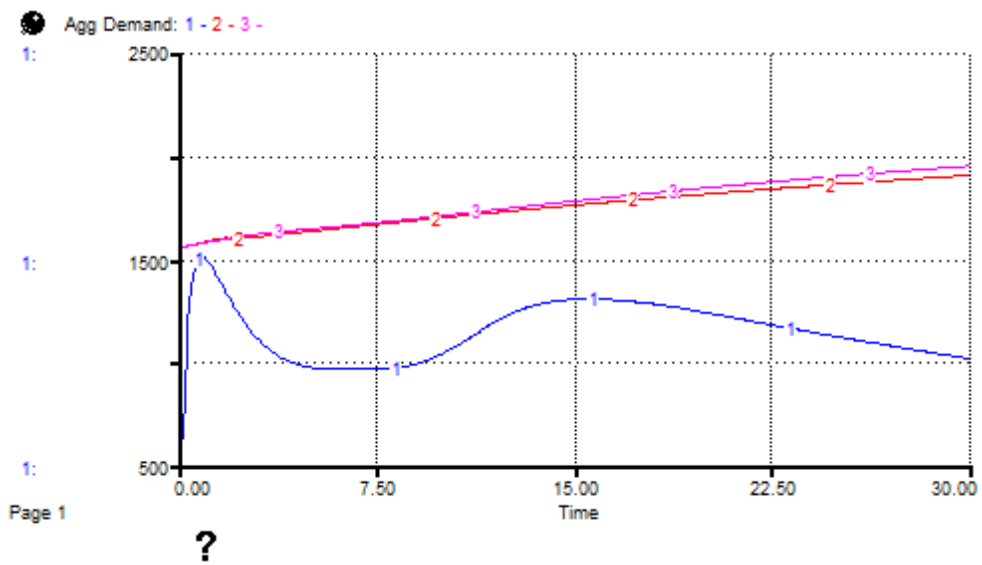


Figure 49. Inventory coverage rate sensitivity test: Aggregate demand

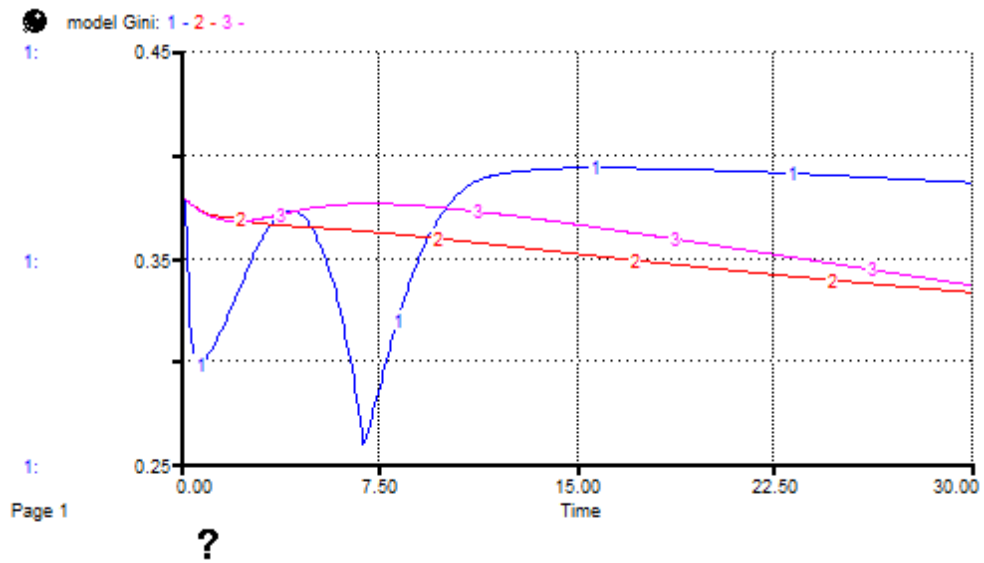


Figure 50. Inventory coverage rate sensitivity test: Model Gini

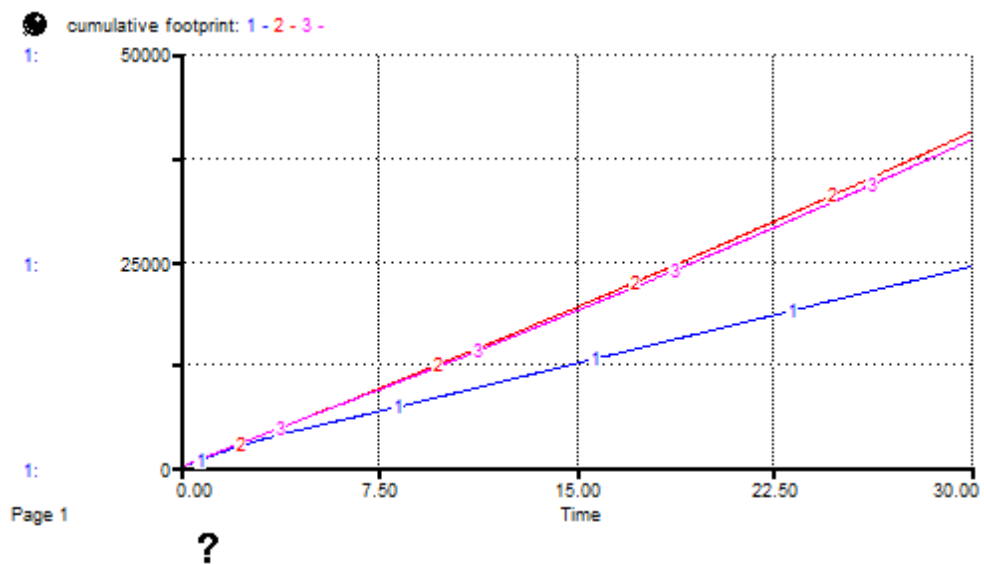


Figure 51. Inventory coverage rate sensitivity test: Cumulative footprint

## 6.2 Behavioral validity

After the structural validity tests, a required trust is put on the model's structure. The next step is to compare the model behavior with the real data and see whether the model behavior is a good representation of the real world.

The model presents an economic growth behavior which realistically matches with the data as Figure 52 depicts. To compare apples with apples, the model behavior should be compared with per capita real GDP growth data and the total

factor productivity gains should be deduced from it. The price movement is generally mild in the model, while in the real-world prices are more volatile. One of the obvious reasons of the price movement mismatch is the resources and resource prices are absent in the model which affect every other price while they are themselves affected by non-market shocks such as political situations. Furthermore, the income inequality index constructed in the model matches poorly with the advanced countries Gini data such as the US, France, and the UK. Figure 53 shows the mismatch between the real Gini data and the model Gini. One reason is that the model misses one of the crucial sources of income inequality: Globalization. The capital flight from advanced economies to emerging countries weighs down the wage growth in the advanced countries. The second reason is that the model also misses technological changes, which affect income distribution by increasing corporate profits and rewarding the labor force which is suitable for the new technologies. The third reason is that the model does not consider the weakness of unionization. Recent years witness that labor bargaining power is falling, which increases income inequality. Hence, the model boundaries are inadequate to capture the income inequality data experienced by the advanced countries.<sup>13</sup>

We introduce a simple external labor market to capture the effect of the capital flight's effect on income distribution. We assume that the firm is able to hire workers from abroad, and the wage rates for these workers are lower than the domestic ones. When the domestic wage rates get higher than the wage rates abroad, then the firm hire more workers abroad. Hence, the external labor market weighs down the domestic wage rates, and Gini index is increasing. We will present some of the equations and results in the Appendix B: Simple Capital Flight Model.

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<sup>13</sup>The model can be modified to capture the unionization and labor bargaining power effect easily. Nominal wage gains can be modeled as a sole function of the unemployment rate and a labor bargaining power parameter. Low values of the bargaining power parameter create increasing income inequality. The labor bargaining power solely determines wages, and there is no role for labor demand made by the firm. This assumption does not seem to be realistic. Hence, we do not modify the model with this type of wage determination formulation.

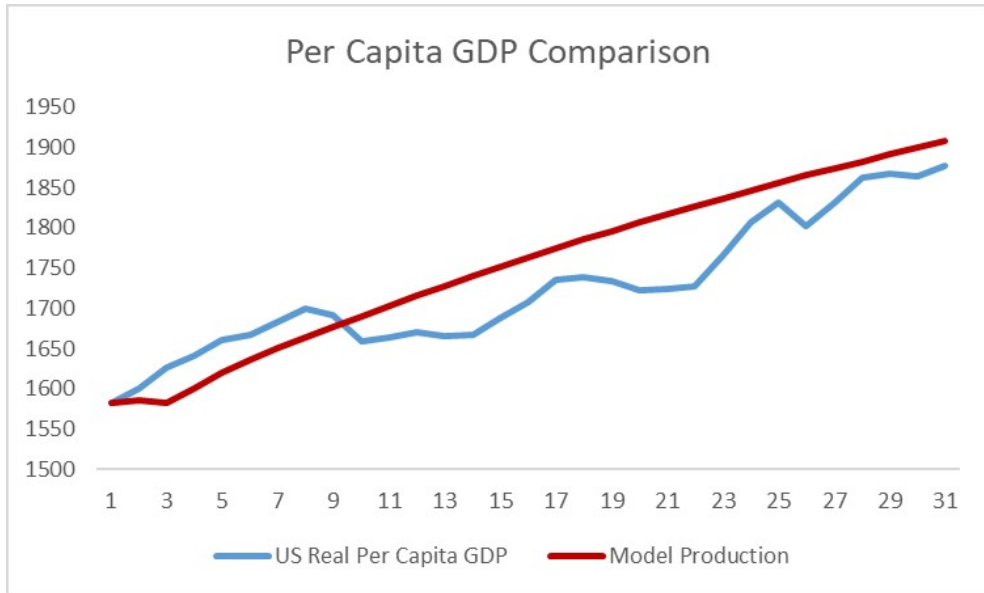


Figure 52. Model economic growth behavior compared to real data

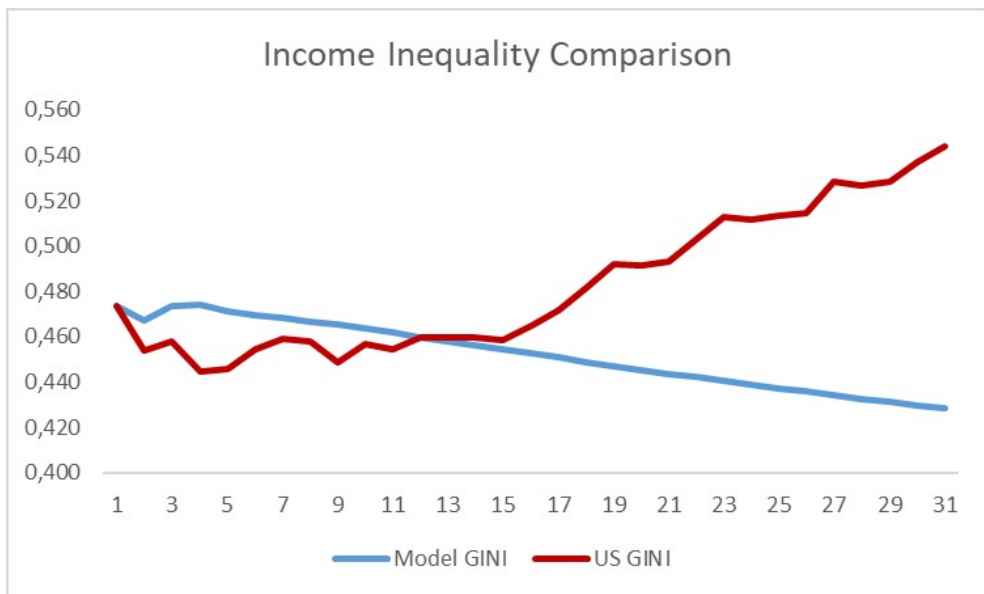


Figure 53. Model Gini index compared to real data

## CHAPTER 7

### MODEL REFERENCE BEHAVIOR/BASE RUN

The reference behavior of the model is an expanding economy which is demand-driven but supply constrained. The expansion under the strong demand is limited due to the diminishing marginal productivity of capital. Weak demand conditions lead to low profits, which decrease capital. As a result, the production decreases to the demanded level of consumption. In the base run, the demand is relatively strong i.e. normal MPC is set to 0.8.

