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**DEGROWTH DYNAMICS  
MODELING POLICY PATHWAYS USING A SYSTEMS  
PERSPECTIVE**

European Master in System Dynamics

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## **SUMMARY**

Degrowth is most commonly defined as a socially sustainable and equitable reduction (and eventually stabilization) of society's throughput, where throughput refers to the materials and energy society extracts, processes, transports, and distributes, to consume and return back to the environment as waste. The origins of degrowth paradigm are traced back to the 1970's and the Romanian economist Nicholas Georgescu-Roegen and his work on entropy in economy. Over the last 50 years supporters of degrowth from academia and practice developed a large theoretical network of concepts and policy proposals designed to offer alternatives to modern economic system. This thesis builds on that work and explores degrowth policy proposals from a system dynamics perspective.

To better understand the underlying causal structure it was necessary to go beyond information available in the literature. Experts in the field of degrowth were contacted by the means of an online questionnaire and the information collected was analyzed and used to develop a simulation model which is capable of testing validity of their claims. The results show that all four policies tested have the potential to positively impact socio-economic and environmental conditions and that the experts have a good understanding of possible dynamic consequences of implementing these policies. They also revealed some surprising unintended consequences and possibility of long term problems.

**Key words:** degrowth, system dynamics, policy, modeling, simulation, basic and maximum income, work sharing, job guarantee, dematerialization.



## **PREFACE**

This research was conducted as a graduation project for European Master in System Dynamics Program, at the New University of Lisbon, Portugal, from March to July 2015, and supervised by Dr. Nuno Videira from the Faculty of Sciences and Technology.

During the two year program I had a privilege to learn from some of the brightest minds in the fields of system dynamics, group model building, and sustainability sciences at three of the finest European universities: University of Bergen, Norway; Radboud University in Nijmegen, Netherlands; and New University of Lisbon, Portugal. The knowledge of the teaching staff and their dedication to the students will forever be an inspiration to me.

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And to Sara, love of my life; for being my rock and my most honest critic, for her patience, love, and support, for being my inspiration every single day.

“There is nothing noble in being superior to your fellow man.  
True nobility lies in being superior to your former self.”

Ernest Hemingway

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# 1 INTRODUCTION

## 1.1 ABOUT THE TOPIC

The French term for degrowth (*'décroissance'*) was first used in 1972 by the French intellectual André Gorz who was inspired by the work of Nicholas Georgescu-Roegen, founder of ecological economics and intellectual precursor of the degrowth. The English term was first used at the first degrowth conference in Paris in 2008. At its core, degrowth is a criticism of economic growth and sustainable development. Its main objective is the abolishment of economic growth as a social objective. It is defined from the ecological economics perspective as an equitable downscaling of production and consumption that will reduce societies' throughput of energy and raw materials (Schneider et al., 2010).

In the aftermath of the global crisis in 2008 degrowth gained a significant amount of attention in academia and mainstream media as it was one of only few intellectual movements claiming that the crisis was result of systemic deficiencies of the modern capitalist system and not just a temporary cyclical anomaly. Supporters of degrowth took this opportunity to promote their own visions of new economic systems based on sharing, simplicity, conviviality, care, and the commons as the primary significations of a prosperous society. It would appear, however, that this was not enough to warrant major changes in society just yet. In fact, governments around the world seem to be convinced as ever that the economic growth is the solution to global problems, and are determined to achieve it. This thesis uses system dynamics analysis on degrowth proposals in order to expand our understanding of their dynamic consequences on systemic level and to provide a new way they can be constructed, described, shared, and tested.

According to its supporters, degrowth is unavoidable, and shrinking of the economy is bound to happen regardless of the policies implemented. What societies can choose is whether these reductions will be voluntary and controlled, or if there will be a disastrous crash. Better understanding of degrowth proposals' dynamic effects can help supporters advocate in their favor as well as detect areas for improvement.

## 1.2 RESEARCH OBJECTIVES AND QUESTIONS

Since the emergence of the degrowth paradigm nearly 50 years ago it has been a subject of extensive debate between its supporters and mainstream economists who oppose it. Supporters often see it as a necessary and possibly unavoidable set of anti-consumerist and anti-capitalist proposals essential for responding to the “limits-to-growth” problem. Opponents on the other hand, see it as a destroyer of wealth and utterly pointless in its essence since, as they believe, most of the problems that degrowth addresses can and will be resolved through technological progress and the self-regulation of the free market. It is reasonable to say that the opponents were more successful in spreading their ideas into the political, economical, and social sphere, since majority of the developed and developing nations in the world try to achieve continued economic growth, while degrowth policies are rarely advocated by relevant political establishments and hardly ever implemented.

This may be because people are intuitively drawn to the competitive nature of the free market or because the supporters of mainstream economy were easily able to point out to many of its benefits and hide its detriments, but a lot can be said about the lack of evidence on claims made by supporters of degrowth proposals. As it will be shown in chapter 2, degrowth is often criticized for being vague and for lacking evidence to support its foundational claims. This is also acknowledged by degrowth advocates such as Kallis et al. (2015), saying that the future of degrowth is still open and that more research is needed to support its foundational claims, which are firmly established within the community, but far from accepted by the academia and society at large.

Because degrowth transcends multiple fields, such as economics, ecology, politics, and sociology to mention a few, and combines them under a single paradigm, it has multiple research fronts, which can be explored in order to build the support for its foundational claims. Kallis et al. (2012) identify twelve of these research fronts, which cover a wide range of issues, from the need to improve degrowth’s philosophical foundations to elaborating on its proposals and relationship with mainstream economics. One of these fronts, named ‘economic and metabolic scenarios’, is about exploring the dynamic complexity<sup>1</sup> of degrowth proposals, or “putting numbers to degrowth proposals” as the authors call it. This dissertation explores some of the most ‘emblematic’ degrowth proposals (Videira et al. 2014) by focusing on their

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<sup>1</sup> Sterman (2000: 46) describes dynamic complexity as complexity arising from the interactions of the agents over time.

dynamic complexity. The main objectives of the thesis are to identify common interpretations of the underlying causal structure of the main degrowth proposals, to use system dynamics modeling to make those interpretations explicit, and to see how this can be used to further expand the knowledge base and provide new evidence for degrowth claims.

The main questions this thesis answers are:

1. What are the most important, dynamically complex degrowth policy proposals which need to be explored using a systems perspective?;
2. What is degrowth experts' perception of the underlying causal structure of these proposals?;
3. How can a system dynamics modeling approach be used to model and simulate a set of 'emblematic' degrowth proposals?;
4. How can these models be used to develop simulation scenarios which could test the foundational degrowth claims?.

Answering these questions brings a new perspective to development, analysis and communication of degrowth proposals. Making the causal structure of proposals explicit is expected to provide a new way for analysis and presentation of degrowth concepts among researchers, help identify their strengths and weaknesses, and provide a visual tool for conveying their message to the political, economical and social sphere. Development of simulation models and scenarios is expected at least to partially deal with the problem that many of the degrowth proposals have never been implemented on a larger scale, which puts them in a disadvantage compared to mainstream economists' proposals which are used by majority of the worlds governments. It would allow researchers and policy makers to tailor certain policies based on the specific needs of a country or a region. This thesis provides an example of how this can be done by exploring the casual structure of some of these proposals using expert consultation, advancing a system dynamics simulation model to test them, and developing scenarios which show both the models' possibilities as well as answer some of the existing questions about their dynamics.

### **1.3 ORGANIZATION OF THE THESIS**

The second chapter provides a theoretical context for the thesis. It is divided into three main sections. First section provides an overview of degrowth's historical development in the 20<sup>th</sup> and 21<sup>st</sup> century and explains the relationship between degrowth and major global crises. Second section provides an overview of the most important aspects of degrowth's philosophy,

which includes its relations to economic growth and sustainable development, as well as most important criticisms of the movement. Third section provides an overview of previous academic work which links degrowth and system dynamics. It also provides a short description of those features of system dynamics which make it best suitable to achieve the research objectives.

The third chapter contains a step-by-step guide through phases of the research.

The fourth chapter is about presenting results of system dynamics analysis of degrowth proposals. This chapter explains which proposals were selected and why. It also provides a system analysis of the selected degrowth policy proposals. Each of them is briefly explained, after which summaries of expert consultations are presented, followed by elicited causal loop diagrams. Last section of this chapter provides a short summary of other policy proposals, which were not subjected to system analysis because of lack of information and time, but were seen as important by the experts.

In the fifth chapter a description of the stock and flow model, validation, and simulation results are provided. The chapter is divided in two sections. First section provides a detailed explanation of the stock and flow diagram constructed to test the experts' claims about the impacts of implementing selected policy proposals. This section also contains a summary of conducted validation tests. Second section provides simulation results. For each selected policy proposal a scenario is designed and explained. The results are presented in the form of graphs over time and compared to basic run.

Sixth chapter provides a short review of work done in the thesis and results of the research. This is followed by the conclusions and future research possibilities.

Additional important information is provided in the appendix.

## **2 HISTORY, PHILOSOPHY AND APPLICATION OF SYSTEM DYNAMICS TO DEGROWTH**

### **2.1 HISTORY OF DEGROWTH**

#### **2.1.1 From the 1930's to the 1970's crisis**

To understand degrowth it is necessary to understand the historical context within which it emerged and evolved. The history of degrowth was not linear. There was not a single event that started it and it didn't develop continuously at a certain pace. In fact the degrowth movement had its ups and downs throughout the 20th and in the first 15 years of 21st century, with periods of great public and scientific interest in the matter, but also periods when it was forgotten and rejected as doomsday prophecies. As it will be shown throughout this chapter, these periods of great interest in degrowth would coincide with periods of economic and social crisis, while periods of rejection would coincide with periods of economic growth.

Martinez-Alier et al. (2010) trace the intellectual roots of degrowth back to 1930's France. This period between the two World Wars was characterized by a major economic crisis, depression and uncertainty. This would prove to be a fertile ground for the ideas of philosophers, such as Jacques Ellul and Bernard Charbonneau, which criticized modernity and called for a "revolution of civilization". One of their biggest concerns was the emergence of technological tyranny over humanity (Charbonneau, 1969; Ellul, 1988) and they would continue to criticize gigantism and the power of technology<sup>2</sup> as the key feature of modernity. Soon after, the Second World War started and France was caught in the middle of it, shifting the focus of the public away from this line of thought.

As the War raged in July 1944, leaders of the 44 allied nations decided to prepare for rebuilding of the international economic system by organizing the United Nations Monetary and Financial Conference in Bretton Woods, New Hampshire, United States. During the Bretton Woods conference a new economic system was agreed upon, which included setting gold and US dollar at the basis of the international economy and establishment of International Monetary Fund (IMF) and International Bank for Reconstruction and Development (IBRD), which is today part of World Bank Group. With the end of World War

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<sup>2</sup> Ellul would define technology as totality of methods rationally arrived at and having absolute efficiency in every field of human activity.

II states undertook a series of nationalizations of strategic enterprises and the partial supervision of the industrial sector, promoting, at the same time, a Keynesian-corporatist regulation of market economy and capitalist growth through policies that aimed at securing domestic demand and mass consumption (Van Creveld, 1999).

Until the early 1970's, the Bretton Woods system stayed in power. Postwar industrialism combined with welfare systems in developed countries achieved a state regulated "class compromise" within nationally defined populations. However, in the 1970's this compromise was gradually shaken as the growth rates started to decline and governments struggled to secure full employment with union pressures in the framework of free collective bargaining (Markantonatou, 2013). In 1971 the USA unilaterally pulled out of the Bretton Woods Accord and abandoned the Gold Exchange Standard which pegged the value of the dollar to the price of gold and all other currencies to the dollar. Shortly after, the rest of the developed world followed. Full blown crisis has started in 1973 after OPEC<sup>3</sup> countries proclaimed an oil embargo against the USA, Canada, Japan, the Netherlands, and the United Kingdom, because of the USA's involvement in Yom Kippur War<sup>4</sup>.

### **2.1.2 Emergence and divergence of growth critiques in the 1970's**

The Second World War started an age of computational technologies, which developed rapidly in the postwar era, opening possibilities for mathematical modeling across scientific fields, testing the validity of particular theories, and formulating scenarios and predictions about the future of systems. In the late 1960's Jay Forrester, a computer engineer with background in control theory, introduced a methodology, which he initially named industrial dynamics, but was later renamed as system dynamics. In his book '*Urban Dynamics*' Forrester (1969) examined the problems of aging urban areas and caused a strong reaction at that time because his models attacked the usefulness of low-cost housing. Few years later Forrester (1971), in his book '*World Dynamics*', used mathematical equations to build a system dynamics model describing the interplay of the world population and economic growth, taking into account the environmental limitations such as available arable land and pollution. This work would serve as an inspiration to Meadows et al. (1972) and their '*Limits to growth*' report, which received worldwide attention, from both supporters and critics.

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<sup>3</sup> Organization of Petroleum Exporting Countries plus Egypt, Syria, and Tunisia.

<sup>4</sup> Yom Kippur War, also known as the 1973 Arab-Israeli War, was a war fought by the coalition of Arab states led by Egypt and Syria against Israel from October 6 to 25, 1973.

A major contribution to the discussion about interconnectivity of environment, population, economy, and technology came from Ehrlich and Holdren (1971) who proposed the 'I=PAT'<sup>5</sup> equation as a conceptual tool to isolate and study the factors determining the pressure that economic activities entail on the environment. This relation indicates that the stress on both environment and natural resources is due to the simultaneous increase of human population and the affluence of the society (the level of consumption per capita). They believed that increases in population and affluence cannot be compensated with better technology. This has provoked a heated debate which divided scientists in two camps (Sorman & Giampietro, 2013):

- The cornucopians - believers in perpetual growth. For them, any increase in population and affluence can be compensated with technological improvements;
- The prophets of doom - those believing that perpetual growth on a finite planet is not possible, regardless of technological improvements.

The idea of degrowth, as defined today, was born in the early 1970's as a response to seemingly undisputed view of need for never ending economic growth and increasing consumption. It started with Romanian economist Nicholas Georgescu-Roegen and his book '*The Entropy Law and the Economic Process*' (Georgescu-Roegen, 1971). He was one of the first economists to claim not only that eternal growth is not possible but also that it is not necessary, and not only should we stop increasing consumption but we should also decrease it in order to prevent completely exhausting scarce natural resources. He would criticize the mainstream economic model for neglecting the second law of thermodynamics according to which increasing economic activity leads to increasing consumption, depletion of useful resources, and ultimately societal collapse. Today he is considered to be an intellectual pioneer of the ecological economics field.

The work of Georgescu-Roegen was an inspiration to French intellectual André Gorz who in 1972 first used the word '*decroissance*', which is French for degrowth. Gorz (1972) claimed that no-growth or even degrowth are necessary conditions for keeping the Earth's natural systems in balance and questioned if that was compatible with the survival of the capitalist system. This problem is still one of the core problems in the degrowth debate and André Gorz is today considered to be a precursor of political ecology. He explicitly used the term degrowth in his book '*Ecology as Politics*' (Gorz, 1980). Other authors adopted this term

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<sup>5</sup> I - Impact on the environment; P - population; A - Affluence; T - Technology

early and used it in the follow up to the *'The Limits to Growth'* report, which used system dynamics modeling to study the effects of exponential economic and population growth in a world with finite resource supplies. In many ways this report commissioned by the *'Club of Rome'* confirmed the claims of early degrowth supporters about the impossibility of sustaining economic growth without depleting natural resources and causing irreversible environmental damage.

The report was based on the incompatibility of finite natural resources and economic growth. The conclusion of its authors was that if the world continues on a current path natural resources would be depleted and environmental limits reached within the next 100 years. Alternative scenarios were developed to compensate for the lack of data in certain areas (such as resource availability, technology development, pollution controls, and agricultural production), but the most realistic scenarios projected collapse, portrayed in the report as rapid population decline and shrinking of the economy. Several scenarios managed to avoid collapse and stabilized in a so called "state of global equilibrium" characterized by demographic and industrial stability. This notion of a stationary state was complementary to the work of Herman Daly (1968) who also advocated for a global transition to it, and claimed that due to the natural limits there was a maximum number of person-years that can be lived in the developed state that cannot be surpassed (Daly, 1991).

Herman Daly was inspired by the earlier work of Kenneth Boulding and Nicholas Georgescu-Roegen when he formulated his own economic steady-state theory. He saw great similarities between economy and biology and similarly to Georgescu-Roegen introduced the concept of entropy to economics. However, unlike Georgescu-Roegen he did not think that the introduction of entropy to economics implies a course toward total degradation. Instead, he envisioned a perpetually reproduced and smoothly functioning economy, which would respect certain constraints regarding its interaction with the nature. To him the economy was a replica of a biological process with permanent steady-state disequilibrium (Markantonatou, 2013). It would have constant stocks of people and artifacts which would be maintained at desired, sufficiently low rates of throughput (Daly, 1991). Although it is still unknown what those desired, sufficiently low rates are, and who would determine them, Daly, in light of new findings about consumption- and population-driven depletion of natural resources, argued against growth as a concept that endangers economic and social equilibrium within the capitalist system.

As previously mentioned, *Limits to Growth* gained a substantial reputation within the scientific community and public, but it also gained a large number of critics, especially by mainstream economists who pointed out flaws in the model assumptions. Among those defending the report was Nicholas Georgescu-Roegen (1975). The critique directed at his fellow economists can be summed up in the following four points:

- They criticized the use of mathematical models and simulation, even though they used it themselves widely;
- They criticized the highly aggregated model, even though they made heavy use of the aggregated models themselves;
- They endorsed the “acceleration principle” regarding the economic outputs, but rejected it when pollution was included in the outputs;
- They criticized the report for using the assumption of exponential growth, even though the very theory of economic development is anchored in exponential growth models.

The fact that Georgescu-Roegen publically defended the “*Limits*” helped to add scientific credibility to the report, but his support was only partial. He defended the methods the report used, as they were already widely accepted by the mainstream economists, but he also saw many similarities between the report and its critics, like the fact that both thought growth is controllable (Markantonatou, 2013). The only difference was that mainstream economists thought it could go on forever while the “*Limits*” called for a steady-state economy. It is at this point of time that one can see a clear divergence between the two major streams of growth critique, one being Daly’s steady-state economy and the other Georgescu-Roegen’s declining state or degrowth as it would be called later. Georgescu-Roegen considered the idea of steady-state overly simplistic and false in the same way as the mainstream economists’ idea that it is possible to have an economy that would not cause irrevocable change in nature. This was because even the steady-state required constant consumption of resources and no matter how far the technology can go in using them effectively, eventually the balancing system will collapse, at which time a steady-state would enter a crisis, which would defeat its alleged purpose and nature (Georgescu-Roegen, 1975).

The rift with steady-state economics was further emphasized in his criticism of the idea that a steady-state would allow people more time to dedicate to spiritual activities. He claimed that the Middle Ages were also a kind of steady state in which people still had to work hard, when leisure depended on the intensity of the need for resources, and optimal levels of population and capital were not reached even in principle (Georgescu-Roegen, 1975). Because of that, he

felt that the notion that a steady-state economy could protect the environment and compensate for the entropic impact was equally misguided as those that claimed growth was controllable. The unavoidable depletion of resources not only excludes the possibility of perpetual economic growth but actually anything more than a constantly declining state, to the point of annihilation (Georgescu-Roegen, 1975: 367).

Georgescu-Roegen would go on to suggest his own bio-economic program, which included measures such as prohibition of weapons manufacturing, organic farming, less wasting of energy, reduction of consumption, and design of products without built-in obsolescence. His suggestions were influential among the 1970's critics of growth, in particular within degrowth, but because of his position on annihilation and emphasis of "mans fallacy that the march of entropy could be reversed", his program was not widely accepted. Divergence with steady-state economics was evident in his views of evolution, history and social relations, which he thought cannot be subjected to prediction or be the product of mental labor by some specialists on the basis of abstractions, assumptions and models that more or less simplify reality (Markantonatou, 2013).

The 1970's were the first phase of the degrowth debate. This phase was fueled by the ongoing oil crisis and many other authors, such as Goldsmith and Prescott-Allen (1972) and Schumacher (1973), also wrote against the growth paradigm and called for downscaling of the production and consumption, protecting the environment, and living more simple lives. However, with the end of the oil crisis in the 1980's neo-liberalism prevailed as the guiding line of thought in the world economy and the interest for both degrowth and limits to growth all but vanished.

### **2.1.3 From the 1970's to the 2008 crisis**

By 1975 the Oil crisis ended, the gold standard was abandoned, and governments around the world started implementing inflation-tolerant policies as a first method of "restarting" their economies and achieving economic growth. In the face of inflation and international trade stagnation, capitalists in Europe and US started to move their capital to countries such as China, South Korea, India, Malaysia, Taiwan and Mexico, which caused a rise in the unemployment in the former countries, and intensification of industrialization in the latter. Growth based on technology and increase in worker productivity was now substituted with growth based on inflation, and high profits were restored by weakening the power of unions. The labor force shifted to less unionized and less localized service industries and enterprises

moved to international markets searching for higher profit sectors (Pontusson & Raess, 2012).