In the base run, aggregate demand starts at 1558 and production at 1583.<sup>14</sup> Aggregate demand starts to rise because the extra income coming from profits and from new employments are directed to consumption, which increases revenue, and hence, profits. The virtuous cycle of aggregate demand loop is in force. The resulting dynamic behavior of the model is depicted in Figure 54.

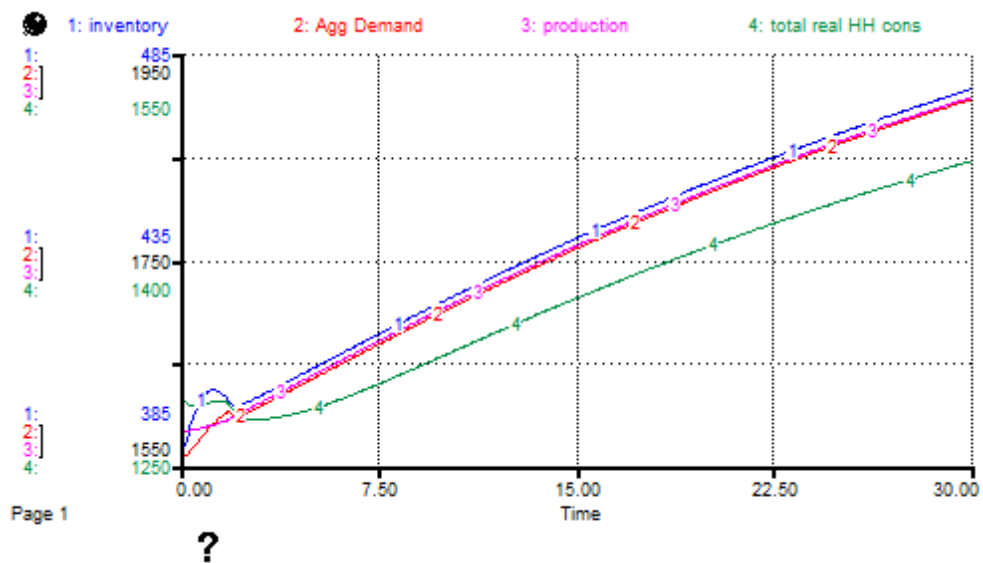


Figure 54. Production, aggregate demand, inventory and the household consumption in the base run

<sup>14</sup>These values reflect the way we set the initial values of the capital and labor force. The number of the low skilled labor force is set to 1000 as a normalization. The percentage of the labor force which has bachelor degree or higher is 40% for the US; hence, the high skilled labor force is calculated accordingly. The initial capital level is calculated from  $K/Y$  ratio. The initial aggregate demand is set to be close to the initial production. Hence, the initial values for the production and the aggregate demand are not real data values; however, the rate of increase is similar to the real rate of increase. Hence, they can be treated as a normalization of the real data

In the base run, the income distribution is mostly determined by the Cobb-Douglas production function which determines the factor incomes by marginal productivity. However, one should bear in mind that the functional factor income distribution is different than personal income distribution. In an economic downturn, the low skilled workers must borrow from the financial market to meet their basic needs, which disturbs the income distribution and makes it more inequitable.<sup>15</sup> Hence, in a moderate economy, the factor income distribution is mostly equal to personal income distribution. Figure 55 presents the dynamic behavior of the model Gini in the base run.

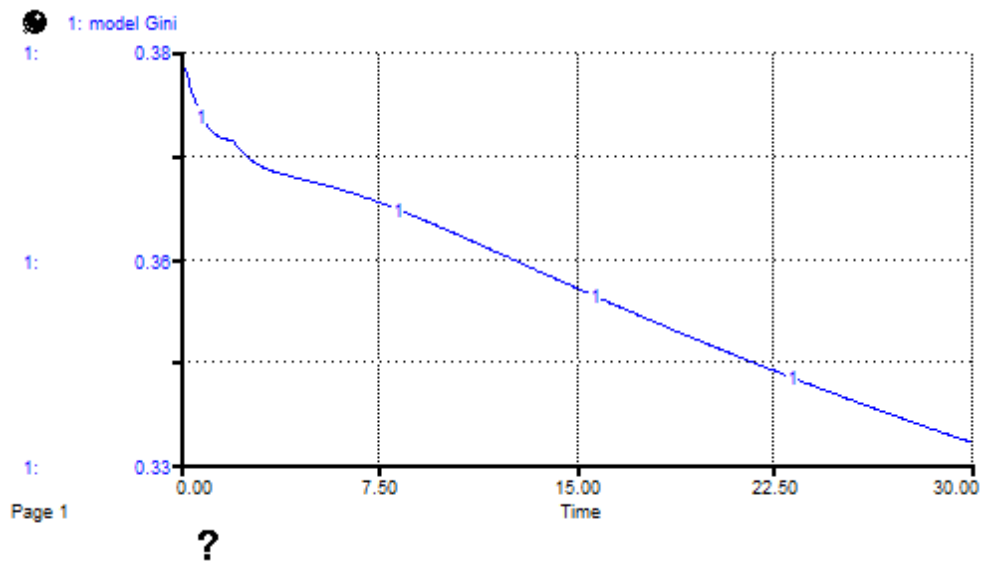


Figure 55. Model Gini index in the base run

When the economy expands, the wage bill rises because the firm employs more. Also, the real wage rates rise since the firm demands more labor. The firm owner household's income is increasing with the rising profits. Increases in the high skilled household's income have mixed effects on the Gini index, while increases in the wages of the low skilled household make income distribution more equitable. The households do not get in debt with each other in the base run within the 30-year range. Hence, factor income distribution equals personal income distribution in this period.

<sup>15</sup>The assumption of low skilled workers' ability to reach the financial market is unrealistic; however, modeling the complex social mechanisms of charitable giving, black markets, criminal jobs and underground economy seems to be beyond the scope of this study.

Figure 56 shows the behavior of the price and inflation rate in the base run. The price level is decreasing in the first years because the demand is weaker than the production. Production is higher than demand. As a result, inventory increases, and the inflation decreases.

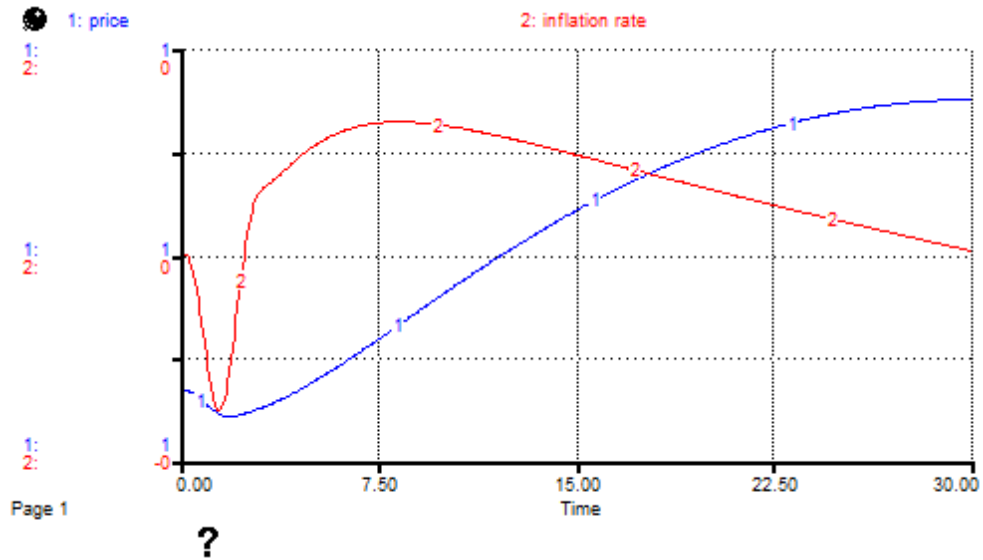


Figure 56. Price and inflation rate in the base run

In the base-run, the cumulative footprint reaches to 40736 CO<sub>2</sub>, as shown in Figure 57.

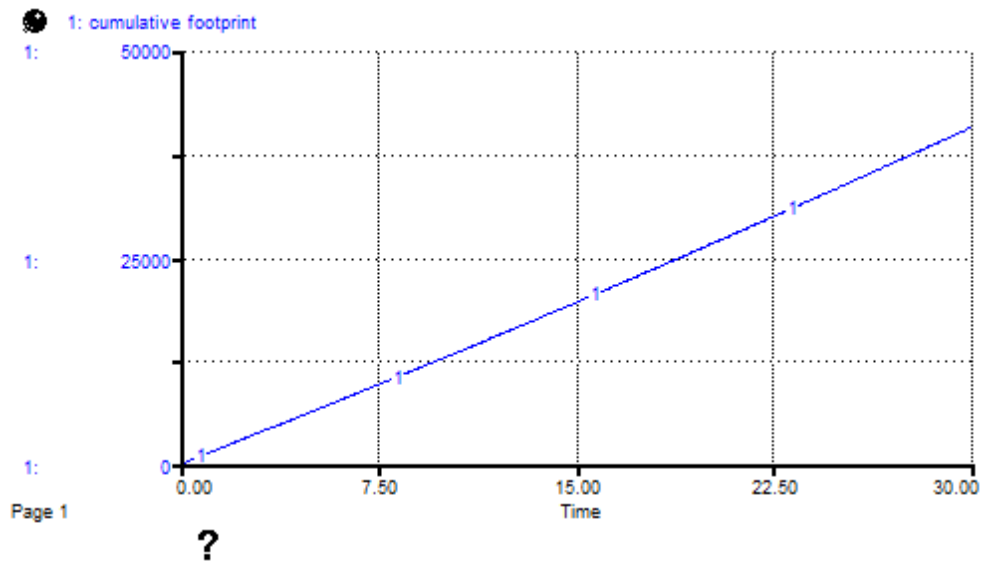


Figure 57. Cumulative footprint in the base run

## CHAPTER 8

### RESULTS/SCENARIO ANALYSIS

#### 8.1 Scenario analysis

##### 8.1.1 Scenario 1: Low skilled workers become high skilled

In this scenario, low skilled workers are assumed to get training and/or education that makes them high skilled workers. Education time is taken as four years. Figure 58, 59, 60, and 61 show how the main variables of the model change under the scenario 1.

Since the firm demands both low skilled and high skilled labor for production, some of the high skilled workers will practice low skilled jobs. The firm is benefiting the abundance of the high skilled workers because the real wage rate of the high skilled labor is lower. On the other hand, the transitivity of high skilled workers from high skilled to low skilled jobs is equalizing low skilled wages and high skilled wages. Higher real wage rates for the low skilled jobs hurt the firm. The reduction in the high skilled real wage rates is more than the increase in the real wage rates of low skilled jobs. Hence, the net effect of the wage rate changes on the firm is positive. As a result, there are higher profits, higher production and consumption. Higher middle-income consumption creates a higher ecological footprint, although middle-income consumption is assumed to be marginally less harmful than low-income consumption.

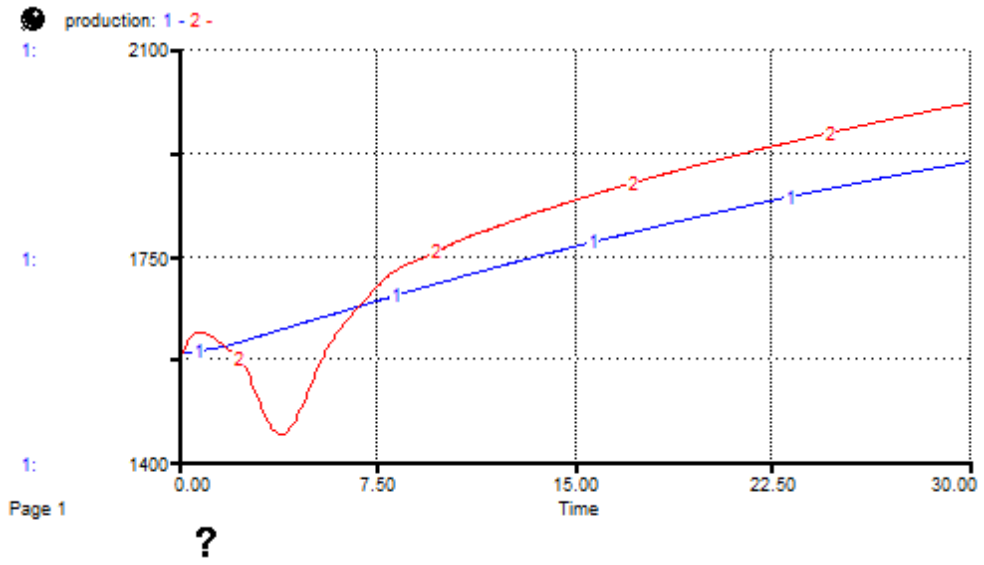


Figure 58. Production under scenario 1

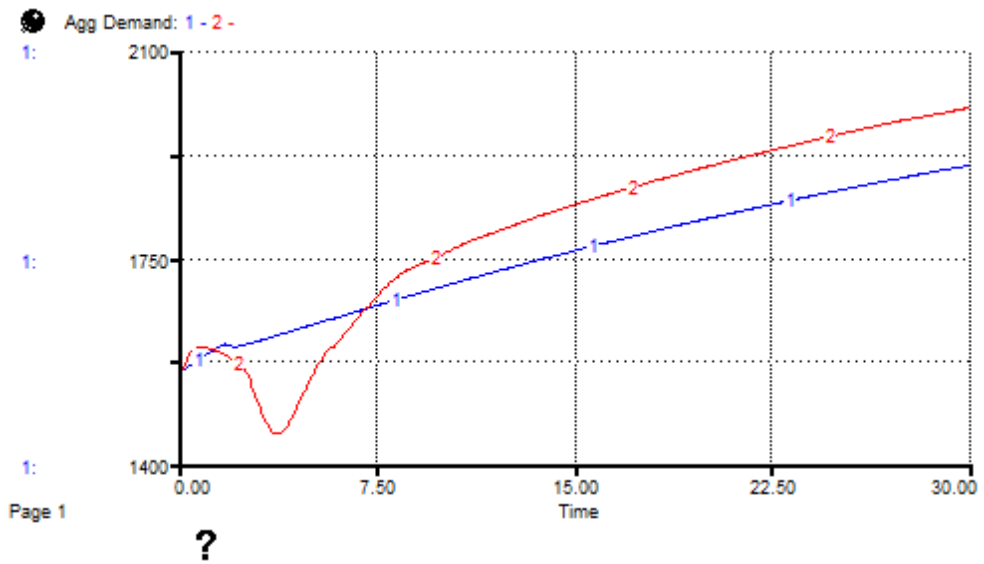


Figure 59. Aggregate demand under scenario 1

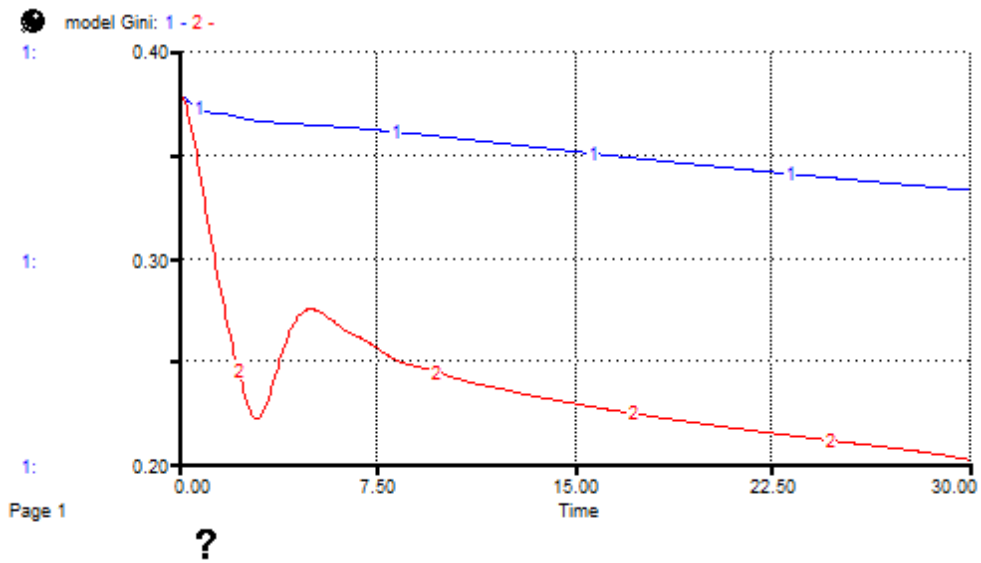


Figure 60. Model Gini under scenario 1

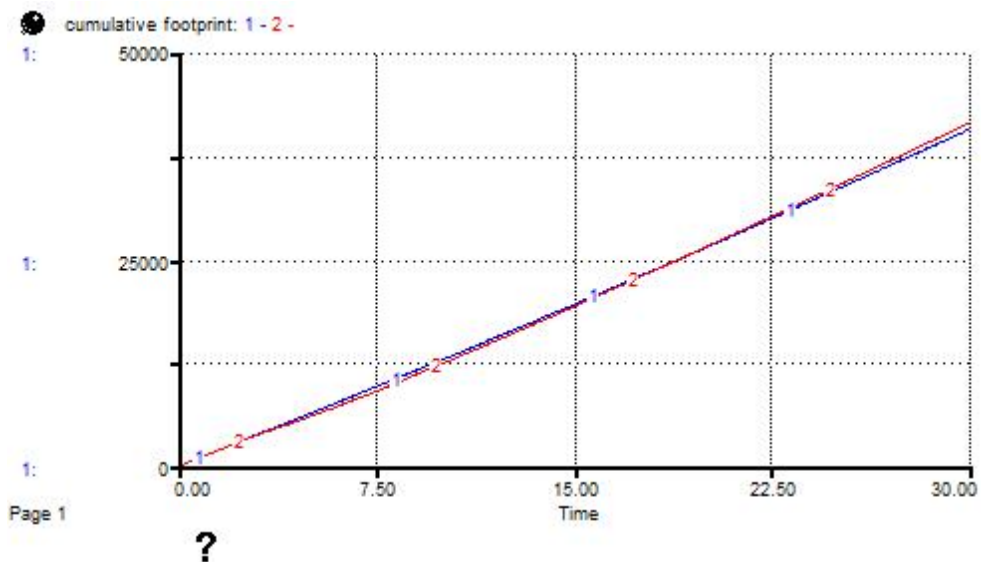


Figure 61. Cumulative footprint under scenario 1

Equalization of low skilled and high skilled wage rates reduces income inequality. Firm owner households, on the other hand, are benefiting from the education of low skilled labor. Firm owner household per capita income is around 6% higher than the base-run.

According to Scenario 1, more education can solve the inequality problem; however, it does not solve the environmental problems on its own.

### 8.1.2 Scenario 2: No consumption competition

In Scenario 2, we assume that people do not display consumption competition behavior. This assumption may well be the case if the government takes measures against the so-called “psychological advertisements” and/or put heavy taxes on luxury consumption. As we do not model the causes of the consumption competition, here we assume that the government can somehow end it. Resulting behavior of the main model variables are displayed in Figure 62, 63, 64, and 65.