These measures caused a rise in public indebtedness during the 1980's. Reducing tax revenues and tax provisions for capitalists caused the debt to become more than a fiscal tool. It became a substitute for growth and replaced inflation in its role of bridging the gap between social demands and market needs (Streeck, 2011). However, creditors started to demand more fiscal discipline which led to implementation of more intense austerity measures and reduction of welfare expenditures. Additional pressures came from reduced birth rates and an aging population. The number of pensioners increased and depended on fewer and fewer working persons, which was one of the reasons growth rates never returned to postwar levels.

Then, in the 1990's and 2000's, governments came up with a new way of obtaining "future resources" (Streeck, 2011) through credit liberalization, financialization, and promotion of private indebtedness, combined with reduced taxation on entrepreneurial profits and new opportunities for profit in finance (Markantonatou, 2013). According to Castells (2011) key characteristics of this new financialization era were: securization of almost every economic entity, activity or asset, elevating financial valuation into the key criterion for assessment of the value of firms, more dependence of financial markets on information and less on supply-demand logics, negligible supervision in derivatives trading, and the intertwining of the Asian/Pacific and US budgets. Continued welfare deregulation was compensated with different policies aimed at improving the living standard of the poor and increasing their consumption power. These policies included the liberalization of the mortgage sector and schemes of self-funded pensions. In particular mortgage loans constituted one more effort to bridge economic with social needs, and adjust the latter to an increasingly liberalized and internationalized capitalism, initiating a period of finance-based growth. Removing the state from the process of fair distribution of social security (e.g., pensions, health insurance), as well as allowing citizens to continue consuming through policies of credit and real estate liberalization to cope with shrinking welfare services was a kind of financialization of the reproduction of the working class that constituted the social background of the 2008 crisis (Markantonatou, 2013).

To cope with the 2008 crisis governments around the world poured in around \$20 trillion as a response to the collapse of some of the world's largest banks and insurance companies. During this so called "Great Bailout" governments transferred private debt into public by

undertaking bank rescues, guaranteeing deposits and financial investments, purchasing temporarily worthless financial assets, nationalizing key financial institutions, imposing emergency taxes to cope with crisis-driven decline in taxation, and socializing losses (Saad-Filho, 2011). The direct result of these measures was an explosion of public debt and deficit in US and Europe, but certain damages were temporarily remedied. However, as Streeck (2011) notes the question remains if the governments have over-extended themselves and if these measures have only further aggravated the crisis in the long term. Overall, the course from a Keynesian growth model and the welfare state, the inflation crisis in the 1970's, through public indebtedness during the 1980's, to credit liberalization and financialization in the 1990's, and finally to the crash of 2008, is showing that modes of regulation of capitalist reproduction, that followed the 1970's crisis, did not manage to provide structural solutions to the problem of ever since falling growth rates and achieved anything but permanent results (Markantonatou, 2013: 9).

#### **2.1.4 Degrowth in the 21<sup>st</sup> century**

Within scientific circles, some attempts to revive the discussion on degrowth were made in the early 1990's in France but not until 2002 and the special issue of the '*Silence*' magazine edited by Bruno Clémentin and Vincent Cheynet, has the degrowth debate spread into public space again. This also marks the beginning of the second phase of the degrowth debate, which is no longer focusing solely on resource limits, but is now criticizing the idea of sustainable development.

In 2002 Serge Latouche, an economic anthropologist and a member of the post-development academic community, at the '*Défaire le développement, refaire le monde*' conference in Paris argued that the very term sustainable development is an oxymoron. In the same year the Institute for Economic and Social Studies on Sustainable Degrowth was founded in Lyon, and the following year it organized the first international colloquium on sustainable degrowth with participants from France, Switzerland and Italy, including Serge Latouche, Mauro Bonaiuti, Paul Ariès, Jacques Grinevald, François Schneider, and Pierre Rabhi. All of these authors would become the intellectual leaders of the second phase of degrowth which lasts to this day. The degrowth movement flourished in Lyon in the early 2000s, and quickly started to spread to Italy ('*decrescita*'), and Catalonia and the rest of Spain ('*decreixement*' and '*decrecimiento*').

The English term degrowth was first used in 2008 at the first degrowth conference in Paris. After that the conferences were held in Barcelona (2010), Montreal (2011), Venice (2012), and Leipzig (2014), with each conference attracting more participants than the previous one, from more different countries worldwide. Degrowth went global and more than 100 published articles and seven special issues in peer-reviewed journals since 2008 are a good indication of widespread interest in the topic. Today it is taught at universities around the world, used in political debates, and covered by news media. Different variations of the term are often used in scientific publications such as a-growth and post-growth. These terms were constructed in order to highlight the notion that degrowth is not the same as recession. Schneider et al. (2010) came up with their own term “sustainable degrowth”, to combat the macroeconomic perspective of degrowth, according to which degrowth means purely a reduction of GDP, as an indicator of economic activity.

It is no surprise that the resurgence of degrowth happened during one of the biggest economic crisis in history. After all, this is what degrowth supporters warned about decades before. As Kallis et al. (2015: 7-8) point out, from a degrowth perspective, this crisis is the result of systemic limits to growth; it is not a cyclical crisis or fault in the credit system. It was first triggered in the US by a spike in oil prices, followed by a fictitious economy of finance and personal loans growth, because it was the only source of growth and a way of stopping the decline in demand. Private and public debt sustained otherwise unsustainable rate of growth (Kallis et al., 2009).

Degrowth today is one of several lines of thought in ecological economics, which include steady-state economics (Daly, 1996), the new economics of prosperity (Jackson, 2009; NEF, 2009; Schor, 2011), and degrowth (Latouche, 2009; Martinez-Alier, 2010), that actively discuss the desirability and feasibility of a degrowth transition, policy instruments for this transition, and socio-political dynamics. Modern proponents of degrowth have, to a certain degree, moved away from Georgescu-Roegen’s harsh criticism of steady-state economics and advocate for a transition towards a lower steady-state, unlike Jackson’s new economics which calls for zero-growth at current levels. The new goal of the degrowth paradigm is to escape from seemingly meaningless and pointless discussions of today’s economy, such as austerity versus spending, and frame a new thesis of degrowth grounded in ‘*dépense*’ (Kallis et al., 2015), or an excess of energy, which any society has, and which is not needed for the mere reproduction of life (Romano, 2015).

## **2.2 PHILOSOPHY OF DEGROWTH**

### **2.2.1 Defining degrowth**

Degrowth signifies, first and foremost, a critique of growth. It calls for the decolonization of the public debate from the idiom of economism and for the abolishment of economic growth as a social objective (Kallis et al., 2015: 3). A more common description of degrowth comes from Daly (1996) who defines it from an ecological-economic perspective as a socially sustainable and equitable reduction (and eventually stabilization) of society's throughput, where throughput refers to the materials and energy society extracts, processes, transports, and distributes, to consume and return back to the environment as waste. This process of extraction, processing, distributing, consuming, and returning of materials and energy as waste is also called society's metabolism, and it causes a slower or faster increase in entropy (Georgescu-Roegen, 1973), which will inevitably lead to humanity and planet Earth dying (Kallis, 2011). Degrowth does not advocate for a state that would continue to infinity, because such state is not possible according to the laws of physics, but calls for a state that will slow down the speed of entropic degradation (Kerschner, 2010).

It's important not to confuse degrowth with negative growth because, as Martinez-Alier et al. (2010) pointed out, a concept like that would be contradictory and absurd. The goal of sustainable degrowth is not to decrease GDP. GDP will inevitably decline as an outcome of sustainable degrowth, but the question is whether this can happen in a socially and environmentally sustainable way (Kallis, 2011: 874), given that under capitalism economies tend to either grow or collapse. Degrowth is carried out deliberately and selectively under constant or even improving social and environmental conditions (Sekulova et al., 2013). Therefore, growth would still be possible and desirable in those economic sectors that improve these conditions.

Schneider et al. (2010) define degrowth as a collective and deliberative process aimed at the equitable downscaling of the overall capacity to produce and consume and of the role of markets and commercial exchanges as a central organizing principle of human lives. However, as supporters of the movement often emphasize, degrowth is about doing things differently, not doing less of the same. A degrowth society would be one built on quality rather than quantity, cooperation rather than competition, with different activities, forms and uses of energy, relations, gender roles, and with social justice as an objective. It should not be understood as an elaborated concept, but rather as a multidimensional idea and vision that

calls for a change in society (Sekulova et al., 2013). Qualitative changes and innovation in the economic, social or cultural sphere will still take place (Daly, 1996).

### **2.2.2 Economic growth**

The paradigm of economic growth has dominated politics and policies since 1945 (Schneider et al., 2010: 511), by promoting more instead of better consumption and private versus public investment in man-made rather than natural capital (Martinez-Alier et al., 2010: 1741). It is usually defined as an increase in goods and services produced by an economy in a given period of time, and conventionally measured as the percent rate of increase in real (inflation adjusted) gross domestic product (GDP) per capita. Defenders of growth often point to benefits even the small rates of growth can have on quality of life, poverty reduction, and happiness. Indeed, developed countries which have sustained long-run economic growth have a high standard of living, better education and health, and happier population than most developing or undeveloped countries.

Most neoclassical economists share the belief of John Maynard Keynes about the desirability of economic growth and its ability for improving the human condition. They argue that economic growth should be the principal objective of government policy, which would lead to other desirable objectives. In particular they see economic growth as the only feasible way to alleviate poverty (Common and Stagl, 2005: 191).

Criticisms of growth can usually be classified into three distinct philosophical courses, which claim that:

- Economic growth is unsustainable in the long run;
- Economic growth is uneconomic in developed countries;
- Continued economic growth in developed countries is unjust.

Economic growth is unsustainable because of environmental and resource limits. Environmental limits refer to planetary boundaries which will be surpassed if global growth continues. The most famous planetary boundary is climate change caused by excessive CO<sub>2</sub> and other GHG<sup>6</sup> emissions to the atmosphere. According to Anderson and Bows (2011) there is a strong and direct correlation between GDP and the carbon emissions that change the climate. Other planetary boundaries (Rockström et al., 2009) are: ocean acidification, ozone depletion, aerosol loading, interference with phosphorus and nitrogen cycles, global

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<sup>6</sup> GHG - Greenhouse Gas

freshwater use, land-system change, rate of biodiversity loss, and chemical pollution. Supporters of growth see a solution in decarbonizing the economy with the advancement of cleaner or more efficient technologies, or by structural shift to services, however with two to three percent global growth per year, the degree of decarbonization needed is next to impossible (Kallis et al., 2015). Jackson (2009) calculated that global carbon intensity would need to be 20 to 130 times lower than it is today to avoid dangerous climate change, and notes that between 1980 and 2008 it was reduced by just 23%. In addition, no country so far has been able to achieve absolute reductions in energy and material use, or reductions in GHG emissions while sustaining economic growth.

Resource limits refer to depletion of both renewable and non-renewable resources which are fueling the economic growth. The '*Limits to Growth*' report in particular emphasized the dependence of economic growth on finite resources as resource depletion was one of the five core variables. One of the most important insights from the report was that if consumption of certain resources is growing at a constant rate those resources would be depleted much sooner than predicted. Defining characteristic of non-renewable resources, such as oil, gas, coal, and minerals for example, is that there is a finite stock of them on Earth. With increasing population and living standards around the world, demand for these resources grows exponentially and extraction rates increase. As the stocks of resources decline it becomes increasingly difficult to find and extract new reserves, which causes the extraction rates to peak, and decline. The economy, being heavily dependent on these resources, is unable to grow, at best stagnates for a while before resources get completely exhausted, and eventually collapses. Similarly, the environmental resource base which includes ecological systems that produce a variety of services can, and in many places around the world does, experience irreversible reduction of their capacity for material production (Arrow et al., 1995).

Daly (1996) considers growth to be uneconomic because in developed economies "illth" increases faster than wealth, meaning that it causes more cost than benefits. One of the reasons why this is often not seen is in the way GDP is measured. The basic problem is that GDP does not distinguish between good and bad economic activity, but counts all activity the same (O'Neill, 2015: 104). GDP does not account for harm done by economic growth, with the most obvious example being pollution. It overlooks the impact of production of goods and services in favor of their value, so if the industry produces a great deal of pollution this can lead to a decrease of life quality and even economic activity in other sectors, and GDP simply does not account for these losses. As a result of this GDP has increased in developed countries

while other welfare indicators such as the Genuine Progress Index (GPI) or the Index of Sustainable Economic Welfare (ISEW) have stagnated since the 1970's.

GDP also does not account for many beneficial activities, done outside the market, such as household and volunteer work, simply because no money exchanges hands. It does not account for the distribution of wealth or economic security. Feminist economists often point out to the fact that most of the household work is done by women, and since growth does not account for that they criticize it for being unjust.

Social limits of growth refer to the inability of growth to satisfy the desire for positional goods, which signify one's position in society and depend on relative income (Kallis, 2015). The positional economy, as described by Hirsch (1977), is composed of "all aspects of goods, services, work positions and other social relationships that are either (1) scarce in some absolute or socially imposed sense or (2) subject to congestion and crowding through more extensive use" (Hirsch, 1977: 27). According to Hirsch (1977) above a certain level of economic growth, after basic material needs are satisfied, a rising proportion of income is directed towards positional goods. Over time they become even less accessible and more expensive. Nevertheless, it is precisely the dream of access to positional goods that sustains the desire for growth. Frank (2000) characterizes the pursuit of positional goods as a zero-sum game with substantial social cost (degradation of basic goods such as education, health, or public infrastructure), and argues that the private and public resources wasted in this game could be used more beneficially elsewhere. For degrowth the notion of social limits of growth is central, not only because growth is unsustainable or uneconomic, but because it depicts growth as a senseless goal in pursuit of an elusive dream, that can never produce enough for everyone to position him- or herself superior to others (Skidelsky and Skidelsky, 2012).

There are several reasons why degrowth considers economic growth to be unjust. Feminist economics, for instance, have shown that growth is subsidized and supported by invisible reproductive work in the household, and women do most of it (Kallis et al., 2015). They see sex and class conflict as endemic to capitalism because it transforms workers lives into capital, for the sake of profit (Picchio, 2015). Another reason is that it benefits from the unequal exchange of resources between developed parts (of nations or the world) that exploit the resources, and periphery that provides them. As resources get exhausted in one area the extraction process moves on to the next, pushing the so called "commodity frontiers" ever further. Conde and Walter (2015) note four different ways in which commodity frontiers and degrowth are linked: (1) the presence of commodity frontiers is rooted in the inherent and

ceaseless drive of capitalism to expand; (2) commodities that supply a global growing economy come from places where peoples' lives are transformed at a high social and environmental cost; (3) social and environmental impacts of extracting resources are increasing as the quality and the availability of resources decrease; (4) economies that in the past mostly imported raw materials are now promoting extraction within their own borders, fostering new industries, dynamics and conflicts.

Apart from the criticisms of economic growth, supporters of degrowth often point out to growing evidence that the growth in developed countries might be coming to an end on its own. Therefore, degrowth might not be an option but an unavoidable fact. What is an option is if we are going to softly land at a new steady-state or if we are going to collapse. This might be because of diminishing marginal returns (Bonaiuti, 2014), the exhaustion of technological innovations (Gordon, 2012), or limits in creating effective demand and investment outlets for capital accumulating at a compound interest rate (Harvey, 2010). Recently Thomas Piketty (2014) in his bestselling book '*Capital in the twenty-first century*' discussed historical growth rates of world output from the beginning of industrial revolution in the 1700's till 2012. What he discovered was that the average growth rate of the world economy was just 1.6 percent over that whole time span, and half of that is due to increase in population. If we assume that global population will stabilize or possibly even decline in the 21st century, along with economic convergence between developed and developing countries, it is reasonable to expect that growth rates will be low in the 21st century. Piketty goes on to demonstrate how slow economic growth will increase the inequalities in the societies, which inspired Jackson and Victor (2014) to write a response demonstrating how low economic growth can happen without increasing inequalities in the society.

### **2.2.3 Sustainable development**

Development is usually defined in terms of economic growth. Countries experience increased growth and as a result their productive capacity expands and they "develop". The term sustainable development was first used in the early 1970's and has since become a catchphrase for international organizations dedicated to achieving environmentally safe and beneficial development. The term itself suggests an idea that lessons from ecology can, and should, be applied to economic processes. To accomplish this, a broad view of both disciplines and political commitment is required (Redclift, 1987). Sachs (2015) defines sustainable development from an analytical and normative perspective. As an intellectual pursuit, sustainable development tries to make sense of the interactions of three complex

systems: the world economy, the global society, and the Earth's physical environment. It is also a normative outlook on the world, meaning that it recommends a set of goals to which a world should aspire (Sachs, 2015: 1-2). Sustainable development, just like other environmental studies including degrowth, tries to deal with humanity's trespassing of the planetary boundaries.

However, unlike degrowth, sustainable development does not advocate against growth. On the contrary, according to Sachs it is a valid goal, especially in low-income and middle-income countries, for which growth means more health, better education, more access to travel and leisure time and more safety from various threats to wellbeing. He and other supporters of sustainable development see a way to achieve a continued economic growth and honoring the planetary boundaries at the same time by choosing the right technologies that would de-carbonize the energy sector and right agricultural techniques that would make it possible to grow more food with less water.

The biggest global problem sustainable development tries to tackle is climate change. Sachs sees two distinct ways of responding to this challenge, namely mitigation and adaptation. Mitigation means reducing the GHG emissions which cause human-induced climate change. A common goal is to limit average global temperature to 2°C above the pre-industrial era temperature. Adaptation means preparing to live more safely and effectively with the consequences of climate change. This would include activities such as safeguarding cities from storm surges, protecting crops from high temperatures and droughts, redesigning agricultural technologies to promote more drought resistance, heat tolerance, and flood tolerance in crops and production systems. In this regard mitigation is viewed as essential and more important of the two, but adaptation is still needed to deal with consequences of climate change that are already happening and will happen in the future. It is interesting to notice that Sachs believes that there are limits to how much we can adapt but at the same time doesn't see any problems with having a growing economy alongside massive reductions in GHG emissions.

According to his calculations the world needs to triple its economy by the year 2050, and at the same time at least halve the emissions than what they are today, in order to secure economic prosperity for everyone and reverse the climate change. This would mean that emissions per dollar of gross world product (GWP) would need to decline by a factor of 6 or even more. As mentioned earlier Jackson's calculations indicate a need for 20-130

times lower emissions per dollar. To achieve this Sachs proposes adoption of a three step plan for deep de-carbonization:

1. Energy efficiency - achieving greater output per unit of input;
2. Reducing the emissions of CO<sub>2</sub> per megawatt hours of electricity - dramatically increasing the amount of electricity generated by zero-emission energy, such as wind, solar, geothermal, hydroelectric, and nuclear power while cutting the production of power based on fossil fuels;
3. Fuel shift - from direct use of fossil fuels to electricity based on clean primary-energy sources.

There are some obvious problems with each of these steps. Even though Sachs mentions some concrete actions for each one, he does not say how much they are actually going to reduce emissions per dollar and what will their impact be on the economic growth. He calls for improvements in energy efficiency but ignores Jevons' Paradox, also known as a rebound effect. This paradox was first observed by William Stanley Jevons (Jevons, 1865) in the heyday of the Industrial Revolution, as Britain worried about running out of coal (Alcot, 2005). He noticed that required coal input per unit of smelted iron or work done by steam engines had long been falling, but total consumption of coal had been rising regardless. This phenomenon has since been observed in other sectors, such as electric lighting, water, phosphorus, arable soil, work-hours, and energy. The basic idea is that rebound consumption will be higher than engineering savings, and even more energy will be consumed than if efficiency stayed the same. What this means for Sachs' proposal is that energy savings from introducing more efficient technologies will not reduce demand for energy, allowing the savings to be directed to transportation, but will actually increase energy consumption or divert those saving to other, less efficient sectors.

In the second step Sachs proposes replacing the fossil fuel production of energy with zero-emission production. This step in particular shows his faith in technological advancement since only with an unprecedented advancement in technology could an undertaking like this be possible. The only power source that currently has the potential to fully replace fossil fuels and keep or increase current energy production is nuclear power, but it is also based on non-renewable resources and creates large amounts of radioactive waste. Both of these things go directly against the concept of sustainability and are some of the reasons why opponents of sustainable development frequently accuse it for contradicting itself and placing human needs above the needs of the environment. Other energy sources, such as solar, have potential to

replace fossil fuels, but they all have certain technological problems that need to be resolved before they become viable alternatives. The last step is a cross-sectoral fuel shift from direct use of fossil fuels to electricity based on zero-emissions power sources. This step also requires further technological advancement and it is unclear how long it would take to reach a required level and how this would be done alongside an increasing economy.

**2.2.4 Criticisms of degrowth**

Degrowth challenges current paradigms regarding economic growth and sustainable development and as such is often a subject of criticism. In the aftermath of the 2008 crisis with the resurgence of the degrowth debate, a number of scientific articles, discussions, and blogs argued against degrowth and its policies. One of the more famous papers criticizing degrowth came from van den Bergh (2011) in which he attacks degrowth for being too vague and having a variety of meanings. He distinguishes five common meanings of degrowth: (1) GDP degrowth; (2) consumption degrowth; (3) work-time degrowth; (4) radical degrowth; and (5) physical degrowth. He analyzed all five meanings according to his criteria (environmental effectiveness, social-political feasibility, economic efficiency, and potential to limit rebound effect) and concluded that none of these different meanings were satisfactory. Table 2-1 shows the comparison of degrowth types he identified and his own a-growth proposal according to his criteria. One point on which he agrees with degrowth supporters is that GDP is not a useful indicator of social progress, but he argues strongly against replacing it and in favor of simply ignoring it. He considers unconditional GDP growth to be an unwise goal since GDP growth is not necessary or sufficient for progress, but also considers GDP degrowth not necessary or sufficient for sustainability.