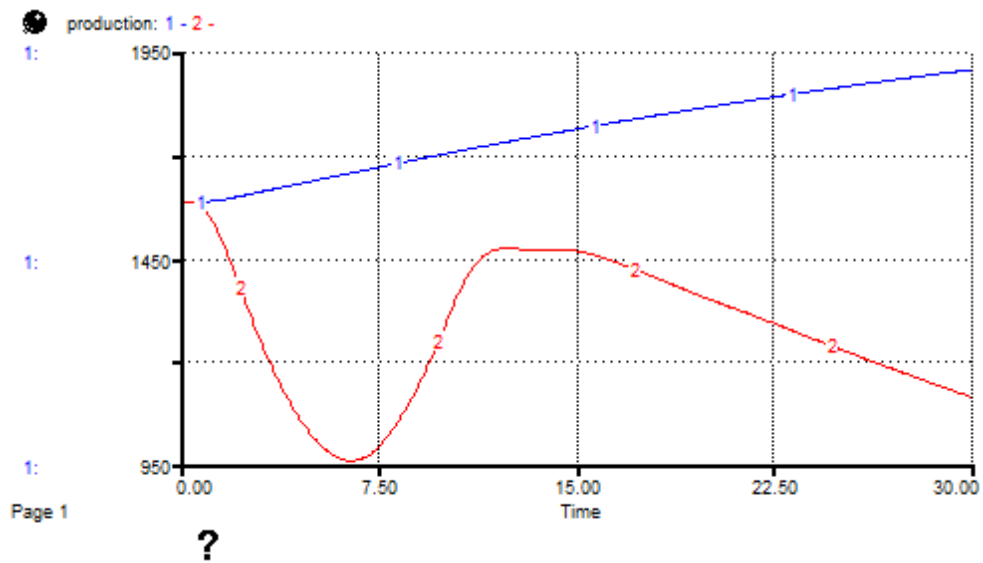


Figure 62. Production under scenario 2

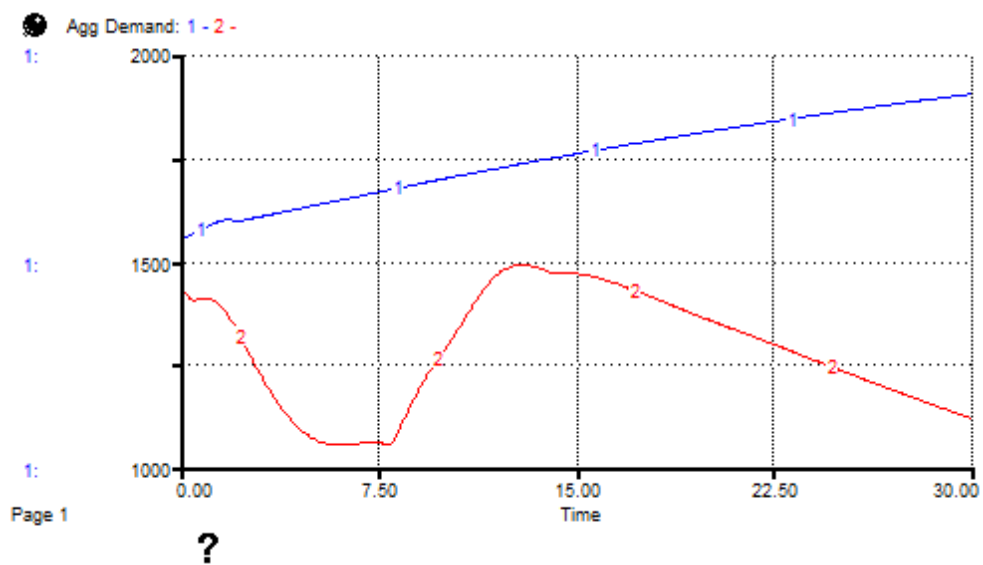


Figure 63. Aggregate demand under scenario 2

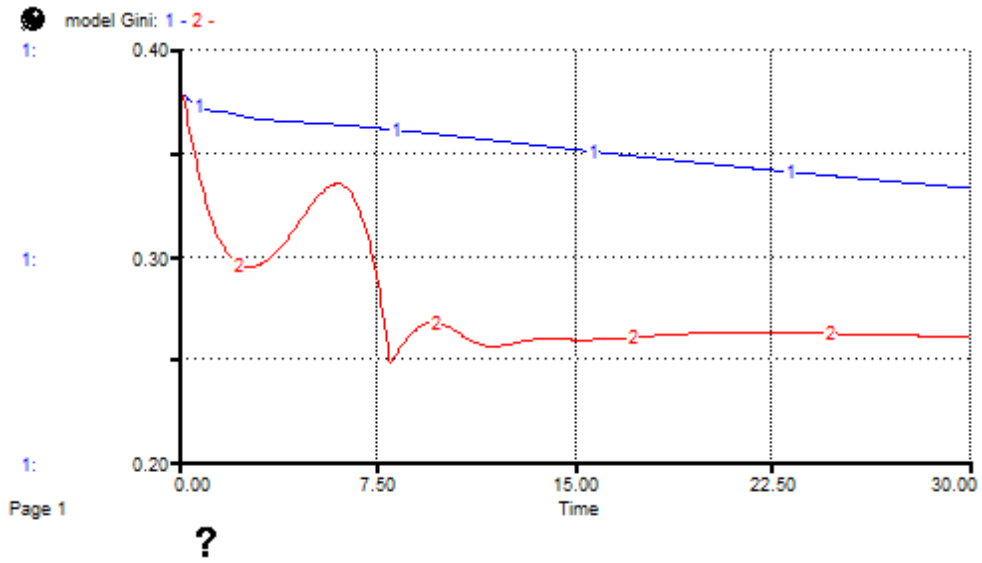


Figure 64. Model Gini under scenario 2

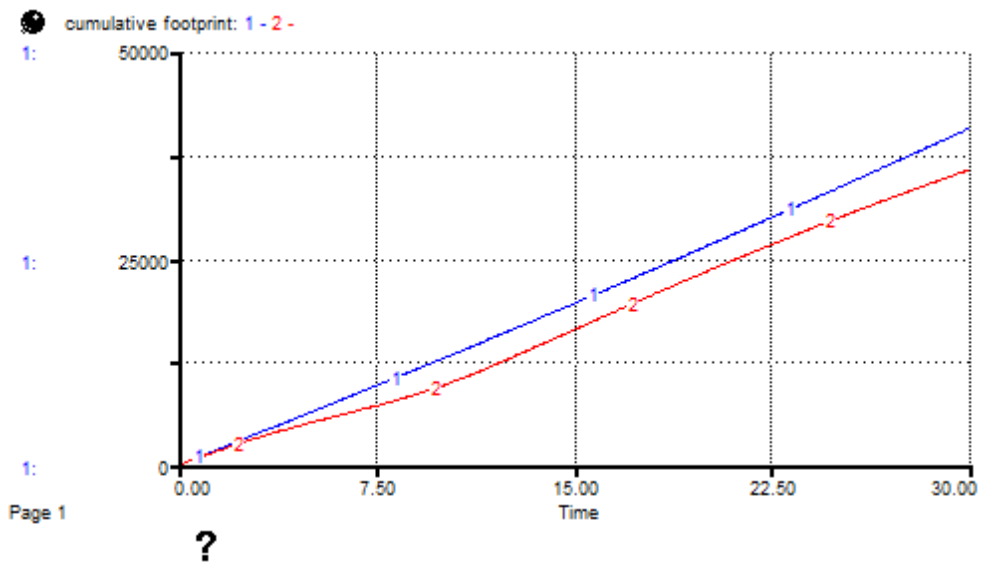


Figure 65. Cumulative footprint under scenario 2

Without the consumption competition, the profits are lower. As a result, investments decrease. Lower investments cause lower employment, which further decreases consumption demand. This process triggers the vicious cycle of aggregate demand. Lower profits leave firm owner households with less income. As a result, income inequality decreases.

In accordance with the economic contraction, the total footprint of the economy goes down compared to the base-run.

### 8.1.3 Scenario 3: Different wage rate determination

As stated in Behavioral Validity Part, the wage determination can be modeled solely as a function of labor bargaining power. Labor bargaining power is the employment rate beyond which workers can push nominal wage rates to higher levels. The cutoff value for the employment rate is determined by the relative institutional power of the labor. For example, when the unemployment rate falls below 2%, then the wage rate starts to increase. We replace effect on wage HS and effect on wage LS variables such that:

$$effectonwageHS = (employedHSinHSjobs / ((employedHSinHSjobs + unemployedHSsearchingforHSjobs) * benchmarkemploymentrate))$$

$$effectonwageLS = ((employedHSinLSjobs + employedLS) / ((employedHSinLSjobs + employedLS + unemployedHSsearchignforLSjobs + unemployedLS) * benchmarkemploymentrate))$$

The resulting changes in the main variables of the model are presented in Figure 66, 67, 68, and 69.

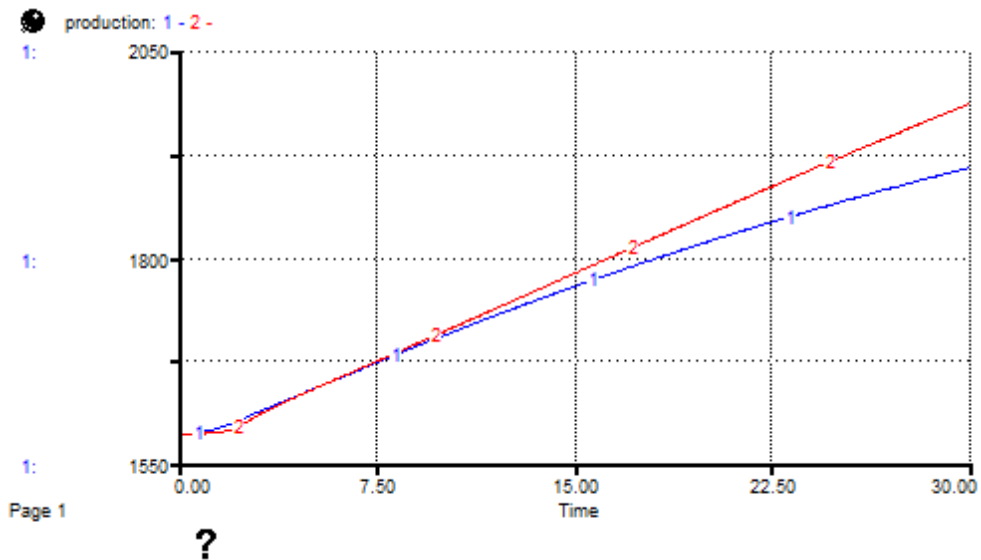
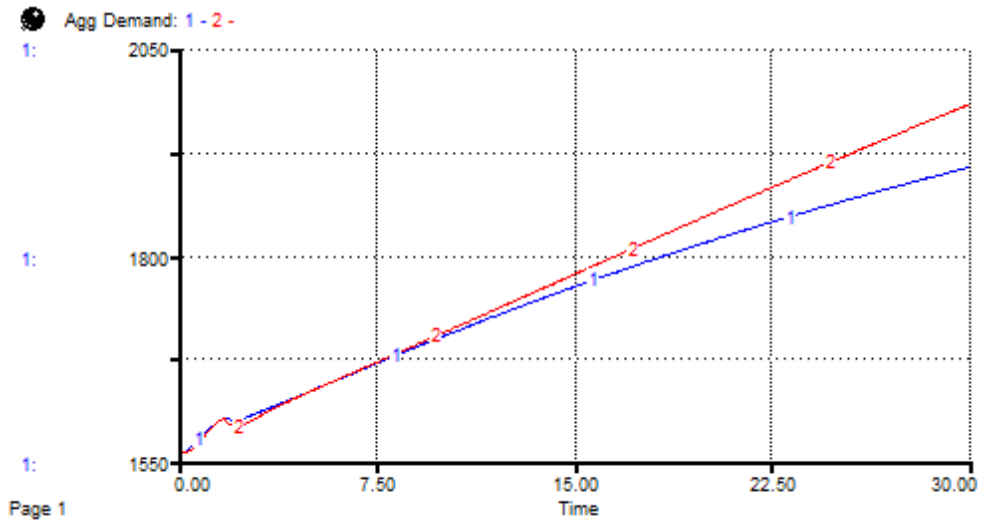
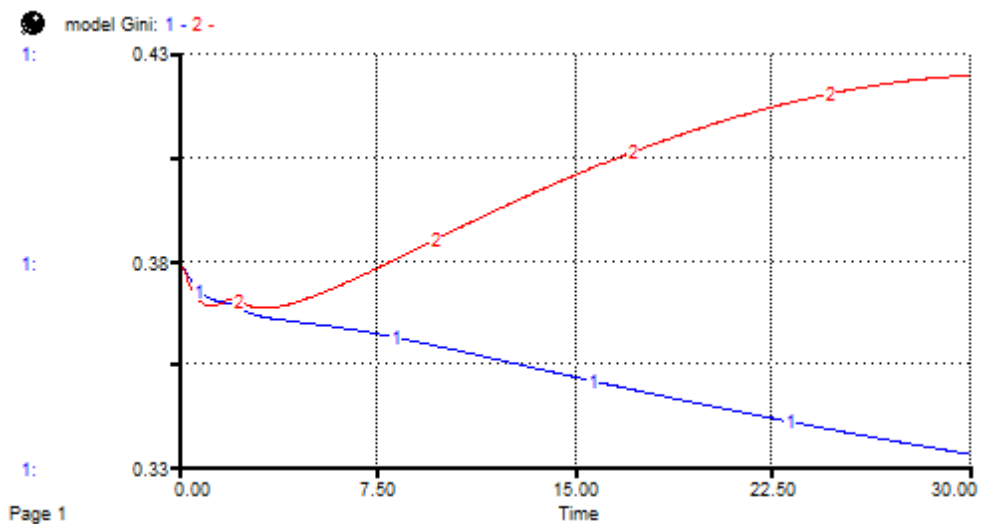


Figure 66. Production under scenario 3



?