Table 2-1 Comparison of degrowth and a-growth strategies

Source: van den Bergh (2011, 887)

Degrowth type	Environmental effectiveness	Social and political feasibility	Economic efficiency (welfare, costs)	Limiting rebound
<b>1. GDP degrowth</b>	- Income reduction not necessarily translates into less consumption of dirtiest goods	-- Voters do not like to hear that their income will drop for sure	- Growth sometimes good for welfare; environmental externalities not efficiently reduced	-/+ Better if takes the form of GDP/capita degrowth
<b>2. Consumption degrowth</b>	- Not all consumption	-- Voters do not like to hear that they for	? Depends on how implemented	- No limit on income and no

	equally bad for the environment, large rebound effect	sure have to reduce overall consumption	(instrumentation)	price regulation
<b>3. Work-time degrowth</b>	-/+ Rebound limited	- Little support in the current time frame (due to ageing population)	- No efficient reduction of environmental externalities	+ Associated reduction of income constraints rebound
<b>4. Radical degrowth</b>	- Radical changes do not guarantee less consumption of the dirtiest goods and services; unlikely for majority of people to adopt alternative lifestyle	- - Most voters and politicians follow the norm and will strongly resist radical changes perceived to have uncertain impacts	- Social and economic cost likely to be huge, also given many uncertain impacts, and social resistance against, radical change	- Lack of mechanisms to guarantee a limit to rebound
<b>5. Physical degrowth</b>	-/+ Physical measure possibly environmentally irrelevant	-/+ Depends on how implemented (instrumentation)	-/+ Depends on how implemented (instrumentation)	+ If the overall aim can be implemented (price regulation or ceiling emissions)
<b>6. GDP a-growth</b>	+ Removal of unconditional growth means increasing support for environmental regulation	-/+ Difficult to get political support but likely to be perceived as less radical than any of the degrowth types 1, 2 and 4	+ A large information failure (GDP information) removed	-/+ No direct connection, but more support for environmental regulation may lead to effective rebound control

Legend: ‘+’ denotes a positive and ‘-’ a negative judgement, all in relative terms on a scale (- -, -, -/+, +, ++)

In the last part of his article van den Bergh proposes his own set of proposals, which he views as an alternative to degrowth and a way to deal with the environmental, social and economic issues without GDP having to be taken into account:

1. International agreements to tackle transboundary environmental problems;
2. Reform of the labor markets to encourage more flexible, part-time work;
3. Regulation of commercial advertisement;
4. Pro-environmental education;
5. Ignoring GDP;
6. Public investment in environmental research and development.

Even though Kallis (2011) responded in detail to van den Bergh and argued extensively in favor of degrowth and against his idea of a-growth, the idea that degrowth was too vague and undefined persisted. Brownhill et al. (2012) found degrowth to be detached from social

struggle, prone to over-generalizing, and disconnected from historical understandings. Instead they suggest their own principles of “de-alienation”. Schwartzman (2012) finds the degrowth program to be problematic because according to him it fails to analyze the qualitative aspects of economic growth and emphasizes local economies without recognizing the urgency to address global anthropogenic change from a transnational political perspective. He continues by dismissing Georgescu-Roegen’s work on entropy, claiming that finite supply of fossil fuel resources to drive the economy can be replaced with sufficient creation of a high-efficiency collection of the solar flux to Earth. Streeck (2013) criticizes the ideas that generally call for slower lifestyles, zero or negative growth, and modest way of life, and considers them unrealistic and naïve. He sees growth as the only way of preventing battles over distribution of wealth, but acknowledges that time will come when growth will no longer be possible.

Sorman and Giampietro (2013) used a multi-scalar methodology of metabolic analysis to show that productivity growth has benefited from access to cheap energy and argued that further economic growth is unsustainable given the exhaustion of resources. They agree that degrowth is inevitable but point out three areas in which it needs to better address its actions:

1. Population - they think that proponents of degrowth often ignore population and focus only on affluence and technology when discussing environmental impacts;
2. Workload - they think that degrowth is wrong to assume that less resources, energy, capital, together with more people and problems can be resolved simply by reducing the workload of the workforce;
3. Planning the degrowth - they think that it is not possible to plan for the downscaling of the economy in the same way it is not possible to plan for the aging. This would happen no matter what, so the only thing we can do is to be prepared, try to understand what is going on, and develop flexible management strategies whilst investing the remaining high quality energy in wise alternative energy options to make the transition smoother (Sorman & Giampietro, 2013: 92).

A frequent criticism of degrowth is that it is applicable only to the overdeveloped economies of the Global North (Kallis et al., 2015: 5). Countries in the Global South still need economic growth to satisfy their basic needs. Degrowth supporters often claim that degrowth in the northern developed countries might open ecological space that would allow developing countries of the south to prosper, since poverty in those countries is often a result of exploitation of their resources by the northern countries. In some developing countries of the south, movements advocating alternative socio-economic systems have appeared.

Movements, such as “*Buen Vivir*” in Latin America, “*Ubuntu*” in South Africa, or Gandian “*Economy of Permanence*” in India, put forward claims for global environmental justice and call for a retreat of the growth imaginary in the northern countries that have promoted and forced it to the rest of the world.

### **2.3 APPLICATION OF SYSTEM DYNAMICS**

The field of system dynamics developed from the early work of Jay W. Forrester, which includes his work on industrial dynamics (Forrester, 1961), urban dynamics (Forrester, 1969), world dynamics (Forrester, 1971), and the national economic model (Forrester et al., 1976). It is commonly defined as a perspective and a set of conceptual tools that enable us to understand the structure and dynamics of complex systems, as well as a rigorous modeling method that enables us to build formal computer simulations of complex systems and use them to design more effective policies and organizations (Sterman, 2000: vii). It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems – literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality (Richardson, 2013: 1519).

The central idea behind system dynamics approach is that the behavior of a system arises from its structure. That structure consists of the feedback loops, stock and flows, and nonlinearities created by the interaction of the physical and institutional structure of the system with the decision-making processes of the agents acting within it (Sterman, 2000: 107). Feedback occurs when outputs of a system are “fed back” as inputs through a chain of cause and effect that forms a loop (Ford, 2009). The fact that input can instigate changes in the system, which eventually change the input itself, is what makes the reasoning about the feedback system difficult, and why systems need to be analyzed as a whole (Åström & Murray, 2008). System dynamics recognizes two types of feedback loops, positive or reinforcing and negative or balancing. Positive feedback loops tend to reinforce or amplify whatever is happening in the system, while negative counteract and oppose change. All systems, no matter how complex, consist of networks of positive and negative feedback, and all dynamics arise from the interaction of these loops with one another (Sterman, 2000: 13).

Previous examples of modeling economic growth and its potential replacements are scarce. Original work was done by Forrester (1971) and Meadows et al. (1972). Their partnership produced two books, ‘*World Dynamics*’ and ‘*The Limits to Growth*’. They worked independently of each other, but arrived at the same conclusion: The world’s economy tends

to stop its growth and collapse as the result of a combination of reduced resource availability, overpopulation, and pollution (Bardi, 2011: 10). Forrester (2007) admitted that he did not anticipate his book to have a significant public response, mostly because of the technical nature of the book, but it nevertheless generated huge interest in religious, economic, political, student, and other media.

The models underlying both Forrester's and Meadows' et al. work (named World2 and World3) are based on similar principles. The world is divided into a number of subsystems (agriculture, capital, population, pollution, natural resources) and the relations among the elements of the subsystems are described by a set of equations which are solved iteratively in order to determine the evolution in time of the system (Bardi, 2011: 38). Models were highly aggregated, meaning that they integrated most of the subsystems together in a small number of parameters. Because of that they didn't require large number of assumptions to run, and were also more of an approximation than an accurate prediction. This was one of the main points critics used to disprove the value of their work, however at the time this was the only possible choice and a good one as long as the limitations and purpose of the model were understood. Meadows et al. (2005) recognized the uncertainties and simplifications in the model, but have stressed they do not put faith in precise numerical path the model generates. They do still feel that the primary interconnections in their model are good interpretations of the important causal mechanisms in human society. Figures 2-1 and 2-2 show the most important of these mechanisms with central stocks and main feedback loops defined.

The discussion launched by Forrester and *Limits* brought computer aided modeling of the world dynamics to global stage. International meetings of global modelers started out with modeling teams seeking to criticize each other's work, but as Meadows (2007) points out, none of the later models contradicted their findings. They elaborated further on their findings or centered on different sets of equations but they still regularly contradicted policies of nations, enterprises, and individuals, instead of conclusions reached by the *Limits* team. As much as this was a good thing, that the subsequent modeling work didn't deviate from their findings, it also meant that not much progress in terms of modeling work was made. And even worse, very little was done to adjust global policies according to these results, despite all evidence corroborating the original analysis. Randers (2000) identified one area of the original world models which needed improvement, or where only slight improvement was made in the decades following their publication. The models were very explicit in their

treatment of financial and environmental sustainability, but were less clear on social sustainability, also referred to as distributional issues.

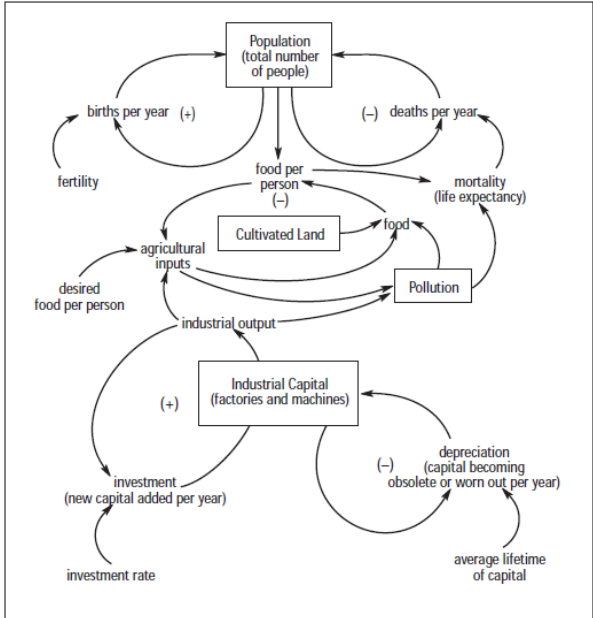


Figure 2-1 Feedback loops of population, capital, agriculture, and pollution  
 Source: Meadows et al. (2005: 144)

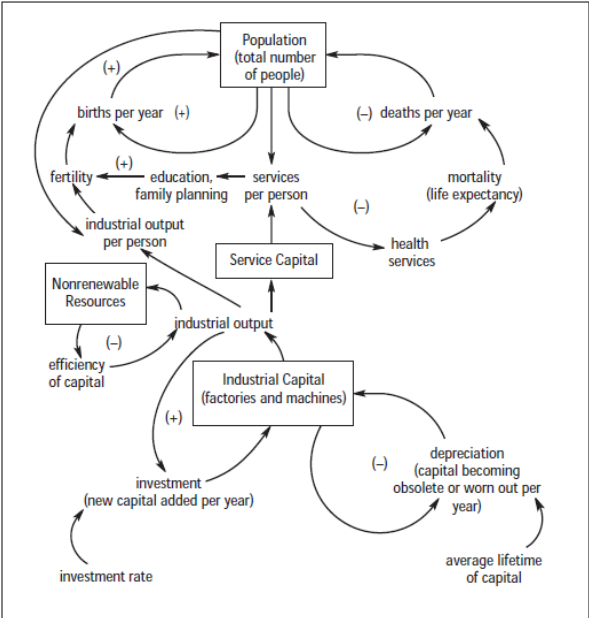


Figure 2-2 Feedback loops of population, capital, services, and resources  
 Source: Meadows et al. (2005: 145)

Slightly different approach to computer modeling of large socio-economic systems came from Victor and Rosenbluth (2007), and Victor (2008) in the form of their "LOWGROW" model (Figure 2-3). The model uses a system dynamics software package to simulate the response of the Canadian economy to several different policy interventions from the year 2000 till 2020. Although the model uses system dynamics software it is not a system dynamics model. It is primarily a macroeconomic model powered by a set of linear equations which determine GDP as aggregate demand, and Cobb-Douglas<sup>7</sup> production function that determines GDP as aggregate supply. Discrepancy between aggregate demand and supply is the source of dynamic behavior in the model which then causes change in other components of the model (employment, fiscal position, poverty). Still, this model is one of the few that uses computer aided simulation to test the effect of no growth, low growth, and other policies on a national economy of a developed country.

<sup>7</sup> Cobb-Douglas production function is a highly simplified representation of a complex and complicated national production system. Cobb-Douglas production functions have been criticized by ecological economists such as Georgescu-Roegen (1971) and Daly (1997) for inconsistency with the laws of thermodynamics.

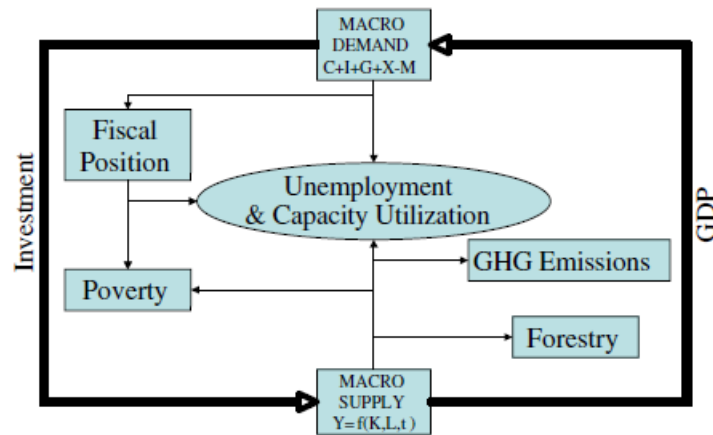


Figure 2-3 Simplified structure of the LOWGROW model

Source: Victor and Rosenbluth (2007: 493)

When it comes to application of system dynamics to the field of degrowth, surprisingly there is not much to talk about. Proponents of degrowth, which ironically drew many of their positions from ‘*Limits to Growth*’ report, have not used system dynamics to test their proposals. Likewise, system dynamicists stayed away from degrowth, possibly because they preferred the idea of sustainable development as one which followed closer in the footsteps of the ‘*Limits*’. A new convergence of two fields came about recently with the work of Videira et al. (2014). They assembled a list of emblematic degrowth proposals and associated questions which were discussed in the Barcelona degrowth conference in 2010. This list was used to develop a preliminary questionnaire, which was sent to prominent members of the degrowth community alongside an invitation to a participatory modeling workshop in Barcelona in 2011. Workshops produced three causal loop diagrams named ‘Social Sector’ (Figure 2-4), ‘Ecological Sector’ (Figure 2-5), and ‘Economic Sector’ Figure (2-6). The models were purely qualitative, meaning their purpose was to make explicit causal relationships and feedback loops between identified variables, but not to produce quantified stock and flow diagram and run computer simulations. Nevertheless, this work is one of very few examples where mental models of various experts in the field of degrowth were elicited and combined using system dynamics tools.

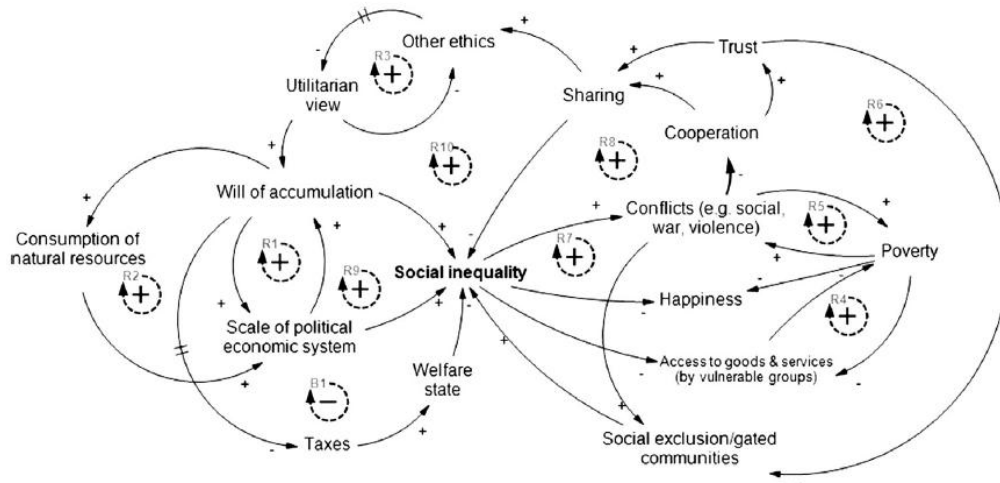


Figure 2-4 Feedback loops in the 'social sector' CLD

Source: Videira et al. (2014: 63)

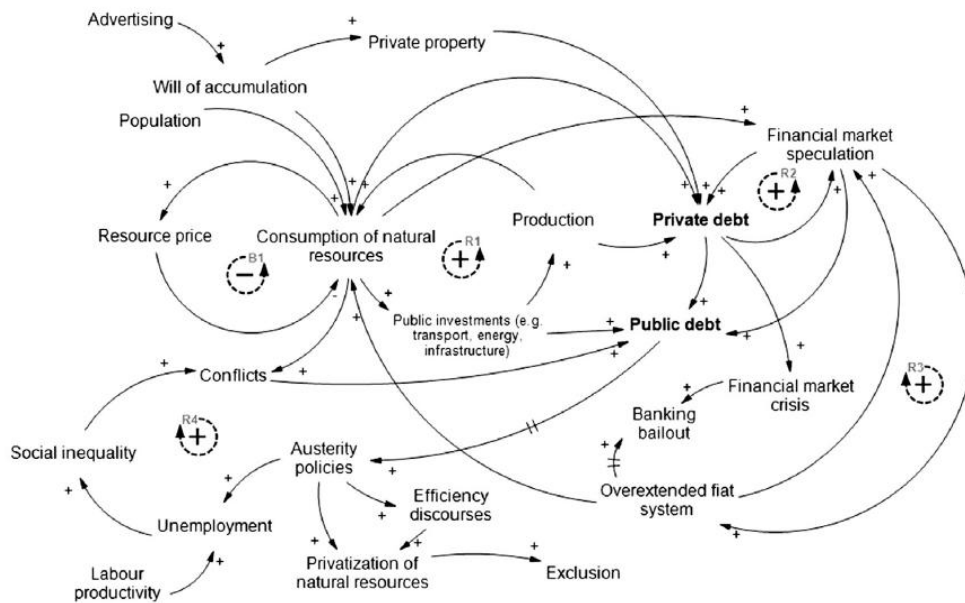


Figure 2-5 Feedback loops in the 'economic sector' CLD

Source: Videira et al. (2014: 66)

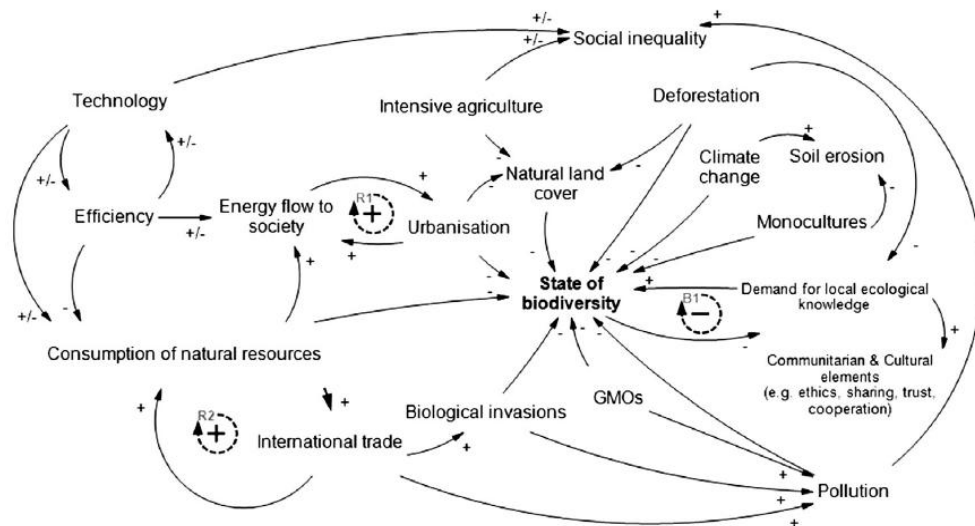


Figure 2-6 Feedback loops in the 'ecological sector' CLD

Source: Videira et al. (2014: 66)

### 3 RESEARCH METHODOLOGY

The research process used in this thesis consists of four steps shown in Figure 3-1. This chapter provides a detailed summary of each step and an explanation how each step answers a specific research question.