Figure 67. Aggregate demand under scenario 3



?

Figure 68. Model Gini under scenario 3

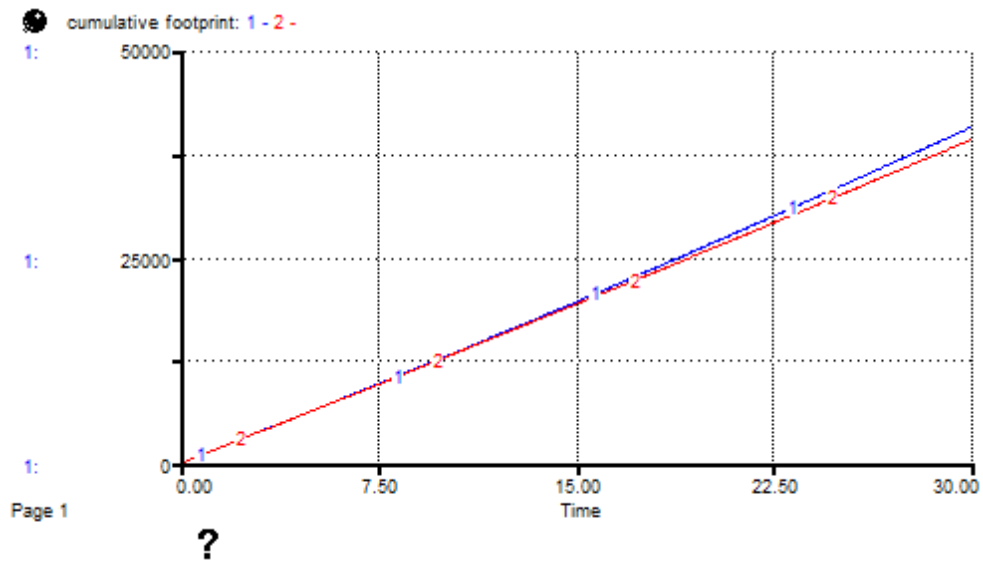


Figure 69. Cumulative footprint under scenario 3

We set the employment level as 0.99. That means only when the unemployment rate falls to 1% and below, then the nominal wages increase. When wages are suppressed, then consumption demand of the households decreases compared to the base-run. However, the cost of the firm also decreases with lower wages. As a result, the firm is more profitable. Investments increase, and the economy expands with these investments.

When wages are suppressed the economic share of the firm owner household increases substantially. On the other hand, the high skilled and the low skilled households' incomes are raising mildly. The more inequitable distribution of income is, the less footprint it creates, because the model assumes that marginal propensity to emit is decreasing with higher levels of spending.

## 8.2 Finding the redistribution scheme

Firm owner household is taxed by 0%, 20%, 40%, 60%, and 70%, in five different runs. All the tax revenue is transferred to the low skilled household. Increasing the tax rate decreases income inequality; however, low levels of taxes slightly expand the economy rather than contract. The reason is that redistributed income generates more consumption demand when the low skilled household has more income. When the tax

rate is further increased, the more equitable income distribution reduces consumption competition. When consumption competition decreases, then the demand decreases; hence, the economy contracts. Figure 70, 71, 72, and 73 show the corresponding changes in the production, aggregate demand, model Gini, and cumulative footprint of the economy.

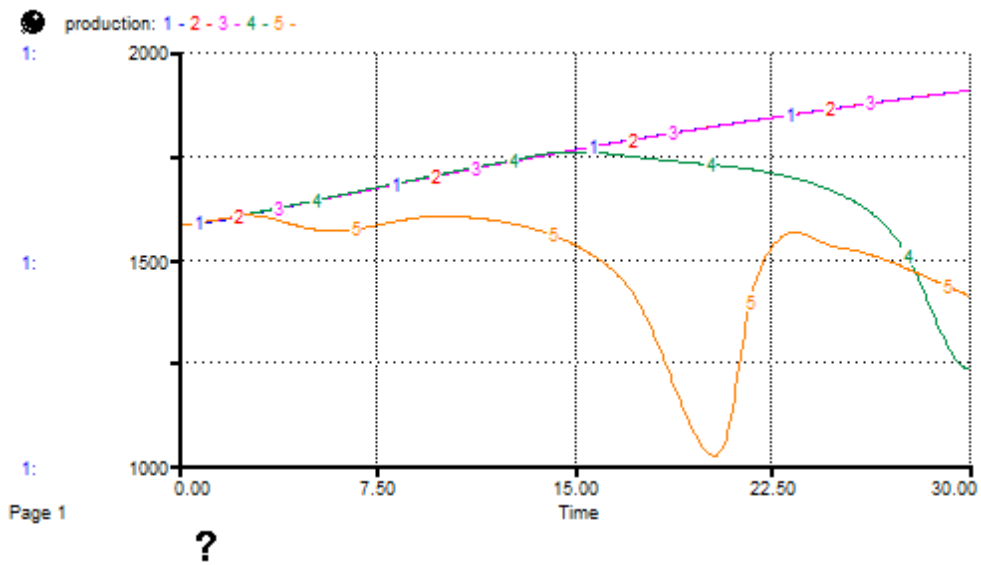


Figure 70. Production under different transfer schemes

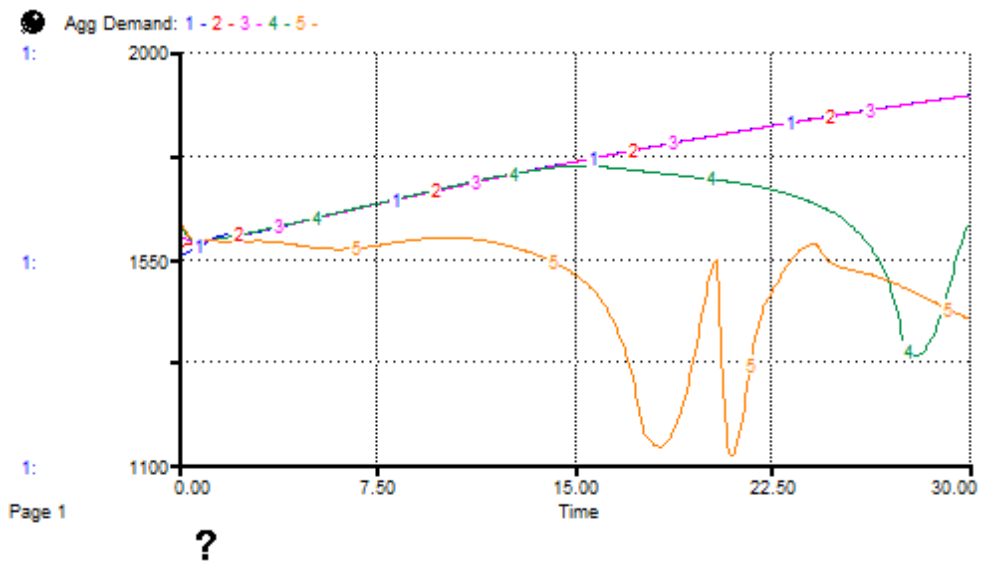


Figure 71. Aggregate demand under different transfer schemes

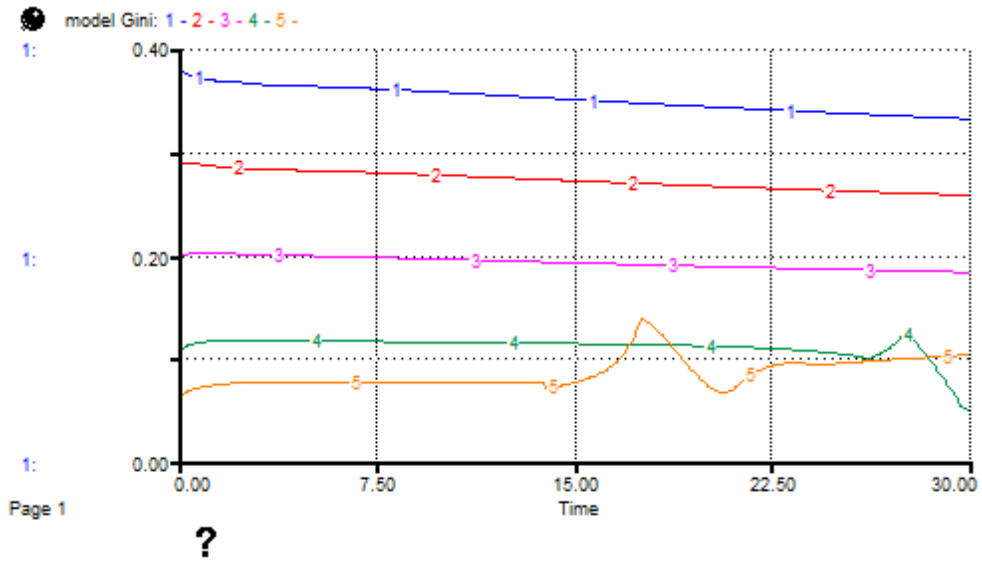


Figure 72. Model Gini under different transfer schemes

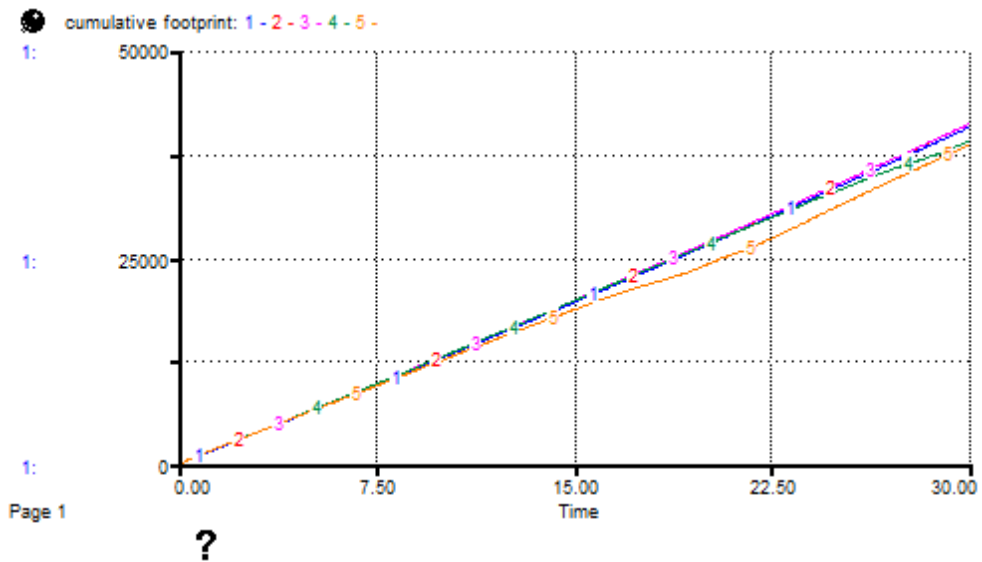


Figure 73. Cumulative footprint under different transfer schemes

The total footprint increases with the low tax rates because marginal propensity to emit is assumed to be diminishing with higher consumption levels. When income is transferred to the low skilled household, then the extra consumption it made is more harmful to the environment. When the tax rate is further increased, then the economy contracts and total environmental impact is lower than the base-run.

## CHAPTER 9

### CONCLUSION

The United Nations Development Program set 17 goals in 2015. These 17 goals include reducing poverty and ending hunger, reducing inequalities, and climate action. We think these four out of seventeen goals can be in conflict. The economic growth is currently seen by many as the main tool to end hunger, to reduce poverty, and to reduce inequalities. However, economic growth is equally known to be harmful to the environment in most cases. On the other hand, environmental taxes as a measure to the environmental problems can increase income inequalities, because they may well be regressive. Redistribution policies seem to be able to solve the four goals at the same time; however, as making poor people more prosperous with the redistributed income will increase their purchasing power, they will consume nearly all the redistributed income—hence, the aggregate demand will likely increase and an increase in the demand will then boost the economy. Moreover, poor people's consumption demand is argued to be more carbon intensive than rich people.

This thesis builds a system dynamic macroeconomic model to incorporate various causes and effects of economic growth, income distribution and environmental impact in a holistic manner. We model a closed economy with heterogeneous households, a firm and a simple banking system. The economy in the model tracks all transactions among the agents. The accounting framework in the model is vital. However, the model contains more than the accounting stocks and flows. A production function, an employment function, a consumption decision model are considered so as to complete the model. We have assumed that the economy's production function is a Cobb-Douglas function, the firm demands labor according to labor's marginal productivity, and consumers decide on their consumption by observing and emulating others.

The model is built on the theories of different school of thoughts in Economics. Hence, it has an eclectic nature. The stock flow consistency principle of ASD gives the model a Post Keynesian feature, while a Cobb-Douglas production function

brings some Neoclassical characteristics. We, also, model conspicuous consumption in a quite original way. All in all, the model cannot be classified into a well-defined tradition.

A system dynamic model should satisfy structural validity and behavioral validity. Unit consistency tests are implemented throughout the modeling process. Extreme condition and parameter sensitivity tests are implemented, and the results show that the model's structure is valid, i.e. the model is consistent on its own. Not surprisingly, when we test the behavioral validity of the model, we see that the model cannot capture real world income inequality data. The main reason is that the model's structure is not comprehensive enough to capture the real data. For example, the absence of international trade and international capital movements strengthens the labor's position and real wage rates increases.

We conduct some experiments in the model. First, we assume all the low-skilled labor force gets education and becomes high-skilled labor force. Income inequality decreases; however, the environmental impact increases under this experiment. The income inequality decreases, because the wage difference disappears among the labor force. The abundance of high-skilled workers makes high-skilled labor's real wage rate to fall. The firm becomes more profitable when high-skilled wage rates are lower. A profitable firm invests more compared to a loss maker. Increase in the investments boosts the economy; hence, environmental impact is higher compared to standard run. In the second experiment, we assume people do not display consumption competition behavior. The environmental impact decreases when people stop displaying consumption competition behavior, because they consume less. Income inequality is lower than the standard run, because the firm is making less profit, and as a result, the firm owners' income is closer to workers'. In the last scenario, we want to show that even in a closed economy with a well-behaved Neoclassical production function, the income inequality can increase. We assume that wage rates are not determined with supply and demand; the relative power of labor is assumed to be decisive on the wage

rates. Both environmental impact and income inequality are higher compared to standard run in that case.

After the scenario analysis, we test several income redistribution schemes. We implement tax on the firm owners and transfer that income to low-skilled workers. High-skilled workers are not taxed, and they do not benefit from the transfers. When the tax rate is at the moderate levels such as 20% and 30%, then the environmental impact increases. The reason is that the tax rate is not enough to discourage the consumption competition. The redistributed income which is extra income for the low-skilled workers manifests itself through consumption. The extra consumption created by the redistribution supports the economic activity. Also, low-skilled people's consumption is assumed to be more carbon intensive than the high-skilled workers' and the firm owners'. When the tax rate is increased to higher levels such as 60%, then the environmental impact is reduced by 4%. Any tax and transfer scheme reduces the income inequality.

## APPENDIX A

### MODEL EQUATIONS

#### A.1 Consumption Decision Sector

$\frac{d}{dt} \text{perceived relative cons of FO acc to HS}(t) = \text{perceived relative cons of FO acc to HS}(t) - dt) + (\text{chg in cons perception HS}) * dt$

INIT perceived relative cons of FO acc to HS = 2

#### INFLOWS:

$\text{chg in cons perception HS} = (\text{relative cons of FO acc to HS} - \text{perceived relative cons of FO acc to HS}) / \text{perception time}$

$\frac{d}{dt} \text{perceived relative cons of HS acc to LS}(t) = \text{perceived relative cons of HS acc to LS}(t) - dt) + (\text{chg in cons perception LS}) * dt$

INIT perceived relative cons of HS acc to LS = 2

#### INFLOWS:

$\text{chg in cons perception LS} = (\text{relative cons of HS acc to LS} - \text{perceived relative cons of HS acc to LS}) / \text{perception time}$

#### Converters

$\text{desired cons FO} = (\max(\min(\text{necessary cons FO} + (\text{total disposable real income FO} - \text{necessary cons FO}) * (\text{normal mpc}), \text{total disposable real income FO}), \text{necessary cons FO}))$

$\text{desired cons HS} = (\max(\min(\text{necessary cons HS} + (\text{total disposable real income HS} - \text{necessary cons HS}) * \text{mpc HS}, \text{total disposable real income HS}), \text{necessary cons HS}))$

$\text{desired cons LS} = (\max(\min(\text{necessary cons LS} + (\text{total disposable real income LS} - \text{necessary cons LS}) * \text{mpc LS}, \text{total disposable real income LS}), \text{necessary cons LS}))$

$\text{income per capita FO} = \text{total disposable real income FO} / \text{population of FO}$

$\text{income per capita HS} = \text{total disposable real income HS} / \text{population of HS}$

$\text{income per capita LS} = \text{total disposable real income LS} / \text{population of LS}$

$\text{mpc FO} = 0.5$

mpc HS = effect on mpc HS\*normal mpc

mpc LS = effect on mpc LS\*normal mpc

necessary cons FO = necessary cons per capita\*population of FO

necessary cons HS = necessary cons per capita\*population of HS

necessary cons LS = necessary cons per capita\*population of LS

necessary cons per capita = 0.15

normal mpc = 0.8

relative consumption perception time = 1

per capita actual cons FO = actual real cons FO/population of FO

per capita actual cons HS = actual real cons HS/population of HS

per capita actual cons LS = actual real cons LS/population of LS

population of FO = 100

population of HS = employed HS in HS jobs+employed HS in LS jobs+unemployed

HS searchign for LS jobs+unemployed HS searching for HS jobs

population of LS = employed LS+unemployed LS

relative cons of FO acc to HS = per capita actual cons FO/per capita actual cons HS

relative cons of HS acc to LS = per capita actual cons HS/per capita actual cons LS

effect on mpc HS = GRAPH(perceived relative cons of FO acc to HS) (0.00, 0.2),  
(0.2, 0.3), (0.4, 0.4), (0.6, 0.6), (0.8, 0.8), (1.00, 1.00), (1.20, 1.10), (1.40, 1.15), (1.60,  
1.20), (1.80, 1.23), (2.00, 1.25)

effect on mpc LS = GRAPH(perceived relative cons of HS acc to LS) (0.00, 0.2),  
(0.2, 0.3), (0.4, 0.4), (0.6, 0.6), (0.8, 0.8), (1.00, 1.00), (1.20, 1.10), (1.40, 1.15), (1.60,  
1.20), (1.80, 1.23), (2.00, 1.25)

## A.2 Determination of Price Sector

$\text{price}(t) = \text{price}(t - dt) + (\text{price adjustment}) * dt$

INIT price = 1

INFLOWS:

price adjustment = (indicated price-price)/price adjustment time

### Converters

indicated price = price\*(1+effect on price)

inflation rate = (price-DELAY(price,1))/DELAY(price,1)

price adjustment time = 1

### A.3 Environmental Footprint Calculation Sector

cumulative footprint(t) = cumulative footprint(t - dt) + (yearly footprint) \* dt

INIT cumulative footprint = 0

### INFLOWS:

yearly footprint = total footprint of the present year

### Converters

total footprint = total footprint FO+total footprint HS+total footprint LS

total footprint FO = population of FO\*per capita footprint FO

total footprint HS = population of HS\*per capita footprint HS

total footprint LS = population of LS\*per capita footprint LS

per capita footprint FO = GRAPH(per capita actual cons FO) (0.00, 0.00), (0.25, 0.25), (0.5, 0.5), (0.75, 0.75), (1.00, 1.00), (1.25, 1.25), (1.50, 1.50), (1.75, 1.75), (2.00, 2.00), (2.25, 2.25), (2.50, 2.50), (2.75, 2.75), (3.00, 3.00), (3.25, 3.15), (3.50, 3.30), (3.75, 3.40), (4.00, 3.50), (4.25, 3.60), (4.50, 3.70), (4.75, 3.75), (5.00, 3.80)

per capita footprint HS = GRAPH(per capita actual cons HS) (0.00, 0.00), (0.25, 0.25), (0.5, 0.5), (0.75, 0.75), (1.00, 1.00), (1.25, 1.25), (1.50, 1.50), (1.75, 1.75), (2.00, 2.00), (2.25, 2.25), (2.50, 2.50), (2.75, 2.75), (3.00, 3.00), (3.25, 3.15), (3.50, 3.30), (3.75, 3.40), (4.00, 3.50), (4.25, 3.60), (4.50, 3.70), (4.75, 3.75), (5.00, 3.80)

per capita footprint LS = GRAPH(per capita actual cons LS) (0.00, 0.00), (0.25, 0.25), (0.5, 0.5), (0.75, 0.75), (1.00, 1.00), (1.25, 1.25), (1.50, 1.50), (1.75, 1.75), (2.00, 2.00), (2.25, 2.25), (2.50, 2.50), (2.75, 2.75), (3.00, 3.00), (3.25, 3.15), (3.50, 3.30), (3.75, 3.40), (4.00, 3.50), (4.25, 3.60), (4.50, 3.70), (4.75, 3.75), (5.00, 3.80)

#### A.4 Firm Accounting Sector

Firm Current Account(t) = Firm Current Account(t - dt) + (revenue + new loans firm - wages - firm debt paymentt - firm interest paymentt - dividends - nominal investment) \* dt

INIT Firm Current Account = 0

##### INFLOWS:

revenue = nominal cons FO+nominal cons HS+nominal cons LS+nominal investment

new loans firm = desired new loans taken by firms

OUTFLOWS: wages = total HS nominal wages+total nominal LS wages

firm debt paymentt = firm debt redemption

firm interest paymentt = firm debt\*nominal interest rate

dividends = dividendss

nominal investment = real investment\*price

firm debt(t) = firm debt(t - dt) + (new loans firmm - firm debt redemption) \* dt