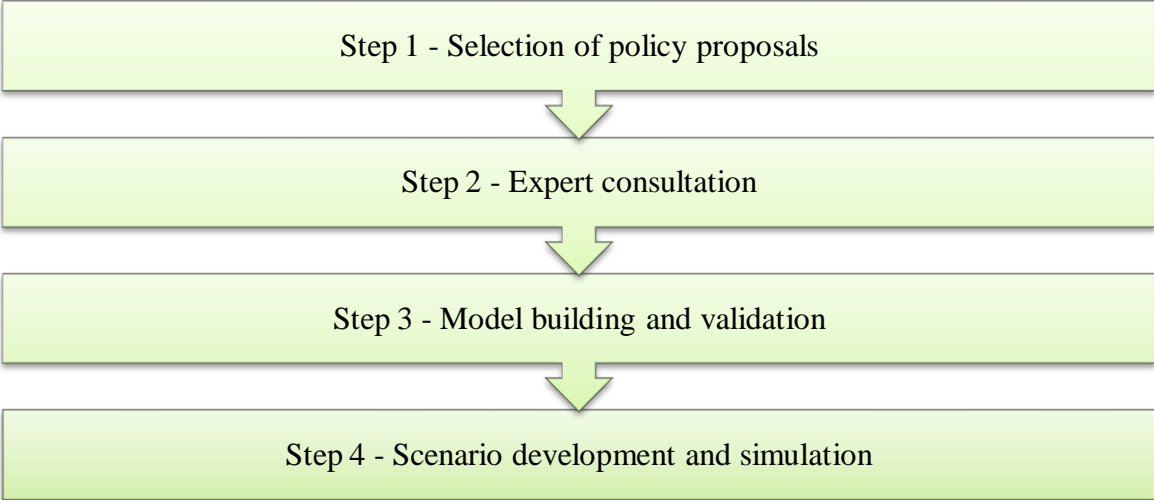


Figure 3-1 Research process

Step 1 of the research process answers the first research question about the most important, dynamically complex policy proposals, which need to be explored using a system dynamics perspective. The number of potential concepts and proposals is quite large because of the multi-disciplinary nature of degrowth. D’Alisa et al. (2015) provide an important overview of the most important concepts within the field and group them into four categories. Concepts contained in two of those categories (Action and Core) were screened according to the following criteria: dynamic nature, causal structure, controversy, and measurability.

Each concept was graded on how well it satisfied each of the four criteria and those with the best grades were selected for the system dynamics analysis. Grading system and the table with all of the grades is provided in the next chapter along with the selected degrowth proposals and results of analysis.

Step 2 of the research process is related to the second question about exploring and eliciting causal structure of the selected proposals, as it is seen by the experts in the degrowth community. This consultation process is conducted by the means of online questionnaires and

is a crucial component of this research because it collects information about the dynamic complexity of the selected proposals directly from the mental data bases of the experts. Mental data bases are seen as far more abundant, in terms of available information, than both written and numerical data bases (Figure 3-2), and Forrester (1992) considers them to be an integral part of all models which represent human systems. Ideally this kind of information would be gathered in direct interviews, but considering geographical displacement of the experts, this would be too time and resource consuming to justify its purpose.

The questionnaire, which can be found in Appendix F, had a question section for each of the selected concepts, and an additional section in which respondents could add a concept they personally feel would be important to model. Each section started with respondents being asked to imagine a situation in a developed country in which that concept was implemented as a policy or an action. They were then asked to answer three open type questions about:

1. Initial changes - respondents were asked to describe the initial changes of the policy/action and how it would change the system in the short term (e.g. 5 years from now). They were asked to identify indicators to track these changes and asked for their prediction on how these indicators would behave over time;
2. Long term changes - respondents were asked to describe the long term effects of the policy/action (e.g. 20 years from now). Again, they were asked to list the indicators and the prediction of their behavior;
3. Unintended consequences - respondents were asked to identify what could potentially go wrong with the policy/action and what could go better than expected.

The questionnaire was designed as a mental exercise asking respondents to go outside of their comfort zone and think in terms of dynamic complexity, which takes time and is not something most people can intuitively do. The purpose of it was to gather specific kind of knowledge about the dynamics of the degrowth concepts, which only exists in experts' minds. The amount of information provided in the answers is substantial and was extremely important for the modeling process. The results of this step are presented in chapter 4, with the summaries of the answers and CLD's developed based on those answers. Figure 3-3 contains a description of symbols used in the CLD's.

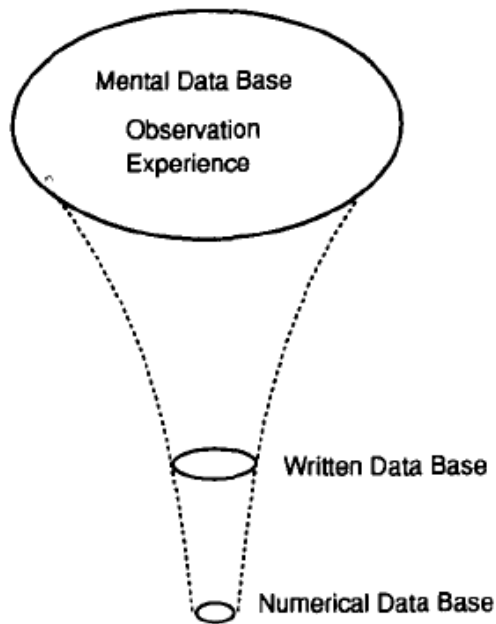


Figure 3-2 Mental data base and the decreasing content of written and numerical data bases  
Source: Forrester (1992: 15)

Step 3 of the research process is related to the third research question about building system dynamics models of these proposals. In this step valuable information gathered in the consultation process are combined with written and numerical data bases to build a stock and flow model which can test the proposals. This step also includes conducting validation tests to demonstrate robustness of the model. The results of this step are presented in chapter 5, while the Appendix A to E holds the full model documentation according to the “Preferred Model Reporting Requirement (PMRR)” guidelines proposed by Rahmandad and Sterman (2012). The software used to build the stock and flow diagram and simulate the results is iThink. The model is simulated between the year 2005 and 2050, with the time step of 0.1 years. The integration method used is the Euler’s method.

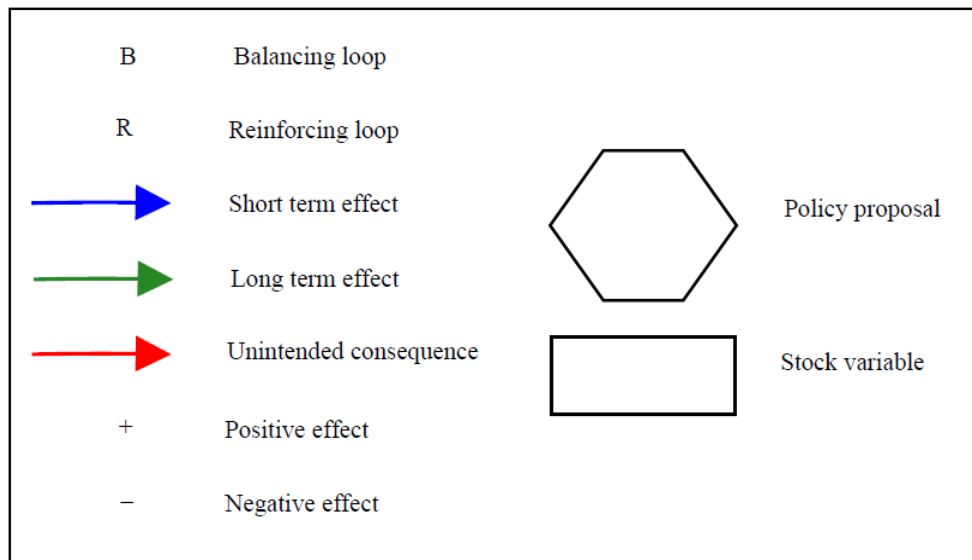


Figure 3-3 Description of symbols used in consultation CLD's

Step 4 of the research process is related to the last research question about developing simulation scenarios. In this step different degrowth scenarios are presented and simulated using the system dynamics model in order to test some of the foundational claims made by degrowth supporters. The results of this step are presented in chapter 5.

## **4 EXPLORING POLICY PROPOSALS USING SYSTEMS LANGUAGE**

### **4.1 SELECTION OF POLICY PROPOSALS**

In order to perform dynamic analysis it was necessary to select a set of proposals which satisfied the following criteria:

- Dynamic nature - the concept is dynamically complex, which means that its implementation would cause difficult to predict changes in the socio-economic and/or environmental systems;
- Causal structure - the concepts has an identifiable cause/effect structure, which can be made explicit by using causal loop diagrams;
- Controversy - the concept and its effects on socio-economic and/or environmental systems is an object of dispute between degrowth community and the mainstream economists, meaning that the two sides have opposing opinions on the desirability of implementing it;
- Measurability - the changes in the system caused by the implementation of the concept must be traceable by measuring small number of indicators over time.

The criteria was applied to concepts contained in D'Alisa et al. (2015), chapters two (the Core) and three (the Action). Each concept was graded on how well it fits each of the four criteria and those with the highest total grade were selected. The list with all of the concepts and their grades is presented in Table 4-1.

The following four concepts had the highest score and were selected for dynamic analysis:

1. Basic and maximum income;
2. Work sharing;
3. Job guarantee;
4. Dematerialization.

It would be possible to add other concepts to this list, however these four were selected because of time restrictions and because they best fit the selected criteria. Future research might add more concepts to this list even if they are less than a perfect fit.

Table 4-1 Degrowth concepts' grades

Concept	Dynamic nature	Causal structure	Controversy	Measurability	Total grade
Autonomy	+	+	+	+	+
Capitalism	++	+	++	++	++
Care	+	+	+	+	+
Commodification	++	+	++	+	++
Commons	+	+	+	+	+
Conviviality	+	+	+	+	+
Dematerialization	+++	++	+++	+++	+++
Dépense	+	+	+	+	+
Depolitization	+	+	+	+	+
Disaster	+	+	+	+	+
Entropy	+++	+	++	+	++
Emergy	++	++	++	+	++
Gross domestic product	+	++	+++	+++	++
Growth	+	++	+++	+++	++
Happiness	+	+	+	+	+
Imaginary	+	+	+	+	+
Jevons' paradox	+++	+	++	++	++
Neo-Malthusians	++	++	++	+	++
Peak-oil	+++	++	++	+	++
Simplicity	+	+	+	+	+
Social limits of growth	+++	+	+++	+	++
Back-to-the-lenders	+	+	+	+	+
Basic and maximum income	+++	+++	+++	+++	+++
Community currencies	++	+	++	+	+
Co-operatives	+++	++	++	++	++
Debt audit	+	+	++	+	+
Digital commons	+	+	+	+	+
Disobedience	+	+	+	+	+
Eco-communities	+	+	+	+	+
Indignados	+	+	+	+	+
Job guarantee	+++	+++	+++	+++	+++
Money	+	+	+	+	+
New economy	+	+	+	+	+
Newtopians	+	+	+	+	+
Post-normal science	+	+	+	+	+
Unions	+	+	++	+	+
Urban gardening	++	++	+	++	++
Work sharing	+++	+++	+++	+++	+++

Legend: '+' denotes a low fit to criteria; '++' denotes a partial fit to criteria; '+++ denotes a full fit to criteria

In order to better understand dynamic complexity of the selected concepts an online questionnaire was designed, as explained in the methodology chapter. The link to the questionnaire was sent via e-mail to 45 individuals who have collaborated on the D'Alisa et al. (2015) 'Vocabulary'. The link was accompanied by a short description of the research

project, explanation of why they were selected, and the importance of the answers they provide to the research. 13 people (28.9%) responded to the e-mail. Six of them (13.3%) apologized for not being able to answer it, mostly because of lack of time in their schedules. Seven of them (15.6%) have completed the questionnaire and the summaries of their answers are presented in the rest of this chapter.

## **4.2 BASIC AND MAXIMUM INCOME (BMI)**

### **4.2.1 BMI: Background**

Both basic and maximum incomes are methods by which wealth can be redistributed in the society. Although different, they are often proposed together since many see them as complimentary to each other. Alexander (2015) sees them as two policies which can help achieve two important egalitarian goals, redistributing wealth and ensuring everyone has “enough”, without relying on growth. They are also seen by some as the means of limiting the possibility of both deflation and inflation of currency or economy, or simply put as the means of establishing the boundaries of the economy.

Basic income, or income floor as it is sometimes called, has a number of different forms but the most straightforward one is that every person living permanently within a nation would receive a periodic payment from the government or any other public institution, which would be sufficient for an individual to live at a minimal, though dignified, standard of economic security, in addition to any other income received from elsewhere. Maximum income, also called income ceiling, is a policy for determining the upper limit to the size of any individual’s income. It is commonly suggested as a progressively increasing tax rate of income, culminating with a 100 per cent tax on all income over a predetermined level.

### **4.2.2 BMI: Consultation results**

The respondents seem to have similar perceptions of the effects basic and maximum income policy would have on society, economy and the environment. Initially there could be some social tensions and unrest, mostly on the part of the high earners, who would see their income reduced. However, in the long run situation should stabilize due to increase in life satisfaction and a more equal society. Environmental conditions should also be improved because new types of clean industries would develop and carbon footprint would decrease. Improvements are expected in the population health, child nutrition and the amount of care work.

Most of the changes would happen in the economy. Almost all respondents feel that basic and maximum income would improve the income equality, raise low end wages, and empower the working and unemployed population. Labor demand might decrease in the long term but labor participation also might decline so the unemployment should actually be lower. Economic indicators should decrease as a result of lower employment and working hours. High end wages would naturally decrease and low end workers would use their new power to drive the low end wages up.

What could go wrong after implementing this policy is massive capital flight to countries without basic and maximum income, which would increase unemployment. Also, the workers might get too powerful which would increase their wages too much and cause the employers to reduce their working force, again increasing unemployment. It is also possible that this policy fails because the government is unable to fund it in the long term or the rich find a way to beat the system.

Most important indicators to track these changes are working hours, income equality indicators, (un)employment, and economic growth indicators. The full summary of the answers can be seen in Table 4-2.

#### **4.2.3 BMI: CLD elicitation**

The answers were used to elicit a causal structure of basic and maximum income for each of the respondents. Final results are shown in Figure 4-1. In the following paragraphs each of the CLD's is explained. Those answers which did not provide enough information to be elicited into a CLD were left out.

Respondent 1: There are three initial changes caused by the implementation of basic and maximum income policy. The quit rate increases because some people will no longer have an incentive to work since basic income will provide them with resources needed to satisfy their basic needs. Low end wages would also go up which would alongside basic income help redistribute wealth and improve income equality. Increase in wages would decrease the working hours. This would decrease the GDP and the carbon footprint but not too much since the productivity would also increase. In the long term two things would happen. First the participation rate would decrease reducing the labor supply, and second quit rate would continue reducing the labor supply and GDP even further. An unintended consequence could be increased capital flight, which would reduce the number of available jobs and labor demand. There is one balancing loop which controls the number of employed people. If labor

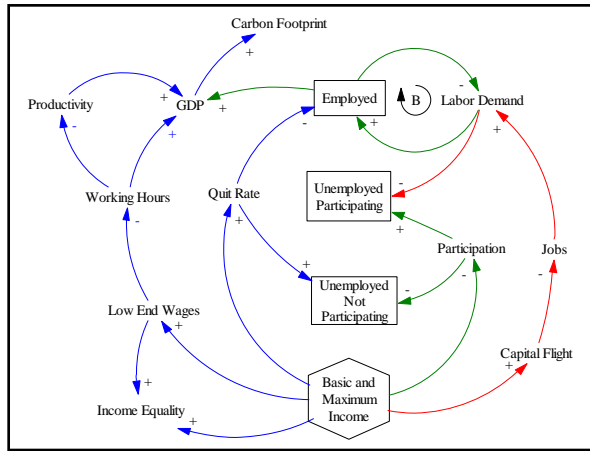
demand increases the number of employed people also increases until it reaches labor demand.

Respondent 2: There are three initial changes caused by the implementation of basic and maximum income policy. The power of workers would increase, power of executives would decrease, and power of population not participating in the labor force would increase. This would increase the low end wages and decrease high end wages which would improve income equality. In addition it would increase tax take which could be used to fund the policy. Long term effect would be reduction of social stress and tension as a result of better income distribution and empowerment of the non-participating population. Possible unintended consequences would be emigration of the high end earners and uncontrollable increase in low end wages, which is represented by a reinforcing feedback loop. If the power of the workers increases their wages increase accordingly. If their wages increase their power increases even further.

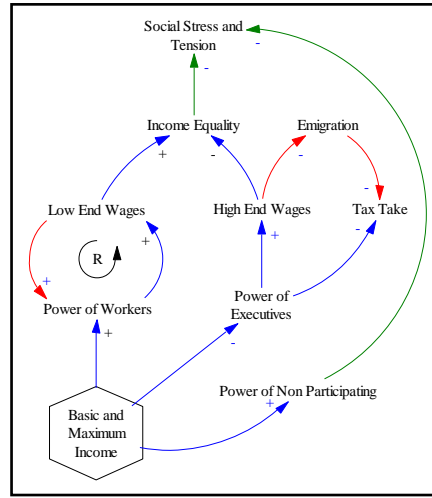
Respondent 3: There are two initial changes caused by the implementation of basic and maximum income policy. Minimum wage would increase causing increase in low end hourly wages, and maximum wage would decrease causing decrease in high end hourly wages. Low end income would increase, which would reduce their working hours, increase the demand for low end labor, and further increase their wages, closing the reinforcing feedback loop. High end income would decrease which primarily because of the lower allowed working hours. Even though high end earners would like to work more it will not be possible because of the maximum income restrictions, so their working hours will decrease, increasing the demand for high end labor and setting their wages to the maximum allowed limit, which also closes a reinforcing loop. Long term effects would be improved income equality and stabilization of the incomes, which is depicted by the two balancing feedback loops. One unintended consequence could be that the high earners find a way to increase their income through bonuses which would activate another balancing loop which would make the policy ineffective.

Table 4-2 Summary of questionnaire answers for basic and maximum income

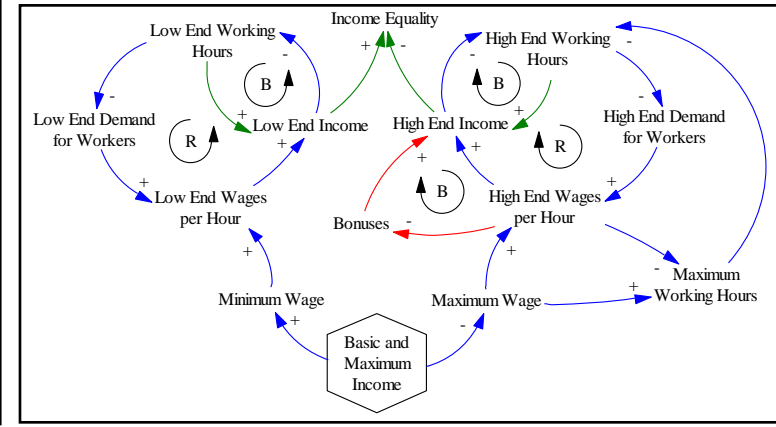
Resp.	Initial changes	Long-term changes	Unintended consequences	Feedback loops	Indicators
1	Increase in: low end wages, productivity, quit rate, income equality; Decrease in: working hours, carbon footprint	Decrease in: labor supply, labor demand, economic growth;	Increase in: capital flight, possibly unemployment	Balancing Labor Demand loop	Wages; productivity; quit rate; hours of work; income distribution; carbon footprint
2	Increase in: power of unwaged, carers and women, power of workers, income equality, tax take; Decrease in: power of executives	Lowering of social tension and stress	Higher than anticipated increase in workers' wages; capital flight; establishment of the size of the economy	Reinforcing Power of Workers loop	Job take up; staff cost; inequality measures
3	Decrease in Low End and High End Working Hours	Increase in: High End Labor Demand, Low End Wages, Income Equality	Better paid beat the system with bonuses; work-life balance; reduced levels of stress and competitiveness	Two balancing Income/Working Hours loops; Two reinforcing Labor Demand loops; balancing Bonuses loop	Total working hours; working hours per person; income inequality
4	Transition from dirty industries to local socio-economic economies	New types of social enterprises	Erosion of social security; lack of motivation to initiate changes and contribute positively to the society	None	Employment
5	Transition from welfare, unemployment, and other forms of income to basic income; anger, resentment, violence of High End Employed	Increase in: valuation of non workers, self-esteem, care work, emigration; Decrease in Working Hours	Violent reaction by high earners; brain drain; improvement in life quality, mental and physical health, relationships; less stress; more care time	None	Employment; unemployment; working hours
6	Increase in opposition; Collapse of economic growth indicators	Decrease in Life Satisfaction; new perspectives	Psychology of the people may go wrong; emergence of new socialist vision	Balancing Life Satisfaction Loop	GDP (growth indicators)
7	Decrease in Poverty and Child Nutrition	Increase in Free Time; Decrease in Unemployment	Decrease in Salaries and other social benefits	None	Poverty; child nutrition; unemployment; free time; salaries



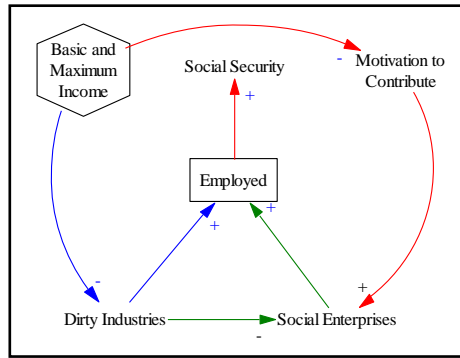
RQ: 1-1



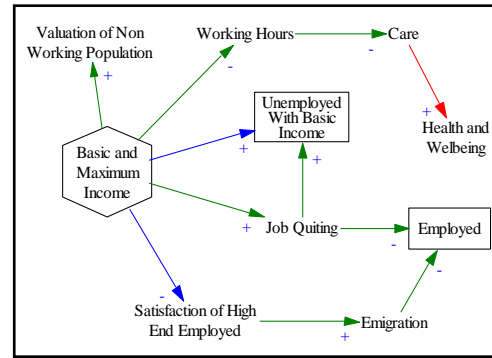
RQ: 2-1



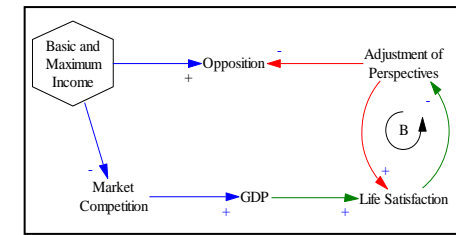
RQ: 3-1



RQ: 4-1



RQ: 5-1



RQ: 6-1

Figure 4-1 Basic and maximum income CLD's derived from the questionnaire answers

Respondent 4: The initial change caused by the implementation of the basic and maximum income policy is reduction of the dirty industries. This would also reduce the number of people employed in those industries so basic income would serve as a safety net for those people. In the long term dirty industries would be replaced with social enterprises. The most important unintended consequence could be that the introduction of the basic reduces the motivation to contribute among the working age population which undermines the social enterprises and the whole policy.

Respondent 5: The initial changes caused by the implementation are increase in the number of unemployed people with income and decrease in satisfaction of high end earners which will in the long term increase their emigration. Other long term effects are reduced working hours and increased job quitting, valuation of non working population, and care. Unintended consequence could be better health and overall human wellbeing as a result of increasing amount of time spent on care.

Respondent 6: There are two initial changes caused by the implementation of basic and maximum income policy. First is increased opposition to the policy, and second reduced market competition which leads to lower GDP. In the long run as a result of declining GDP life satisfaction will be reduced, which will inspire creation of new perspectives. Unintended consequences of these new perspectives could be decreased opposition and increased life satisfaction, which also closes a balancing feedback loop. As life satisfaction goes down new perspectives are born, some of which can cause an increase in life satisfaction.

## **4.3 WORK SHARING (WS)**

### **4.3.1 WS: Background**

Work sharing, also called job sharing, is a policy which proposes reduction of working hours so that a job previously done by a single individual working full-time, would be done by more than one individual (usually two) working part-time and sharing the income. Reductions in working hours might be unavoidable in a degrowth economy because of declining levels of production and work sharing might be a way of avoiding unemployment for some of the employees (Schor, 2015).

### **4.3.2 WS: Consultation results**

In many ways the effects of work sharing are seen as same or similar to those of basic and maximum income. All respondents agree that the amount of time worked will decline causing

at the same time an increase in available free time. Other common effects are increase in employment and improvements in environmental conditions.

What could go wrong with the policy is that the demand for labor decreases causing unemployment. Also some aspect of the policy might not work as expected which could make only certain jobs shared and not all of them. For example household or high end jobs might not be shared if the policy is not implemented properly. In addition giving more people a source of income could increase consumption and actually increase carbon emissions. On the other hand work sharing policy might have some unexpected benefits such as increase in solidarity in the work place.

Most important indicators to track these changes are working hours, free time, (un)employment, wages, and income equality indicators. The full summary of the answers can be seen in Table 4-3.

#### **4.3.3 WS: CLD elicitation**

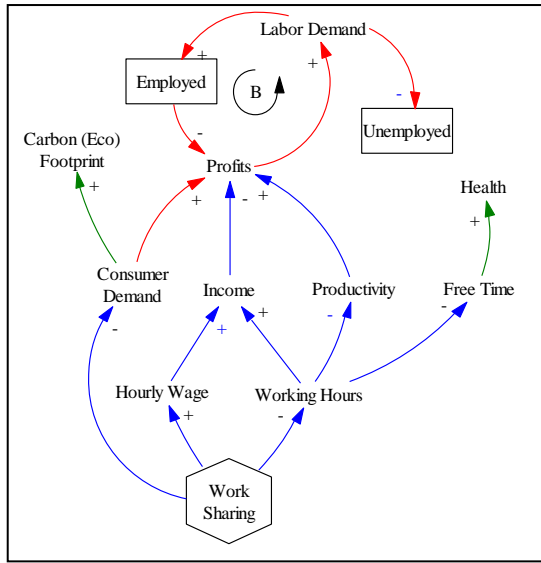
The answers were used to elicit a causal structure of work sharing for each of the respondents. Final results are shown in Figure 4-2. In the following paragraphs each of the CLD's is explained. Those answers which did not provide enough information to be elicited into a CLD were left out.

Respondent 1: There are three initial changes caused by the implementation of the work sharing policy. Consumer demand will decrease, or at least stop growing, working hours will also decrease and hourly wage will increase. Decline in working hours will increase the amount of free time available and reduce the income. Reduction of income because of the declining working hours will be compensated at least partially by the increase in hourly wages. In the long term decreased consumer demand should lead to lower carbon and eco footprint, and more free time should have beneficial effect on human health. Unintended consequence could be that decreased consumer demand decreases profits for the employers, which could lead to decreased labor demand and increased unemployment. This is presented with a balancing feedback loop. If the profits go down labor demand will also decrease and the employers will reduce the number of employed people to keep their profits.

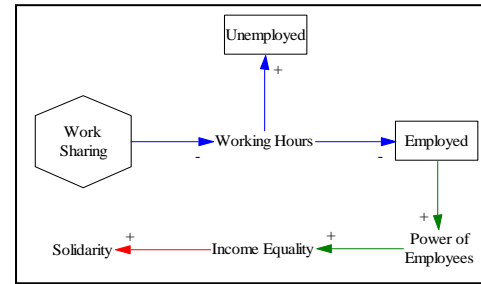
Respondent 2: The initial change caused by the implementation of the work sharing policy will be reduction of working hours, which will increase the number of employed people and decrease the number of unemployed people. In the long term the power of employees will

Table 4-3 Summary of questionnaire answers for work sharing

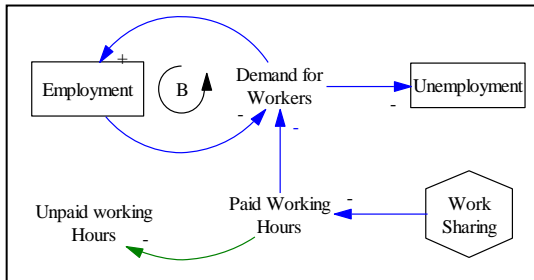
<b>Resp.</b>	<b>Initial changes</b>	<b>Long-term changes</b>	<b>Unintended consequences</b>	<b>Feedback loops</b>	<b>Indicators</b>
<b>1</b>	Increase in: wages, productivity, free time, population health; Decrease in carbon and eco footprints; Consumer demand flattens	Same as initial changes	Profit squeeze, reduced labor demand, increase in unemployment	Balancing labor demand loop	Wages; productivity; consumer demand; free time; carbon and eco footprints; profits; unemployment
<b>2</b>	Increase in employment; Decrease in work time	Increase in the bargaining power of the workers and working conditions; Decrease in inequality	Increase in the sense of solidarity in the work place	None	Employment: work time, wages, income inequality
<b>3</b>	Increase in employment; Decrease in work hours	Increase in sharing of all forms of work, gender balance in paid and unpaid work	Unpaid work not shared; high end work not shared	Balancing worker demand loop	Employment; work hours
<b>4</b>	Similar to basic and maximum income and job gurantee	Similar to basic and maximum income and job gurantee	Similar to basic and maximum income and job gurantee	Similar to basic and maximum income and job gurantee	Similar to basic and maximum income and job gurantee
<b>5</b>	Increase in alcohol and drug consumption, shopping, eating, etc.; Decrease in working hours	Adjustment to new working regime	It might take too long to adjust	Balancing expected output loop	Working hours
<b>6</b>	Confusion and hesitation from the beurocratic level	Depends on how the mass will understand	None	None	None
<b>7</b>	Increase in free time; Decrease in unemployment	Decrease in consumption and carbon emissions	Increase in cost of labor, unemployment, consumption/carbon emissions	None	Free time; unemployment; consumption; carbon emissions; cost of labor



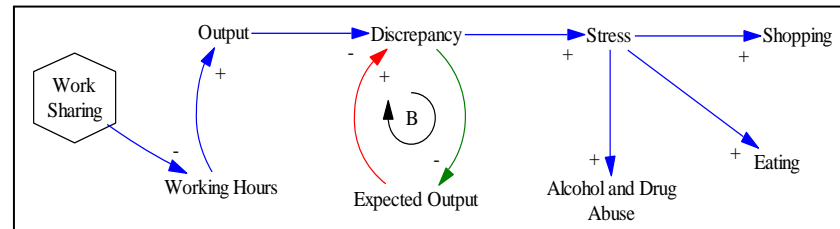
RQ: 1-2



RQ: 2-2



RQ: 3-2



RQ: 5-2

Figure 4-2 Work sharing CLD's derived from the questionnaire answers

increase which will help redistribute wealth. Unintended consequence could be the increase in solidarity in the work place.

Respondent 3: The initial change caused by the implementation of the work sharing policy will be reduction of paid working hours which will increase demand for workers. This demand will be satisfied by hiring unemployed people. The process of satisfying demand for workers is depicted with a balancing feedback loop. In the long term reduction in paid working hours will increase the unpaid working hours.

Respondent 5: The initial change caused by the implementation of the work sharing policy will be reduction of working hours, which will reduce their output. Their expected output will remain the same for the time being which means that the workers will create a discrepancy between actual and expected demand. This will be the cause of stress and other forms of undesired behavior such as excessive shopping, eating, and alcohol and drug abuse. In the long term businesses should adapt and expected output should decrease, which is depicted with the balancing feedback loop. However, an unintended consequence could be that this process takes too much time and undermines the policy.

#### **4.4 JOB GUARANTEE (JG)**

##### **4.4.1 JG: Background**

Job guarantee is an economic policy proposal aimed at providing a sustainable solution to both inflation and unemployment. It stems from the recognition that the chronic unemployment in capitalist societies is involuntary and it calls on governments to provide a job to any qualifying person seeking employment (Unti, 2015). The most general approach, and the one used in this research, is known as universal guarantee, with the government providing the funds necessary to offer a uniform wage and benefit package to anyone willing to work.

##### **4.4.2 JG: Consultation results**

In job guarantee policy, just like work sharing, there are again many similarities to the basic and maximum income. One of the first things that should happen is the increase in workers power because the government would provide a safety net if they lose or quit their job. This would drive their wages and working conditions up as private employers would need to at least be on par with public jobs working conditions. As it can be expected the unemployment would effectively be eliminated with the introduction of this policy. It is worth noting that the

respondents saw this policy little less positive than the previous two, even noting that this might be just a temporary measure which is not needed in the long run.

What could go wrong is that the workers get too powerful which drives their wages too high and starts reducing private employers' profit. This could cause massive capital outflows and reduction in private employment. This could eventually lead to social unrest and ultimately doom the policy; however it is also possible to see some unexpected benefits such as reduced crime rates and better health.

Most important indicators to track these changes are employment, wages, income equality indicators, and satisfaction indicators. The full summary of the answers can be seen in Table 4-4.

#### **4.4.3 JG: CLD elicitation**

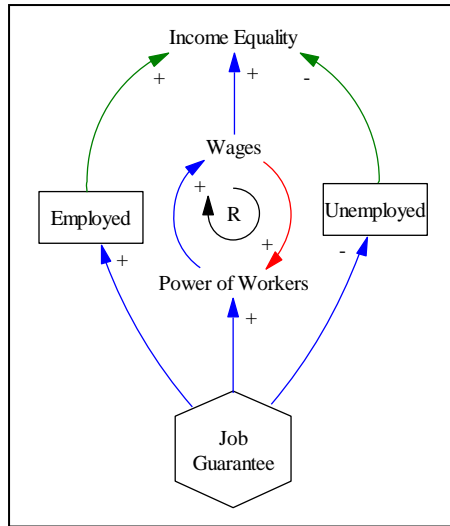
The answers were used to elicit a causal structure of job guarantee for each of the respondents. Final results are shown in Figure 4-3. In the following paragraphs each of the CLD's is explained. Those answers which did not provide enough information to be elicited into a CLD were left out.

Respondent 2: There are two initial changes caused by the implementation of the job guarantee policy. The creation of new jobs will cause a decline in unemployment and increase the power of the workers. Higher wages should have a beneficial effect on income equality. In the long term as the number of unemployed people reduces even further and number of employed increases, along with rising wages, income distribution should be much improved. An unintended consequence could be that the workers gain too much power, which causes their wages to grow too much, which could undermine the policy.

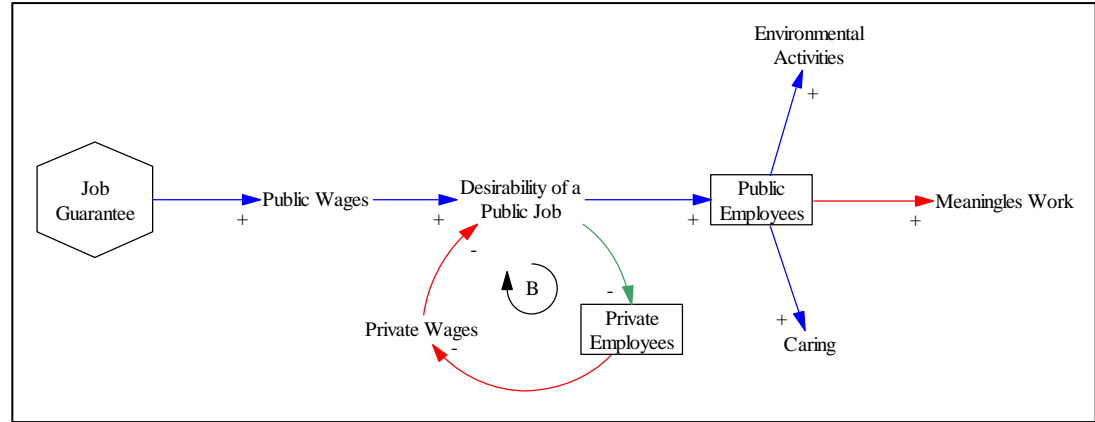
Respondent 3: The initial change caused by the introduction of job guarantee policy will be the increase in public wages. As the number of public employees increases so do the amount of environmental and care work. In the long term private employees will start migrating towards public jobs because of the better working conditions. There are two possible unintended consequences. First is that alongside environmental and care work there could be an increase in the meaningless work, especially if too many people enter the job guarantee program. Second is that private employers might increase the private wages to compete with the public jobs which would make public jobs less desirable. This process is presented with the balancing feedback loop.

Table 4-4 Summary of questionnaire answers for job guarantee

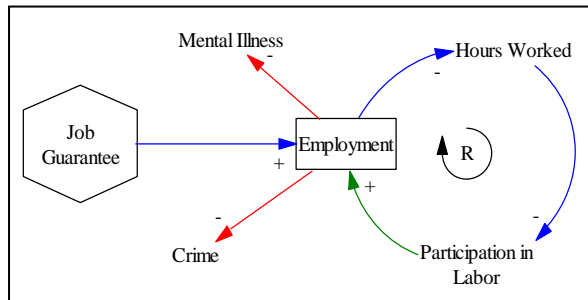
<b>Resp.</b>	<b>Initial changes</b>	<b>Long-term changes</b>	<b>Unintended consequences</b>	<b>Feedback loops</b>	<b>Indicators</b>
<b>1</b>	Increase in: wages, productivity, quit rate	Same as intial changes	Profit squeeze and capital outflows	Same as for basic and maximum income	Same as for basic and maximum income
<b>2</b>	Increase in living standards and bargaining power of the workers; Lower inequality	Decrease in unemployment and wage disparities	Too much power of the workers; low respect for job guarantee jobs	Reinforcing power of the workers loop	Income inequality; unemployment; wages
<b>3</b>	Increas in: wages, wealth for the public sector, caring and environmental activities	Shift employment from the private to the public sector	Increase in meaningless work; Decrease in private wages	Balancing desirability of a public job loop	Wages; employment
<b>4</b>	Similar to basic and maximum income	Not needed in the long run	Similar to basic and maximum income	Same as for basic and maximum income	Same as for basic and maximum income
<b>5</b>	Increase in employment, happiness, self worth; Decrease in working hours	Higher participation	Reduced crime, mental illness, etc.	Reinforcing participation loop	Employment; working hours; happiness; participation; crime
<b>6</b>	Stagnation, confusion, anarchy; emergence of new ideas	Different understanding about work; increase in satisfaction	Agitation and mass protest; reversal to old ways	Balancing adjustment of perceptions loop; reinforcing public uderstanding loop	Satisfaction
<b>7</b>	Decrease in unemployment	Increase in number of NGO's; Decrease in poverty	Increase in cost of labor; Decrease in employment in private sector	None	Employment; wages



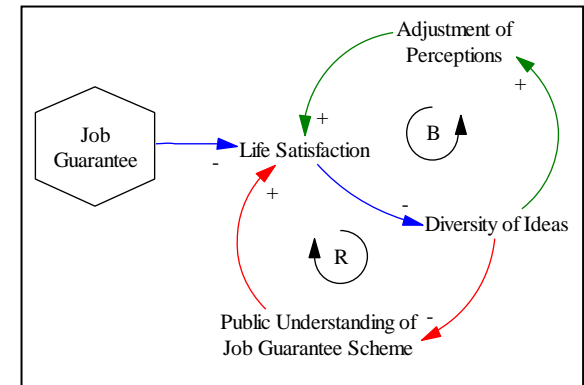
RQ: 2-3



RQ: 3-3



RQ: 5-3



RQ: 6-3

Figure 4-3 Job guarantee CLD's derived from the questionnaire answers

Respondent 5: The initial change caused by the introduction of job guarantee policy will be the increased in the number of employed people. This will bring down the working hours and increase participation. In the long run increasing participation will cause even higher employment, closing a reinforcing feedback loop. Unintended consequences of job guarantee could be reduction in mental illness and crime.

Respondent 6: The initial change caused by the implementation of job guarantee policy will be a decrease in life satisfaction. This will initiate creation of new ideas of how society should work. In the long run new ideas should cause change in perceptions, which should increase life satisfaction, closing the balancing feedback loop. An unintended consequence of having variety of new ideas is that public understanding of the policy decreases, which reduces the life satisfaction even more, closing a reinforcing feedback loop.

## **4.5 DEMATERIALIZATION (DM)**

### **4.5.1 DM: Background**

Dematerialization refers to the absolute or relative reduction in the quantity of materials required to serve economic functions in society (Rosenberg, 1982: 72), and it indicates how much our social metabolism has to decrease in order to tackle environmental problems at their source (Lorek, 2015). Absolute dematerialization means absolute reductions in material and carbon use, while relative dematerialization means that material and carbon usage grow slower than the GDP. Supporters of degrowth, as well as majority of environmental scientists, focus mostly on the absolute dematerialization and consider relative dematerialization to be insufficient.

### **4.5.2 DM: Consultation results**

In the dematerialization proposal there seems to be a high level of consensus among the experts. Common belief is that it would decrease material and energy throughput. This would have beneficial effect for the environment and human wellbeing in the long term. Economic activity, especially in the dirty industries, would be reduced.

What could go wrong is that prices of materials and energy increase as well as prices of non-material services. Shutting down dirty extractive industries could also lead to high unemployment.

Most important indicators to track these changes are GDP, material throughput indicators, carbon and eco footprints, and work time. The full summary of the answers can be seen in Table 4-5.

#### **4.5.3 DM: CLD elicitation**

The answers were used to elicit a causal structure of dematerialization for each of the respondents. Final results are shown in Figure 4-4. In the following paragraphs each of the CLD's is explained. Those answers which did not provide enough information to be elicited into a CLD were left out.

Respondent 1: The initial changes caused by the implementation of dematerialization policies will be increases in both natural resources and labor productivity. In the long term increase in natural resources productivity will cause reduction carbon and eco footprint. An unintended consequence could be higher unemployment in extractive industries.

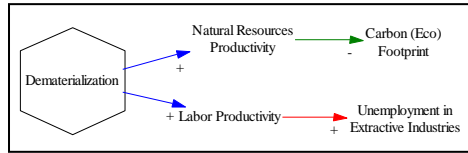
Respondent 2: The initial changes caused by the implementation of dematerialization policies will be decrease in working hours and economy throughput. Decrease in working hours will also lower the material consumption. In the long term these changes will reduce the stress on the environment.

Respondent 3: The initial change caused by the implementation of dematerialization policies will be a decrease in material consumption. This would reduce the price of materials and energy consumption, and increase non-tangible activities. Reduced price of energy would reduce energy consumption, which would drive price of materials even further down. Causal link between price of materials and material consumption closes two balancing feedback loops and prevents the consumption from declining too much. There are several things that will happen in the long term. Material and energy production should decline, collective re-use of resources should increase, travel speed should decline, paid work should decline, and obsolescence time should increase. There are three possible unintended consequences. Reduced material production could increase the price of materials, closing a reinforcing feedback loop. Similarly reduced energy production could increase the price of energy, again closing a reinforcing loop. Another effect could be an increase in hoarding.