INIT firm debt = 0

##### INFLOWS:

new loans firmm = new loans firm

##### OUTFLOWS:

firm debt redemption = firm debt/debt maturity

firm earnings(t) = firm earnings(t - dt) + (revenuee - waggess - nominal depreciation -

firm interest paymentttt - dividendss) \* dt

INIT firm earnings = 450\*price

##### INFLOWS:

revenuee = revenue

##### OUTFLOWS:

waggess = wages

nominal depreciation = nominal depreciationn

firm interest paymentttt = firm interest paymentt

dividendss = max((firm earnings/dividend payment time), 0)

nominal capital(t) = nominal capital(t - dt) + (nominal investment - nominal depreciation) \* dt

INIT nominal capital = real capital\*price

INFLOWS:

nominal investment = real investment\*price

OUTFLOWS:

nominal depreciation = price\*real depreciation

desired new loans taken by firms = wages+nominal investment+firm interest

paymentt+firm debt paymentt+dividends-revenue

Converters

dividend payment time = 1

nominal interest rate = 0.02

profit = revenue-firm interest paymentt-nominal depreciation-wages

#### A.5 Firm Owner HH Accounting Sector

FO Deposits(t) = FO Deposits(t - dt) + (saving FO - dissaving FO) \* dt

INIT FO Deposits = 0

INFLOWS:

saving FO = max(total disposable nominal income FO-nominal cons FO,0)

OUTFLOWS:

dissaving FO = min(nominal cons FO-total disposable nominal income FO,possible dissaving FO)

FO HH Current Account(t) = FO HH Current Account(t - dt) + (factor incomes FO + interest income FO + bank dividends FO + dissaving FO + new loans taken by FO + transfers FO - nominal cons FO - interest payment FO - saving FO - debt payment FO - income tax FO) \* dt

INIT FO HH Current Account = 0

INFLOWS:

factor incomes FO = dividendss

interest income FO = FO Deposits\*nominal interest rate

bank dividends FO = bank dividends

dissaving FO = min(nominal cons FO-total disposable nominal income FO,possible  
dissaving FO)

new loans taken by FO = desired new loans taken by FO

transfers FO = transfer percentage FO\*total transferable income

OUTFLOWS:

nominal cons FO = price\*actual real cons FO

interest payment FO = FO HH debt\*nominal interest rate

saving FO = max(total disposable nominal income FO-nominal cons FO,0)

debt payment FO = debt paymentt FO

income tax FO = total nominal income FO\*tax percentage FO

FO HH debt(t) = FO HH debt(t - dt) + (new loans takenn by FO - debt paymentt FO)

\* dt

INIT FO HH debt = 0

INFLOWS:

new loans takenn by FO = new loans taken by FO

OUTFLOWS:

debt paymentt FO = FO HH debt/debt maturity

Converters

debt maturity = 5

desired new loans taken by FO = nominal cons FO+saving FO-dissaving FO-total  
disposable nominal income FO

money flow time = 1

possible dissaving FO = (FO Deposits/money flow time)

tax percentage FO = 0

total compulsory expenditure FO = debt payment FO+interest payment FO+income  
tax FO

total disposable nominal income FO = total nominal income FO+transfers FO-total  
compulsory expenditure FO

total disposable real income FO = total disposable nominal income FO/price

total nominal income FO = bank dividends FO+factor incomes FO+interest income FO

#### A.5 High Skilled Wage Earner HH Account Sector

HS Deposits(t) = HS Deposits(t - dt) + (saving HS - dissaving HS) \* dt

INIT HS Deposits = 0

##### INFLOWS:

saving HS = max(total disposable nominal income HS-nominal cons HS,0)

##### OUTFLOWS:

dissaving HS = min(nominal cons HS-total disposable nominal income HS,possible dissaving HS)

HS HH Current Account(t) = HS HH Current Account(t - dt) + (factor incomes HS + interest income HS + dissaving HS + new loans taken by HS + transfers HS - nominal cons HS - interest payment HS - saving HS - debt payment HS - income tax HS) \* dt

INIT HS HH Current Account = 0

##### INFLOWS:

factor incomes HS = total HS nominal wages

interest income HS = HS Deposits\*nominal interest rate

dissaving HS = min(nominal cons HS-total disposable nominal income HS,possible dissaving HS)

new loans taken by HS = desired new loans taken by HS

transfers HS = total transferable income\*transfer percentage HS

##### OUTFLOWS:

nominal cons HS = price\*actual real cons HS

interest payment HS = HS HH debt\*nominal interest rate

saving HS = max(total disposable nominal income HS-nominal cons HS,0)

debt payment HS = debt paymentt HS

income tax HS = total nominal income HS\*tax percentage HS

$$\underline{\text{HS HH debt}(t)} = \text{HS HH debt}(t - dt) + (\text{new loans taken by HS} - \text{debt paymentt HS}) * dt$$

$$\text{INIT HS HH debt} = 0$$

INFLOWS:

$$\text{new loans taken by HS} = \text{new loans taken by HS}$$

OUTFLOWS:

$$\text{debt paymentt HS} = \text{HS HH debt/debt maturity}$$

$$\text{desired new loans taken by HS} = \text{nominal cons HS} + \text{saving HS} - \text{dissaving HS} - \text{total}$$

$$\text{disposable nominal income HS}$$

$$\text{possible dissaving HS} = (\text{HS Deposits/money flow time})$$

Converters

$$\text{tax percentage HS} = 0$$

$$\text{total compulsory expenditure HS} = \text{debt payment HS} + \text{interest payment HS} + \text{income tax HS}$$

$$\text{total disposable nominal income HS} = \text{total nominal income HS} + \text{transfers HS} - \text{total compulsory expenditure HS}$$

$$\text{total disposable real income HS} = \text{total disposable nominal income HS} / \text{price}$$

$$\text{total nominal income HS} = \text{factor incomes HS} + \text{interest income HS}$$

A.6 Inventory Sector

$$\underline{\text{inventory}(t)} = \text{inventory}(t - dt) + (\text{production} - \text{Agg Demand}) * dt$$

$$\text{INIT inventory} = \text{desired inventory}$$

INFLOWS:

$$\text{production} = (\text{total LS employment} \hat{L} \text{S productivity}) * (\text{real capital} \hat{c} \text{capital}$$

$$\text{productivity}) * (\text{employed HS in HS jobs} \hat{H} \text{S productivity}) * \text{tfp}$$

OUTFLOWS:

$$\text{Agg Demand} = \min(\text{total real desired consumption}, \text{possible real consumption})$$

Converters

$$\text{actual real cons FO} = \text{Agg Demand} * (\text{desired cons FO} / (\text{total real desired consumption}))$$

actual real cons HS = Agg Demand\*(desired cons HS/(total real desired consumption))

actual real cons LS = Agg Demand\*(desired cons LS/(total real desired consumption))

actual real investment = Agg Demand\*(desired real investment/(total real desired consumption))

capital productivity = 0.4

desired inventory = total real desired consumption\*desired inventory coverage

desired inventory coverage = 0.25

distribution time = 0.25

effect on price = ((desired inventory/inventory)-1)

HS productivity = 1-capital productivity-LS productivity

LS productivity = 0.25

possible real consumption = inventory/distribution time

tfp = 1

total real cons = actual real cons FO+actual real cons HS+actual real cons LS+actual real investment

total real desired consumption = desired cons FO+desired cons HS+desired cons LS+desired real investment

#### A.7 Investment Decision Sector

perceived profit rate(t) = perceived profit rate(t - dt) + (profit rate adjustment) \* dt

INIT perceived profit rate = 0.045

#### INFLOWS:

profit rate adjustment = (profit rate-perceived profit rate)/profit rate perception time

real capital(t) = real capital(t - dt) + (real investment - real depreciation) \* dt

INIT real capital = 4500

#### INFLOWS:

real investment = actual real investment

### OUTFLOWS:

real depreciation = real capital\*depreciation rate

### Converters

depreciation rate = 0.05

desired capital = if(real capital<0.1)then((1+perceived profit rate-nominal interest rate)\*0.1)else((1+perceived profit rate-nominal interest rate)\*real capital)

desired real investment = max(((desired capital-real capital)/investment adj time+real depreciation,0)

investment adj time = 3

profit rate = (if(real capital<0.1)then(profit/(0.1\*price))else(profit/(real capital\*price)))

profit rate perception time = 2

### A.8 Labor Market Sector

employed HS in HS jobs(t) = employed HS in HS jobs(t - dt) + (hiring HS in HS jobs - firing HS in HS jobs - quitting HS jobs to search LS) \* dt

INIT employed HS in HS jobs = 666

### INFLOWS:

hiring HS in HS jobs = min(((desired HS employment-employed HS in HS jobs)/labor market adj time,unemployed HS searching for HS jobs/labor market adj time)

### OUTFLOWS:

firing HS in HS jobs = min(((employed HS in HS jobs-desired HS employment)/labor market adj time,employed HS in HS jobs/labor market adj time)

quitting HS jobs to search LS = min(((1-real wage rate ratio)\*employed HS in HS jobs/switching job search adj time,employed HS in HS jobs/switching job search adj time)

employed HS in LS jobs(t) = employed HS in LS jobs(t - dt) + (hiring HS in LS jobs - firing HS in LS jobs - quitting LS jobs to search HS) \* dt

INIT employed HS in LS jobs = 0

INFLOWS:

hiring HS in LS jobs = min(actual hiring HS in LS jobs,unemployed HS searchign for LS jobs/labor market adj time)

OUTFLOWS:

firing HS in LS jobs = min(actual firing HS in LS jobs,employed HS in LS jobs/labor market adj time)

quitting LS jobs to search HS = min((real wage rate ratio-1)\*employed HS in LS jobs/switching job search adj time,employed HS in LS jobs/switching job search adj time)

employed LS(t) = employed LS(t - dt) + (hiring LS - firing LS) \* dt

INIT employed LS = 999

INFLOWS:

hiring LS = actual hiring LS

OUTFLOWS:

firing LS = actual firing LS

nominal HS wage rate(t) = nominal HS wage rate(t - dt) + (HS wage adjustment) \* dt

INIT nominal HS wage rate = 0.8\*price

INFLOWS:

HS wage adjustment = (indicated wage HS-nominal HS wage rate)/wage adjustment time

nominal LS wage rate(t) = nominal LS wage rate(t - dt) + (LS wage adjustment) \* dt

INIT nominal LS wage rate = 0.4\*price

INFLOWS:

LS wage adjustment = (indicated wage LS-nominal LS wage rate)/wage adjustment time

unemployed HS searchign for LS jobs(t) = unemployed HS searchign for LS jobs(t - dt) + (firing HS in LS jobs + switching to LS + quitting HS jobs to search LS - hiring HS in LS jobs - switching to HS) \* dt

INIT unemployed HS searchign for LS jobs = 0

INFLOWS:

firing HS in LS jobs = min(actual firing HS in LS jobs, employed HS in LS jobs/labor market adj time)

switching to LS = min((1-real wage rate ratio)\*unemployed HS searching for HS jobs/switching job search adj time, unemployed HS searching for HS jobs/switching job search adj time)

quitting HS jobs to search LS = min((1-real wage rate ratio)\*employed HS in HS jobs/switching job search adj time, employed HS in HS jobs/switching job search adj time)