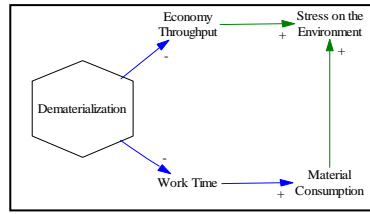
Respondent 4: The initial change caused by the implementation of dematerialization policies will be a decrease in material throughput. This will reduce the paid working time and increase free and household time. In the long term environmental and urban conditions should improve, which will together with better working hours increase life satisfaction.

Table 4-5 Summary of questionnaire answers for dematerialization

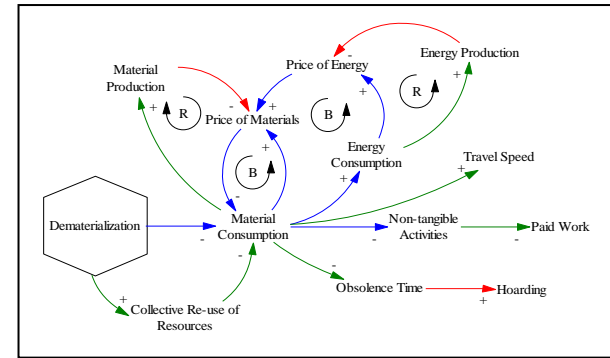
<b>Resp.</b>	<b>Initial changes</b>	<b>Long-term changes</b>	<b>Unintended consequences</b>	<b>Feedback loops</b>	<b>Indicators</b>
<b>1</b>	Increase in: natural resources productivity, productivity of labor; Decrease in eco and carbon footprints	Lower GHG emissions and eco footprints	Increase in unemployment in extractive industries	None	Eco and carbon footprint; GHG emissions; labor productivity
<b>2</b>	Decrease in economic throughput and work time	Decrease in environmental stress	None	None	GDP; work time
<b>3</b>	Decrease in material and energy consumption	Decrease in: GDP, obsolescence, travel, globalised consumption and production; Increase in: collective re-use of resources, local provisioning	Increase in: hoarding, price of energy and materials; New types of conviviality	Two balancing consumption loops for material and energy; Two reinforcing production loops for materials and energy	Material and energy consumption; GDP; price of materials and energy
<b>4</b>	Decrease in material throughput, work time and increase of household/reproductive time	Increase in: free time, community, voluntary, practical work, life satisfaction, environmental and urban conditions	Higher prices for non material exchanges	None	Material throughput; work time; prices
<b>5</b>	Decrease in throughput in industrial production, farming, etc., and economic earnings	Increase in economic earnings, satisfaction and meaning	People will take more care of their belongings	Balancing economy adjustment loop	Material throughput; economic earnings
<b>6</b>	Increase in human health; Decrease in number of accidents, mental cases	Improvements in human wellbeing and environment	Increase in opposition; Decrease in variety of production	None	Health indicators; number of accidents
<b>7</b>	Decrease in domestic consumption of materials and material imports	Decrease in prices of key commodities and new extraction projects	None	None	Material consumption; imports; prices



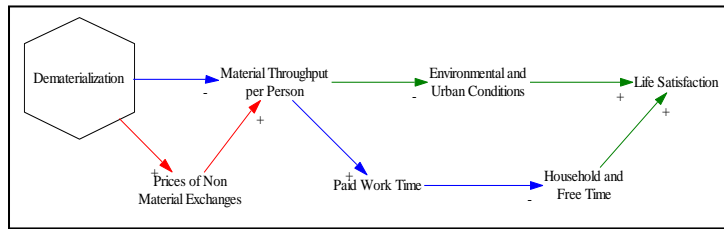
RQ: 1-4



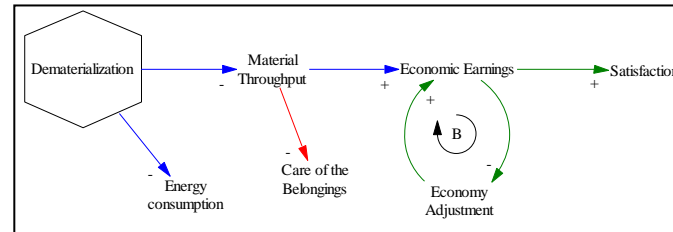
RQ: 2-4



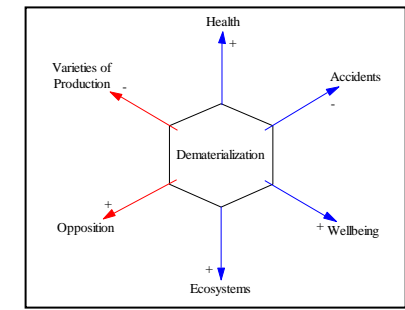
RQ: 3-4



RQ: 4-4



RQ: 5-4



RQ: 6-4

Figure 4-4 Dematerialization CLD's derived from questionnaire answers

An unintended consequence could be reduction in prices of materials which could increase material consumption again.

Respondent 5: The initial changes caused by the implementation of dematerialization policies will be a reduction in energy consumption and a decrease in material consumption, which will cause losses in economic earnings. In the long term economy will adjust which will bring the earnings back up. This process is presented with a balancing feedback loop. With higher economic earnings life satisfaction should also increase.

Respondent 6: The initial changes caused by the implementation of dematerialization policies will be improved human health and wellbeing, better ecosystems, and reduced number of accidents. Unintended consequence could be increased opposition and reduced varieties of production.

**4.6 OTHER POLICY PATHWAYS**

In the last section of the questionnaire respondents were asked to suggest another policy proposal which they felt was important to study dynamically. Four of them (respondents 2, 3, 4, and 6) have submitted their own suggestion with various levels of detail attached to them. Table 4-6 holds a summary of their answers. These proposals could provide a good starting point for the future research but more information about the experts’ perception of them needs to be collected first. In particular social/cooperative enterprises seems to be a promising proposal.

Table 4-6 Summary of questionnaire answers for additional policy proposals

<b>Resp.</b>	<b>Policy name</b>	<b>Initial Changes</b>	<b>Long-term changes</b>	<b>Unintended consequences</b>
2	Cooperative enterprises	Increase in dealing with deficiencies of the labor market	Increase in importance of cooperative forms of enterprise	Privatization through sale or investing ownership solely through the initial group of employees
3	Care first	Resources allocated to maintaining people and the environment	Distribution toward quality instead of quantity	Survival of neoliberal mindset or its demise
4	Social enterprises	Decrease in large-scale corporate production	Shift towards ecological production and distribution	None stated
6	User to pay principle	None stated	None stated	None stated

## **5 MODELING THE DYNAMICS OF DEGROWTH**

### **5.1 STOCK AND FLOW MODEL**

#### **5.1.1 Population sector**

Population sector is the central part of this model. Its basic structure is well known within system dynamics and is presented in Figure 5-1. This sector contains four stocks, each representing a different age group. As the people are born they are added to 0 to 14 age group. Here they stay 15 years and if they do not die they move to 15 to 44 age group. This age group is the one containing women capable of reproducing, and along with the 45 to 64 age group, represents the working age population. Eventually after spending 30 years in 15 to 44 and 20 years in 45 to 64 age groups, and assuming they do not die, people retire and move into 65 plus age group. Apart from births, maturation and deaths the stocks of people can change because of migration. Net migration rates are determined as percentages of the total migration. These percentages were estimated based on the Eurostat data in Figure 5-2.

Eurostat migration data was also used to estimate the normal migration rate which is used to calculate total migration. The high end emigration part of the structure was added to the standard ageing chain to incorporate consultation results. Several respondents felt that some of the degrowth policies could lead to increased emigration of the high end earners and this structure represents that view. The full report on all variables and parameters in this sector is available in Appendix A. This sector provides input to jobs and employment sectors and receives input from employment and income sectors.

Results of basic run for the population sector are presented in Figures 5-3 and 5-4. Figure 5-3 shows development of total population which increases between year 2005 and 2020, peaks in 2020, and declines until the final year of simulation in 2050. Figure 5-4 shows development for each of the four age groups. Groups 0 to 14, 15 to 44, and 45 to 64 all decline between years 2005 and 2050. At the same time the oldest age group 65 plus is increasing, which means that the overall population is getting older.

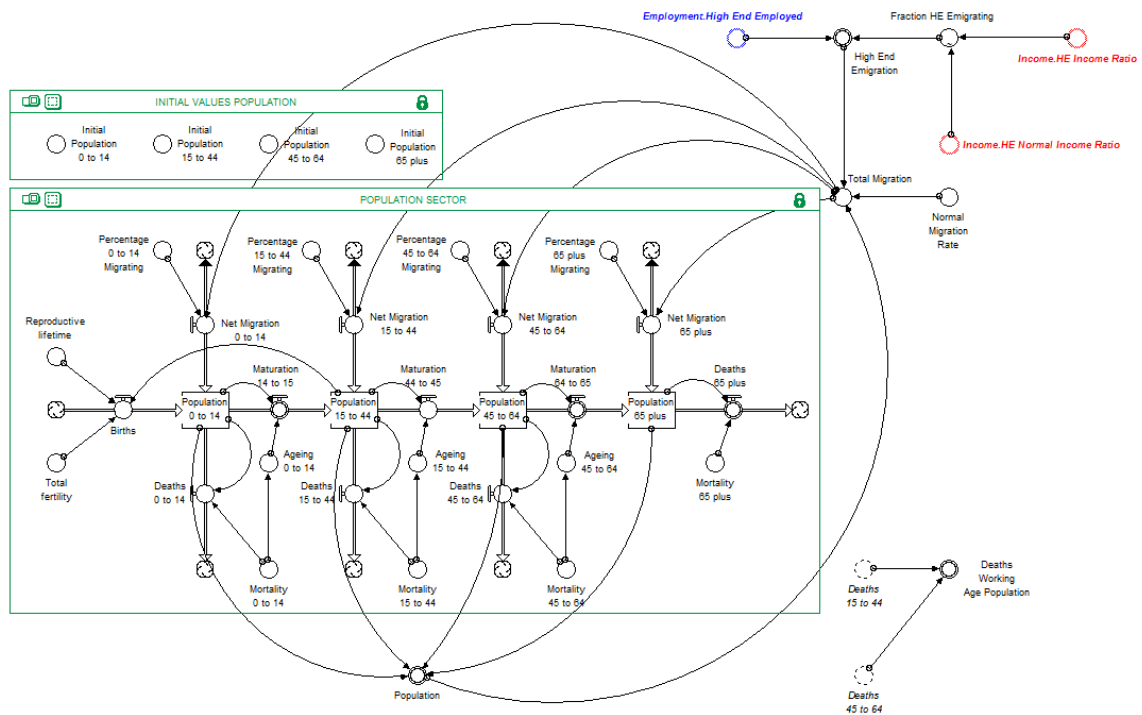
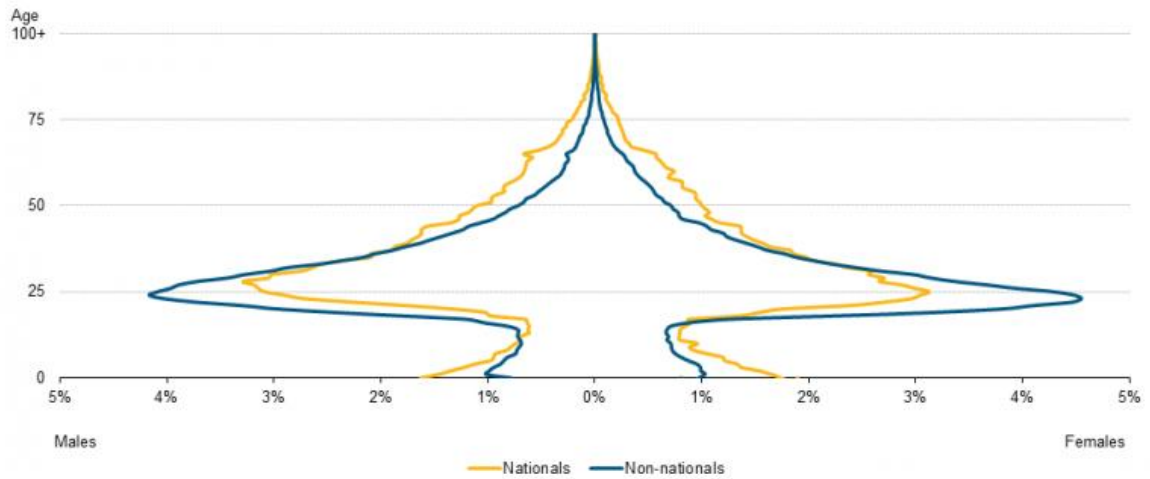


Figure 5-1 Stock and flow diagram of the population sector



Source: Eurostat (online data code: migr\_imm2ctz)

Figure 5-2 Age structure of national and non-national EU immigrants  
Source: Eurostat

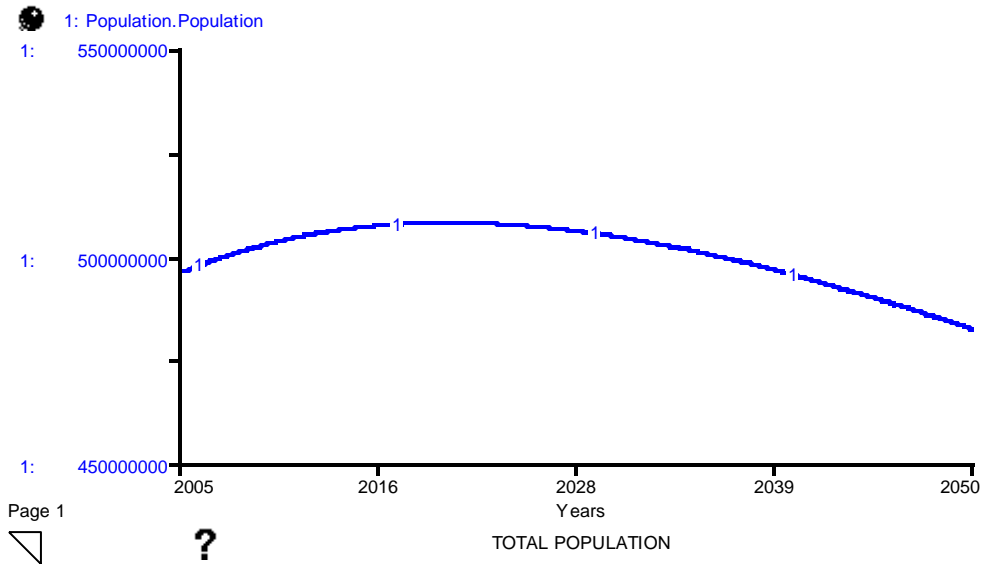


Figure 5-3 Simulated population - basic run

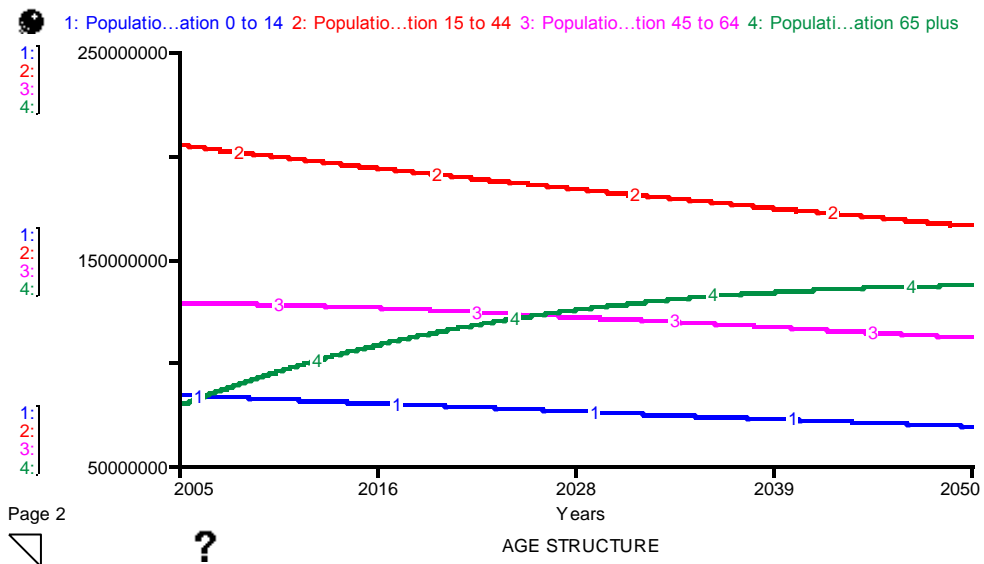


Figure 5-4 Simulated age structure - basic run

### 5.1.2 Jobs sector

Jobs sector is a simplified version of four different sectors from the World 3 model:

- Land development,
- Industrial output,
- Services output.
- Jobs.

This sector is responsible for determining the total number of available jobs in agriculture, industry and service sectors. Some of the original loops were cut and turned

into parameters for the sake of simplicity. Having the full version of these sectors from the World 3 model is not necessary because of the shorter simulation time (50 compared to 200 years) and because it does not add any more insight than the simplified version. The full structure used in this model is shown in Figure 5-5.

The sector is divided into three subsectors, one for each type of jobs. The central feature of the agriculture subsector are the two stocks representing land development chain. Land moves from arable to urban and industrial land. Land development for urban and industrial use rate which transfers land from arable to urban and industrial land depends on the need for urban and industrial land and time required to develop.

The industry subsector has a single stock of industrial capital where the total value of the industrial capital is expressed in units of money. This stock is increased with investment rate and decreased with depreciation rate. Industrial capital investment rate depends on industrial output and the fraction of the industrial output allocated to investment. Industrial capital depreciation rate depends on the stock of industrial capital and average life time of industrial capital. Service capital sector works in the same way.

Stocks of arable land, industrial capital and service capital determine the total number jobs available. This value is compared to the number of people in the labor force to get the labor utilization fraction. Higher the labor utilization fraction is, lower the capacity utilization fraction will be. If the capacity utilization fraction is low then both industrial and service outputs will be low, causing low investments in both industrial and service capital. Initial values for all stocks in this sector were estimated using World Bank data and the World 3 model. The full report on all variables and parameters is available in Appendix B. This sector provides inputs to employment sector and receives input from employment and population sectors.

Results of basic run for the jobs sector are presented in Figures 5-6 and 5-7. Figure 5-6 shows development of total jobs which increases between year 2005 and 2010, decreases between 2010 and 2017, again increases between 2017 and 2028, peaks around 2028, and declines until the final year of simulation in 2050. Figure 5-7 shows development for each of the three each job groups. Agriculture jobs decline between 2005 and 2050 as a result of shrinking agriculture land in favor of urban and industrial land. Industry jobs increase between 2005 and 2019, peak around 2019 and decline until 2050 because of declining industrial capital.

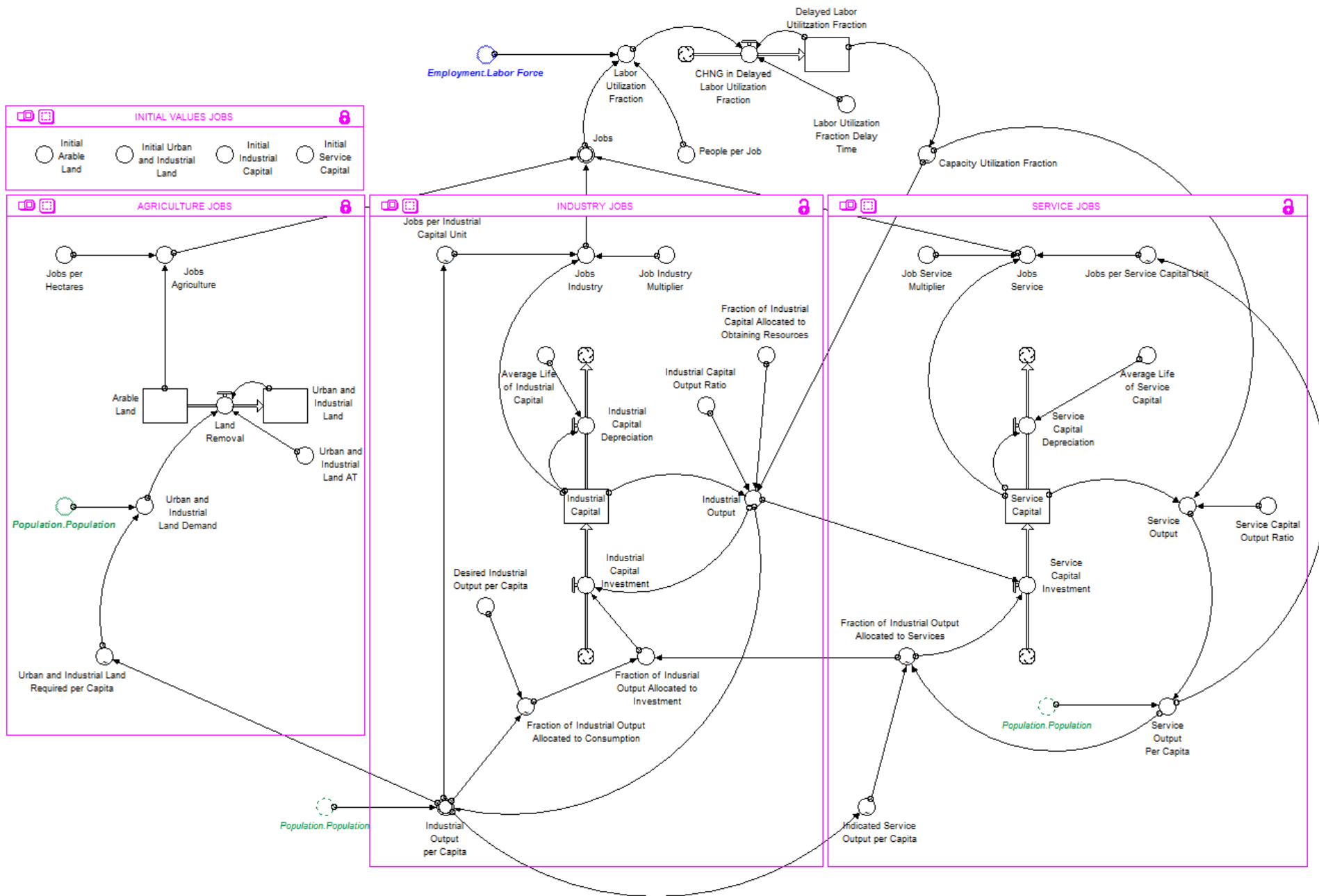


Figure 5-5 Stock and flow diagram of the jobs sector

Service jobs increase between year 2005 and 2010, decreases between 2010 and 2017, again increases between 2017 and 2031, peaks around 2031, and declines until the final year of simulation in 2050. First decline is caused by increasing service output per capita which reduces the number of employees needed per unit of service capital. Second decline is caused by declining service capital.

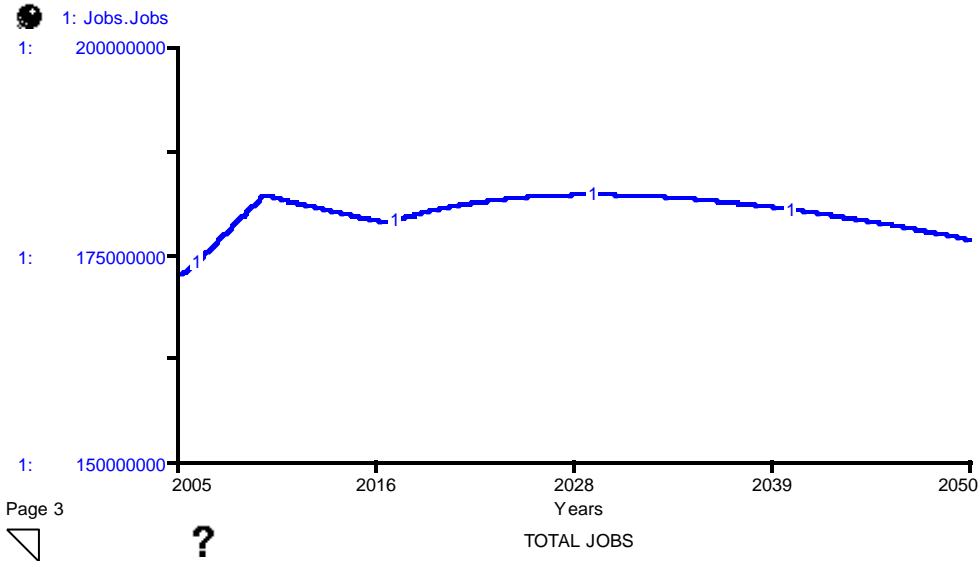


Figure 5-6 Simulated jobs - basic run

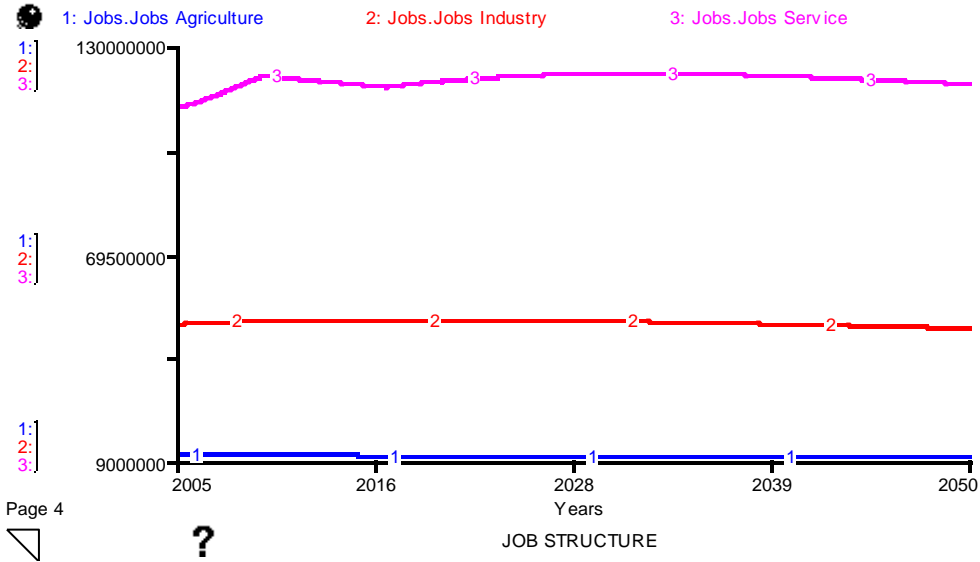


Figure 5-7 Simulated job structure - basic run

### 5.1.3 Employment sector

This sector covers three different population groups: unemployed, employed, and retired. Unemployed population is presented with two stocks which can be seen in Figure 5-8. One stock holds unemployed population participating in the labor force which is increased with people maturing to age 15 who decide to participate in the labor force. The other stock holds the unemployed population not participating in the labor force. This stock is increased with people maturing to age 15 and deciding not to participate in the labor force.

People can move between these two stocks depending on the participation rate, which can change depending on the average income levels of employed and unemployed people, and working hours. Both of these effects were established by the respondents in the consultation process. Effect of income on participation was established by respondents 1 and 5, and effect of working hours was established by respondents 3 and 5. Increasing mean income of employed people compared to mean income of unemployed people will increase the participation rate, while decreasing it will also decrease the participation. Increasing working hours will decrease participation and vice versa. In addition, certain fraction of people in these stocks dies and retires each year.

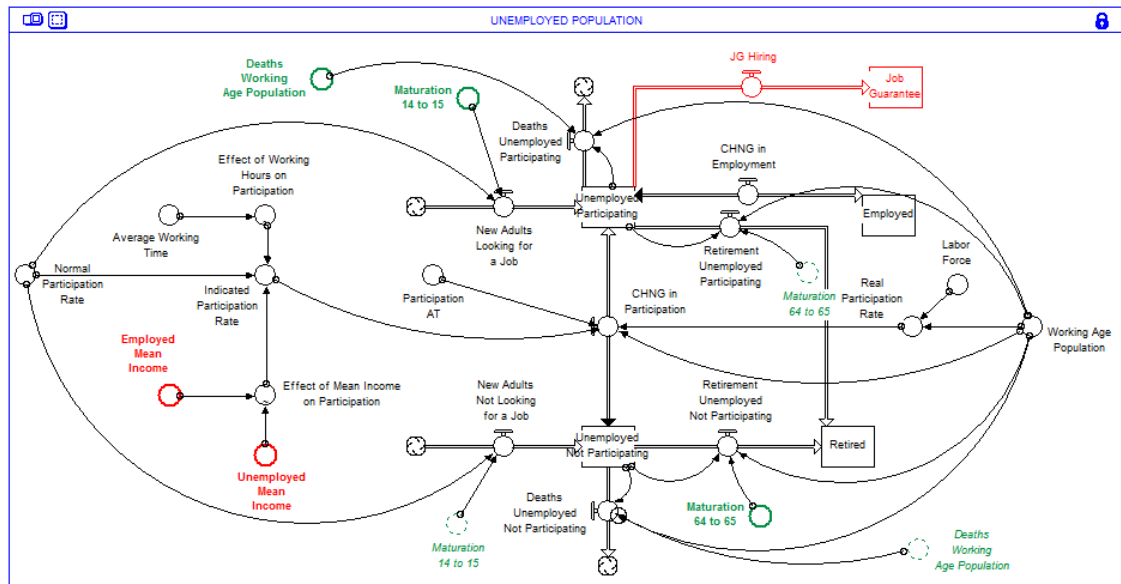


Figure 5-8 Stock and flow diagram of the employment sector - unemployed section

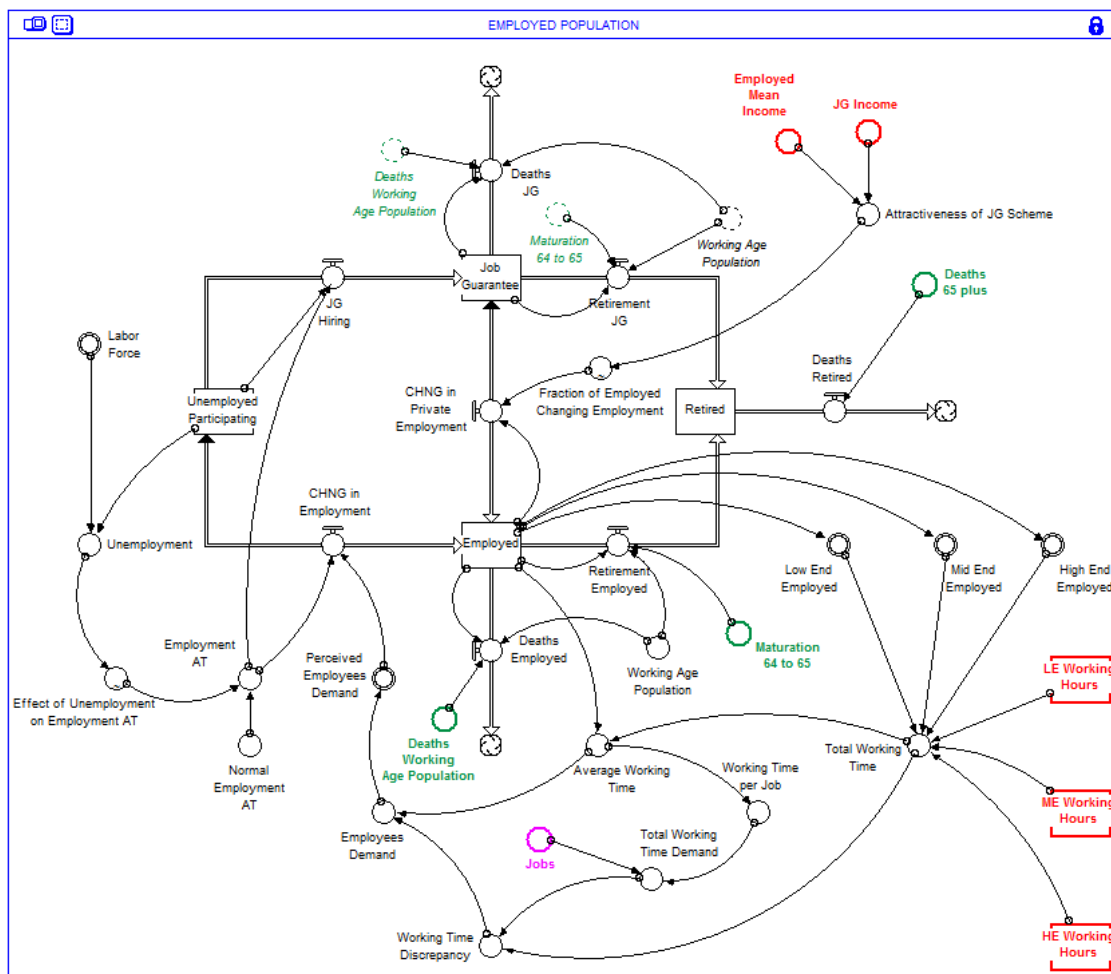


Figure 5-9 Stock and flow diagram of the employment sector - employed section

Employed and retired populations are presented with three stocks which can be seen in Figure 5-9. Stock of employed people presents all people employed in a population, job guarantee stock represents all people employed by the job guarantee scheme, and retired stock represents all people within the population currently above the working age and receiving pensions. Demand for employees is satisfied by moving people from unemployed participating stock into the employed stock or, if the job guarantee policy is activated, by moving people from the job guarantee stock. If the policy is active all people unable to find employment through regular employment are employed in job guarantee scheme.

Similarly to unemployed people, both employed and job guarantee employed people can retire and die. Once people get into the retired stock they are removed at the same rate people in 65 plus age group die. Initial values of all stocks are estimated using Eurostat population data and World Bank employment and unemployment data. The full report on all variables and

parameters is available in Appendix C. This sector provides inputs to all other sectors and receives input from all sectors.

Results of basic run for the employment sector are presented in Figure 5-10. Blue line shows the development of unemployed participating population. Demand for employees increases as a result of job creation, which causes increase in population participating in the labor force. This population stays relatively stable until the year 2017, when it starts to decrease as a result of increasing employment. Red line shows the development of unemployed not participating population, which decreases from the beginning of simulation in 2005 until the end in 2050. This is primarily caused by increasing participation in the labor force.

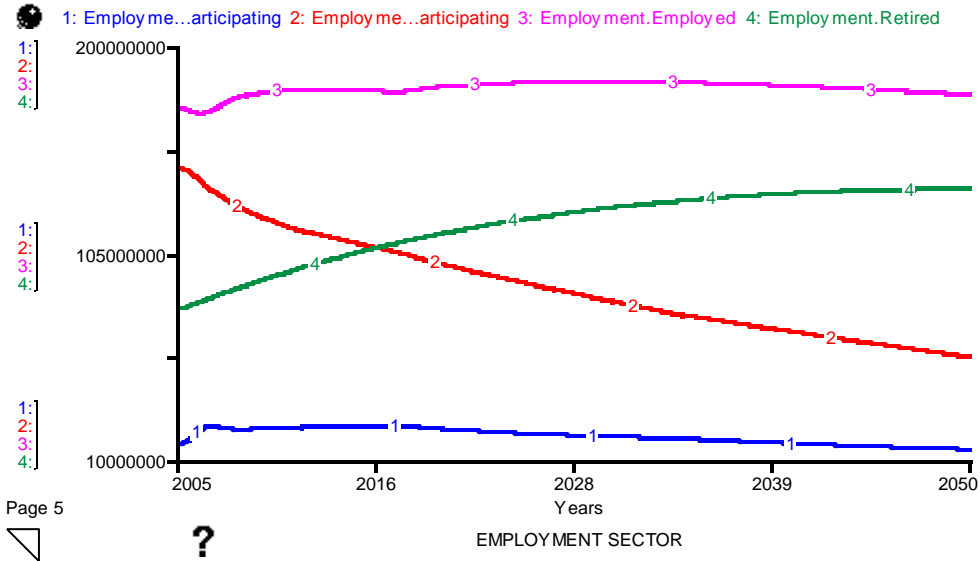


Figure 5-10 Simulated employment sector stocks - basic run

Employed population is presented with a pink line. Its behavior resembles the behavior of jobs, which is expected since the desired number of employees depends on number of jobs available. Retired population is presented with a green line. The behavior of this stock matches the behavior of population age 65 plus, which is expected since they represent the same population.

**5.1.4 Income sector**

Stock and flow structure of the income sector is presented in Figure 5-11. There are six stocks representing average hourly wages and working hours for three income groups: low end earners, mid earners, and high end earners. These are used to calculate average monthly

incomes of each income group. Wages are changed according to the demand for employees and their power. Both of these relationships were established during the consultation process.

Demand for employees is calculated by using total number of available jobs from the jobs sector and total number of available employees from the employment sector. If the demand for employees increases and there is a shortage of available labor force, the wages will increase. They will decrease if there is an excess of employees. This relationship is established by respondent 3 and represented by a graphical function.

The ratio between the income and the mean income is used as a proxy for the power of employees. If the ratio increases for a certain income group, that group becomes more powerful and is able to force employers to increase their wages. This relationship is established by respondent 2 and represented by a graphical function.

Working hours of each income group are changed according to their average income, which is a relationship established by respondents 1, 2 and 5. The average income is compared to GDP per capita, which can be seen as a proxy for material throughput. The link between material throughput and working hours was established by respondents 2 and 4. If the ratio between income and GDP per capita increases, that income group is seen as more productive and their working hours decrease. If it decreases their working hours increase. Initial values for the stocks were estimated using Eurostat income distribution data and World Bank Employment data. The full report on all variables and parameters is available in Appendix D. This sector provides inputs to population and employment sector and receives input from employment and indicator sectors.

Results of basic run for the income sector are presented in Figure 5-12 and Figure 5-13. Development of hourly wages for all three income groups is shown in Figure 5-12. All wages are increasing steadily from the beginning of simulation in 2005 until 2050. This can be explained with positive demand for employees and a reinforcing loop which causes a steady increase in expected wages. Similarly average incomes are also increasing but at a slower rate. This can be explained with declining working hours, which is caused by the effect of income on working hours.

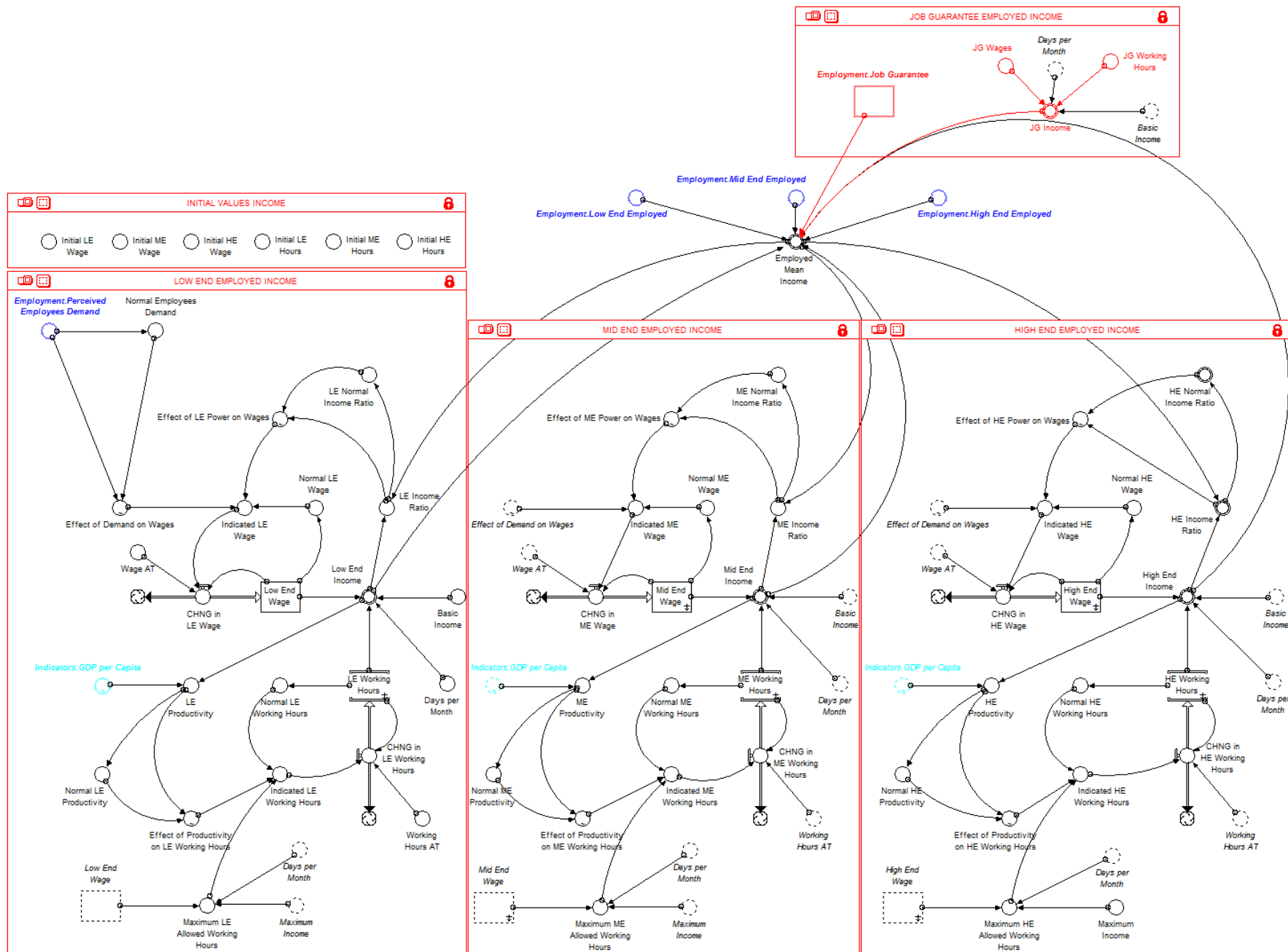


Figure 5-11 Stock and flow diagram of the income sector



Figure 5-12 Simulated wages - basic run

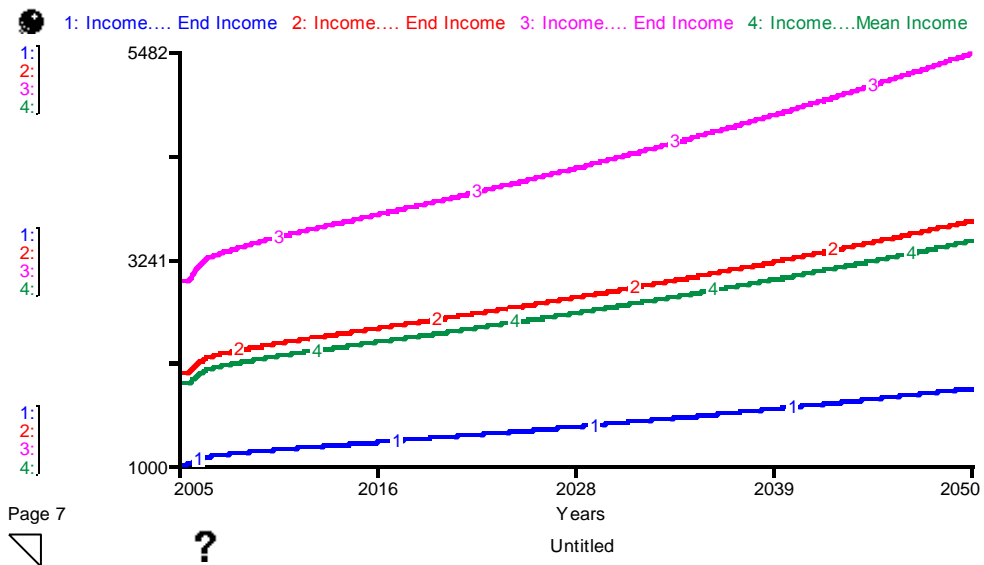


Figure 5-13 Simulated incomes - basic run

### 5.1.5 Indicators

This sector is the smallest one and it contains variables which did not fit in any of the main four sectors. Figure 5-14 presents stock and flow structure of this sector. It contains three indicators: GDP per capita, Human Welfare Index and GINI index. GDP per capita is calculated as a graphical function with industrial output per capita as its input. This graphical

function is adapted from the World 3 model, with the values adjusted for inflation and converted to Euros.