OUTFLOWS:

hiring HS in LS jobs = min(actual hiring HS in LS jobs, unemployed HS searchign for LS jobs/labor market adj time)

switching to HS = min((real wage rate ratio-1)\*unemployed HS searchign for LS jobs/switching job search adj time, unemployed HS searchign for LS jobs/switching job search adj time)

unemployed HS searching for HS jobs(t) = unemployed HS searching for HS jobs(t - dt) + (firing HS in HS jobs + switching to HS + quitting LS jobs to search HS - hiring HS in HS jobs - switching to LS) \* dt

INIT unemployed HS searching for HS jobs = 1

INFLOWS:

firing HS in HS jobs = min((employed HS in HS jobs-desired HS employment)/labor market adj time, employed HS in HS jobs/labor market adj time)

switching to HS = min((real wage rate ratio-1)\*unemployed HS searchign for LS jobs/switching job search adj time, unemployed HS searchign for LS jobs/switching job search adj time)

quitting LS jobs to search HS = min((real wage rate ratio-1)\*employed HS in LS jobs/switching job search adj time, employed HS in LS jobs/switching job search adj time)

OUTFLOWS:

hiring HS in HS jobs = min(((desired HS employment-employed HS in HS jobs)/labor market adj time,unemployed HS searching for HS jobs/labor market adj time)

switching to LS = min(((1-real wage rate ratio)\*unemployed HS searching for HS jobs/switching job search adj time,unemployed HS searching for HS jobs/switching job search adj time)

unemployed LS(t) = unemployed LS(t - dt) + (firing LS - hiring LS - Noname 5) \* dt

INIT unemployed LS = 1

INFLOWS:

firing LS = actual firing LS

OUTFLOWS:

hiring LS = actual hiring LS

actual firing HS in LS jobs = desired firing LS\*(employed HS in LS jobs/(employed HS in LS jobs+employed LS))

actual firing LS = desired firing LS\*(employed LS/(employed HS in LS jobs+employed LS))

actual hiring HS in LS jobs = desired hiring LS\*(unemployed HS searching for LS jobs/(unemployed LS+unemployed HS searching for LS jobs))

actual hiring LS = desired hiring LS\*(unemployed LS/(unemployed LS+unemployed HS searching for LS jobs))

Converters

desired firing LS = min(((total LS employment-desired LS employment)/labor market adj time,total LS employment/labor market adj time)

desired hiring LS = min(((desired LS employment-total LS employment)/labor market adj time,total LS unemployment/labor market adj time)

desired HS employment = (real wage rate HS/(HS productivity\*(real capital<sup>α</sup>capital productivity)\*(total LS employment<sup>1-α</sup>LS productivity)))<sup>1/(HS productivity-1)</sup>\*tfp

desired LS employment = (real wage rate LS/(LS productivity\*(real capital<sup>α</sup>capital productivity)\*(employed HS in HS jobs<sup>1-α</sup>HS productivity)))<sup>1/(LS productivity-1)</sup>\*tfp

effect on wage HS = (desired HS employment/((employed HS in HS jobs+unemployed HS searching for HS jobs)))

effect on wage LS = ((desired LS employment)/((employed HS in LS jobs+employed LS+unemployed HS searching for LS jobs+unemployed LS)))

indicated wage HS = nominal HS wage rate\*(1)\*effect on wage HS

indicated wage LS = nominal LS wage rate\*(1)\*effect on wage LS

labor market adj time = 1

real wage rate HS = nominal HS wage rate/price

real wage rate LS = nominal LS wage rate/price

real wage rate ratio = real wage rate HS/real wage rate LS

switching job search adj time = 0.5

total HS nominal wages = (employed HS in HS jobs\*nominal HS wage rate)+(employed HS in LS jobs\*nominal LS wage rate)

total LS employment = employed HS in LS jobs+employed LS

total LS unemployment = unemployed HS searchign for LS jobs+unemployed LS

total nominal LS wages = nominal LS wage rate\*employed LS

wage adjustment time = 1

#### A.9 Low Skilled Wage Earner HH Account Sector

LS Deposits(t) = LS Deposits(t - dt) + (saving LS - dissaving LS) \* dt

INIT LS Deposits = 0

##### INFLOWS:

saving LS = max(total disposable nominal income LS-nominal cons LS,0)

##### OUTFLOWS:

dissaving LS = min(nominal cons LS-total disposable nominal income LS,possible dissaving LS)

LS HH Current Account(t) = LS HH Current Account(t - dt) + (factor incomes LS + interest income LS + dissaving LS + new loans taken by LS + transfers LS - nominal cons LS - interest payment LS - saving LS - debt payment LS - income tax LS) \* dt

INIT LS HH Current Account = 0

INFLOWS:

factor incomes LS = total nominal LS wages

interest income LS = LS Deposits\*nominal interest rate

dissaving LS = min(nominal cons LS-total disposable nominal income LS,possible  
dissaving LS)

new loans taken by LS = desired new loans taken by LS

transfers LS = total transferable income\*transfer percentage LS

OUTFLOWS:

nominal cons LS = price\*actual real cons LS

interest payment LS = LS HH Debt\*nominal interest rate

saving LS = max(total disposable nominal income LS-nominal cons LS,0)

debt payment LS = debt paymentt LS

income tax LS = total nominal income LS\*tax percentage LS

LS HH Debt(t) = LS HH Debt(t - dt) + (new loans taken by LS - debt paymentt LS)

\* dt

INIT LS HH Debt = 0

INFLOWS:

new loans taken by LS = new loans taken by LS

OUTFLOWS:

debt paymentt LS = LS HH Debt/debt maturity

desired new loans taken by LS = nominal cons LS+saving LS-dissaving LS-total  
disposable nominal income LS

possible dissaving LS = (LS Deposits/money flow time)

Converters

tax percentage LS = 0

total compulsory expenditure LS = debt payment LS+interest payment LS+income  
tax LS

total disposable nominal income LS = total nominal income LS+transfers LS-total  
compulsory expenditure LS

total disposable real income LS = total disposable nominal income LS/price

total nominal income LS = factor incomes LS+interest income LS

#### A.10 Simple Banking Sector

Bank Earnings(t) = Bank Earnings(t - dt) + (interest paid to bank - interest paid by banks - bank dividends) \* dt

INIT Bank Earnings = 0

##### INFLOWS:

interest paid to bank = firm interest payment<sub>tt</sub>+interest payment<sub>FO</sub>+interest payment<sub>HS</sub>+interest payment<sub>LS</sub>

##### OUTFLOWS:

interest paid by banks = interest income<sub>FO</sub>+interest income<sub>HS</sub>+interest income<sub>LS</sub>

bank dividends = interest paid to bank-interest paid by banks

Bank Reserves(t) = Bank Reserves(t - dt) + (borrowing from CB + total savings + total debt redemption - paying back to CB - total dissavings - total loans taken) \* dt

INIT Bank Reserves = 0

##### INFLOWS:

borrowing from CB = desired CB borrowing

total savings = saving<sub>FO</sub>+saving<sub>HS</sub>+saving<sub>LS</sub>

total debt redemption = debt payment<sub>FO</sub>+debt payment<sub>HS</sub>+debt payment<sub>LS</sub>+firm debt payment<sub>tt</sub>

##### OUTFLOWS:

paying back to CB = -desired CB borrowing total dissavings = dissaving

FO+dissaving<sub>HS</sub>+dissaving<sub>LS</sub> total loans taken = new loans<sub>firm</sub>+new loans taken by FO+new loans taken by HS+new loans taken by LS

CB Vaultt(t) = CB Vaultt(t - dt) + (paying back to CB + printing moneyy - borrowing from CB) \* dt

INIT CB Vaultt = 0

##### INFLOWS:

paying back to CB = -desired CB borrowing

printing money = net money creation

OUTFLOWS:

borrowing from CB = desired CB borrowing

desired CB borrowing = total dissavings + total loans taken - total debt redemption - total savings

net money creation = borrowing from CB - paying back to CB

## APPENDIX B

### SIMPLE CAPITAL FLIGHT MODEL

We define exogenous real wage rates for high skilled and low skilled labor abroad. Then we calculate the nominal wage rates by multiplying them with the domestic price level. The calculation of nominal wage rates abroad is not realistic; however, otherwise we need to build a full model for the external economy as well. We do not change the firm's decision model on how many workers to employ. Based on the wage rates abroad, the firm decides how many workers it will employ abroad and in domestic economy. The demand for domestic labor eases with the existence of labor supply in the external economy; hence, the rate of increase of the domestic wage rates is lower compared to the base run. Here are some of the important equations in the simple capital flight model:

$$\begin{aligned} HS \text{ employment abroad}(t) &= \\ HS \text{ employment abroad}(t - dt) &+ (HS \text{ hiring firing abroad}) * dt \end{aligned}$$

$$\begin{aligned} LS \text{ employment abroad}(t) &= \\ LS \text{ employment abroad}(t - dt) &+ (LS \text{ hiring firing abroad}) * dt \end{aligned}$$

$$\begin{aligned} \text{desired } LS \text{ employment abroad} &= \\ (\text{home over abroad } LS \text{ wage rate}) &* \text{desired } LS \text{ employment} \end{aligned}$$

$$\begin{aligned} \text{desired } HS \text{ employment abroad} &= \\ (\text{home over abroad } HS \text{ wage rate}) &* \text{desired } HS \text{ employment} \end{aligned}$$

The main variables of the model do not change except Gini index. Gini index is now increasing with respect to time, which is a desirable outcome for us.

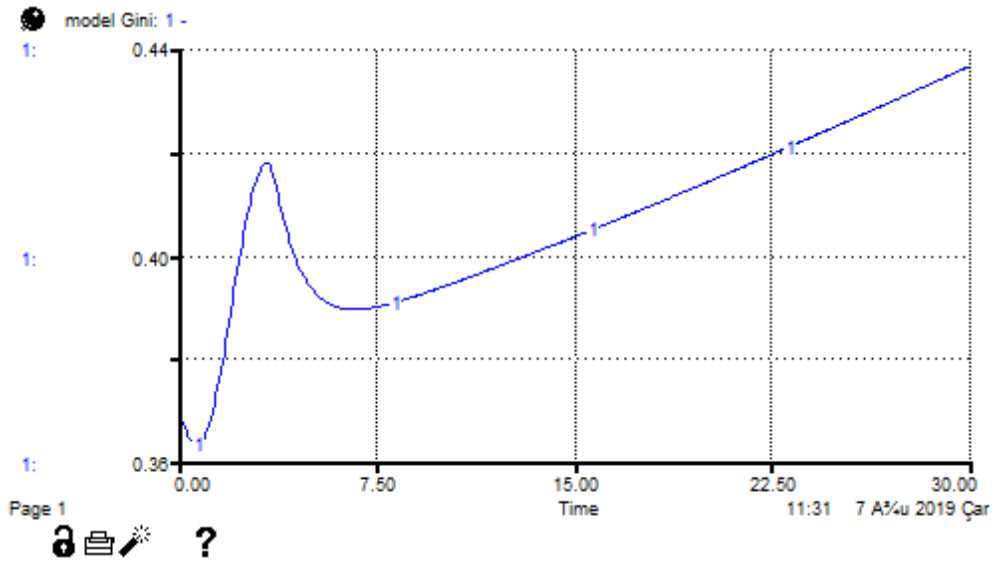


Figure B1. Model Gini under simple capital flight model

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