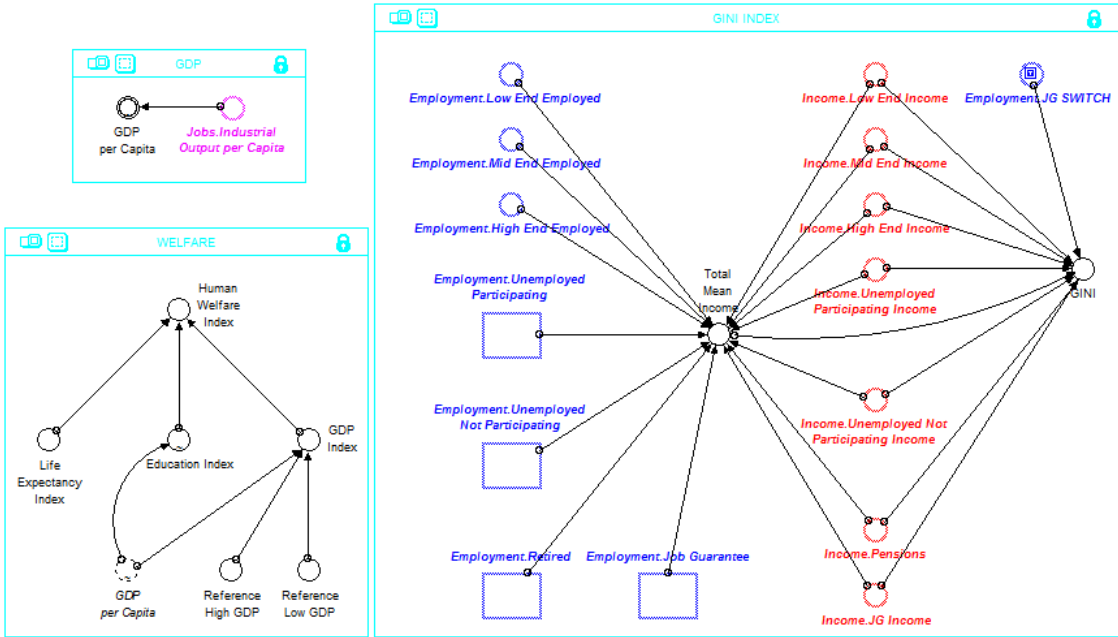


Figure 5-14 Stock and flow diagram of indicator sector

Human Welfare Index is calculated as a mean value of life expectancy index, education index and GDP index. Life expectancy index was set at 0.9 which is the value suggested by the World 3 model for life expectancy of 80 years. Education index is calculated as a graphical function with GDP per capita used as its input. This graphical function was adapted from the World 3 model. GDP index is calculated using GDP per capita and reference values of high and low GDP per capita. Both values are obtained from the World 3 model, adjusted for inflation and converted to Euros. The full report on all variables and parameters is provided in Appendix E.

Results of basic run for the indicator sector are presented in Figure 5-15. GDP per capita increases rapidly in the beginning of the simulation until around year 2010. After that it still increase but at much slower pace. This behavior can be explained with behavior of industrial output which drives the initial increase in GDP. As the output declines increase in GDP slows down but continues to increase because of decline in population. GINI index increases steadily throughout the simulation which indicates rising inequalities in the population. This is because of uneven increase in wages among low, mid and high end earners. The overall increase in GINI is probably higher than it would be in the reality because incomes of retired

and unemployed people are set at constant value. The behavior of Human Welfare Index resembles behavior of GDP per capita, which is expected since the GDP is one of its main drivers.

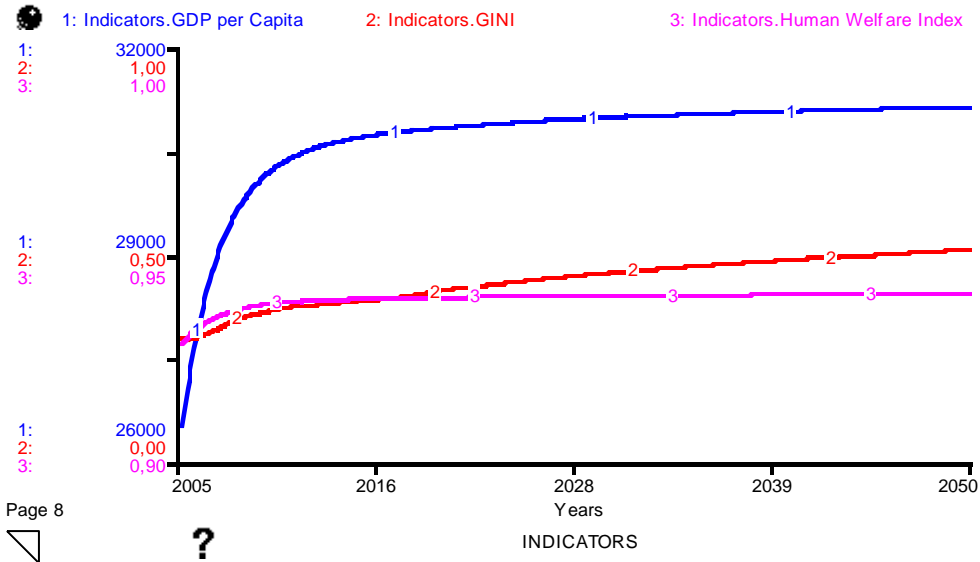


Figure 5-15 Simulated indicators - basic run

5.1.6 Validation

This section presents a review of conducted validation tests and their results. Table 5-1 contains a full list of tests and a short description of the results. These tests were recommended by Barlas (1996).

Table 5-1 Validation tests

<b>Structure verification</b>	Models structure is in line with description provided by the experts during the consultation process and does not contradict available degrowth literature.
<b>Parameter verification</b>	All parameters are within plausible ranges. Some are extracted directly from the available data bases while others are estimated using best judgment.
<b>Extreme condition</b>	Each rate equation exhibits expected behavior under extreme conditions.
<b>Boundary</b>	Model contains the most important aspects mentioned by the experts

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<b>adequacy</b>	during the consultation process. Certain aspects were not modeled because they would be extremely difficult to model or were not clearly explained by the experts.
<b>Dimensional consistency</b>	Unit consistency was tested using iThink's built in unit consistency check. All units are consistent.
<b>Symptom generation</b>	Simulation results are very similar to historical data for those variables for which the data exists, such as population and employment.
<b>Multiple mode</b>	Model exhibits multiple mode behavior for some variables. All of the modes can be structurally explained.
<b>Characteristics</b>	Some variables exhibit unusual behavior because of the non linear functions. The existence of these functions is confirmed by the experts during the consultation process but the values are estimated using best judgment.
<b>Pattern/event prediction</b>	Patterns of behavior predicted by the model are plausible in the real system.
<b>Anomaly</b>	Model makes predictions which are in line with estimates made by the experts during the consultation process.
<b>Family member</b>	Population sector uses generic structure for modeling population. Jobs sector is a simplified partial structure of the World 3 model. Other sectors are not generic.
<b>Sensitivity</b>	Model is sensitive to changes in certain parameters. This is not unusual considering the use of non linear functions. The models purpose of presenting experts personal views does justify their use.
<b>Policy sensitivity</b>	Model is sensitive to changes in policies. Similarly to sensitivity tests this is caused by the non linear functions and the models purpose justify their use.

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## 5.2 SCENARIOS

### 5.2.1 Scenario 1 - Introducing basic and maximum income policy

In this scenario, effects of implementing the basic and maximum income policy are explored. The policy is implemented in the year 2015 and it stays in effect till the end of simulation time in the year 2050. Basic income is implemented through a basic income parameter which adds to regular income of all people, employed and unemployed.

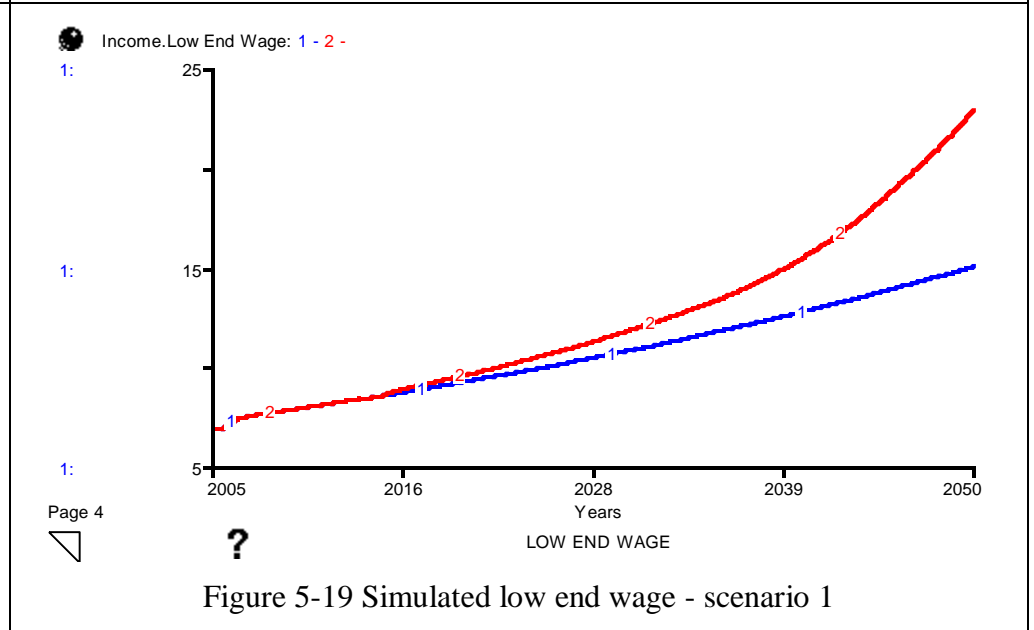
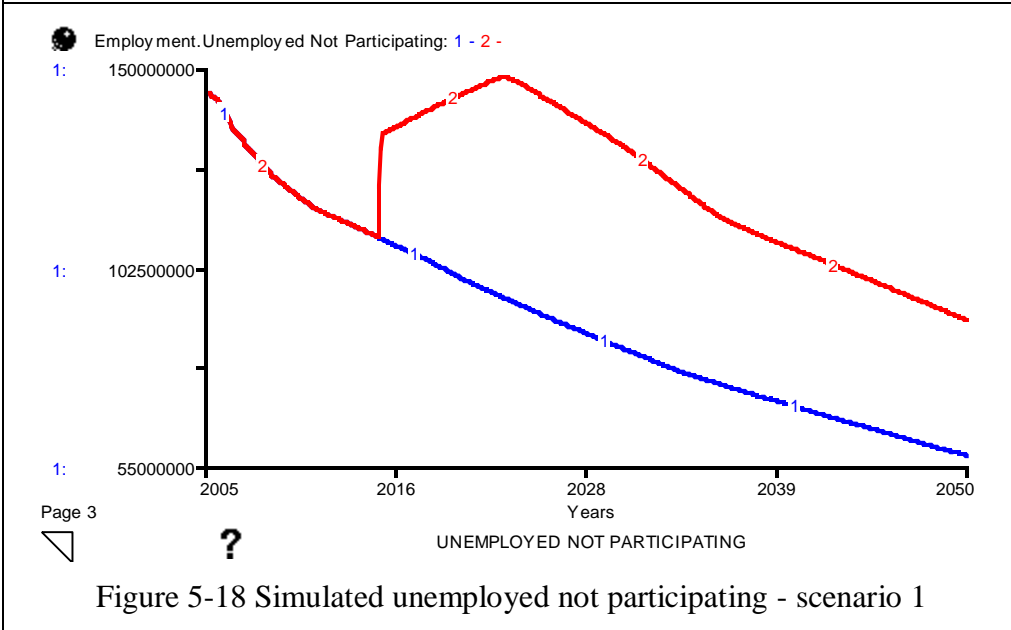
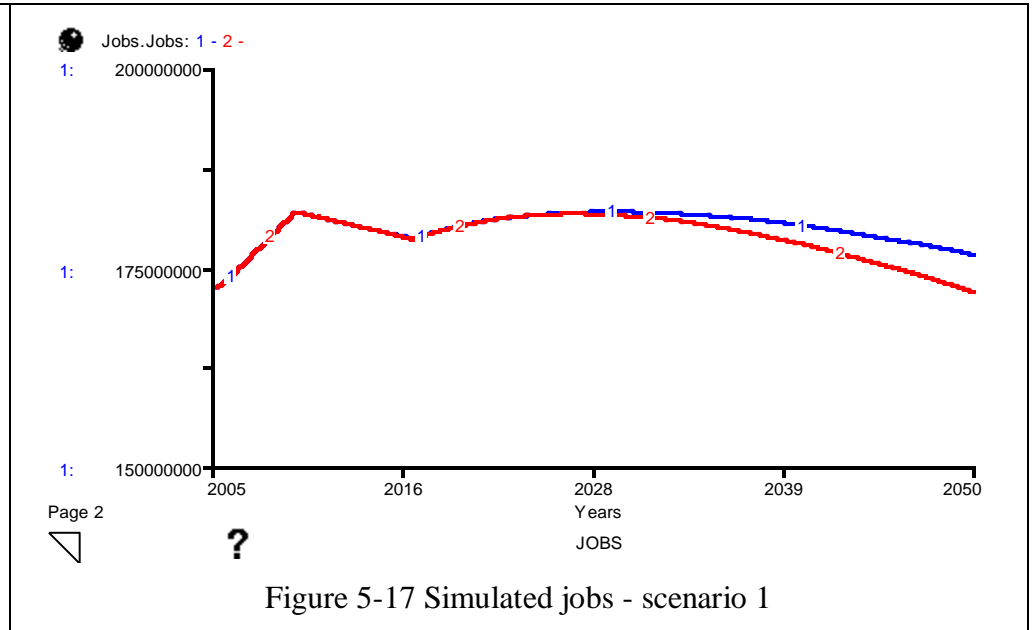
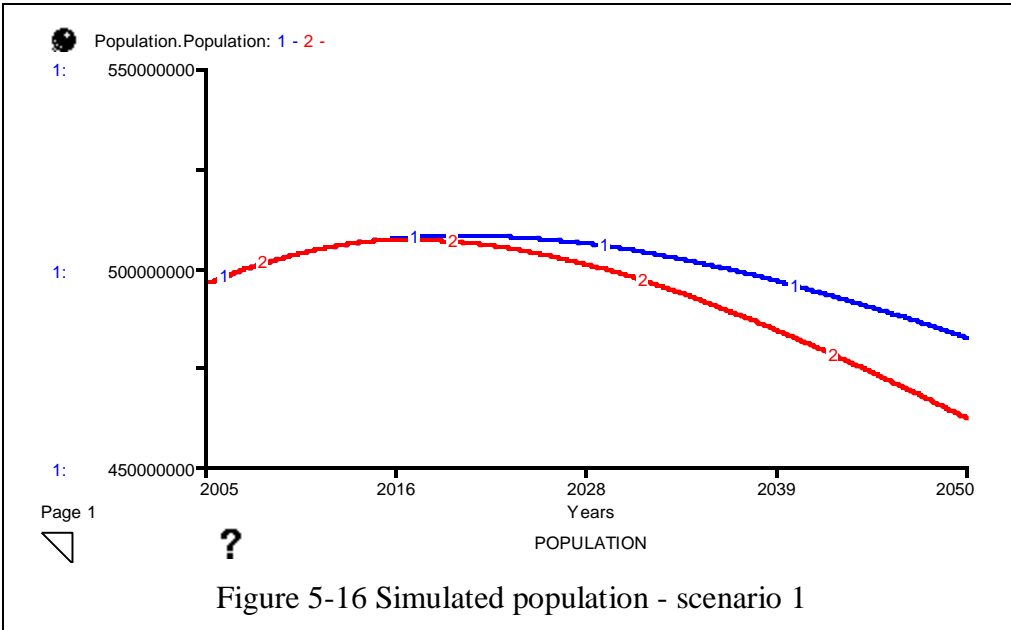




Figure 5-20 Simulated high end wage - scenario 1

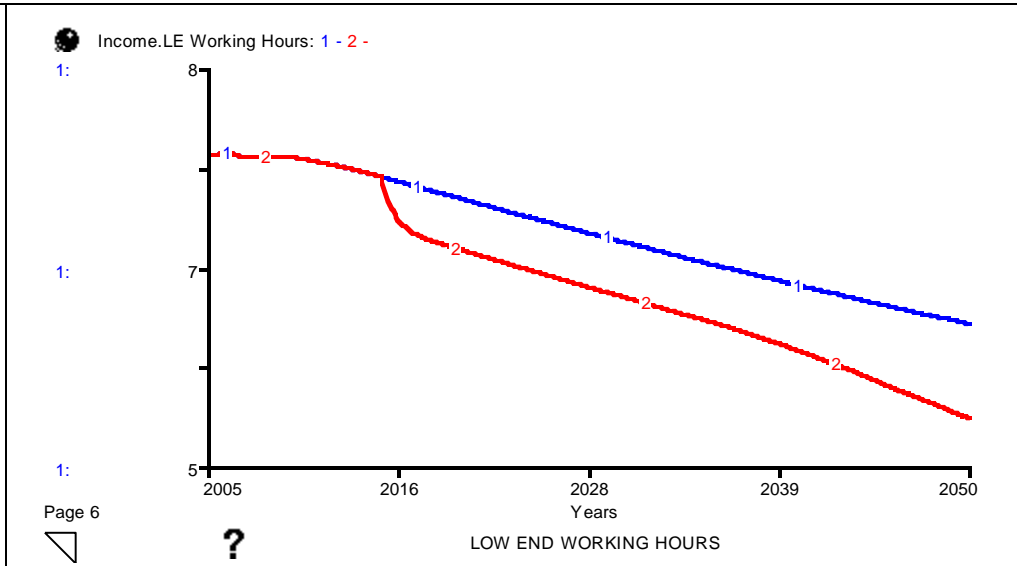


Figure 5-21 Simulated low end working hours - scenario 1

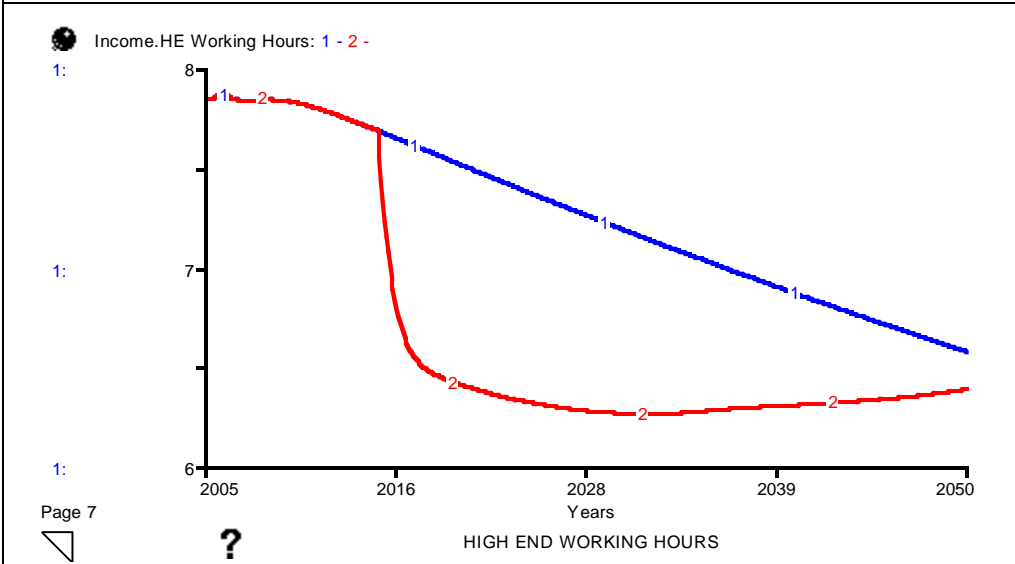


Figure 5-22 Simulated high end working hours - scenario 1

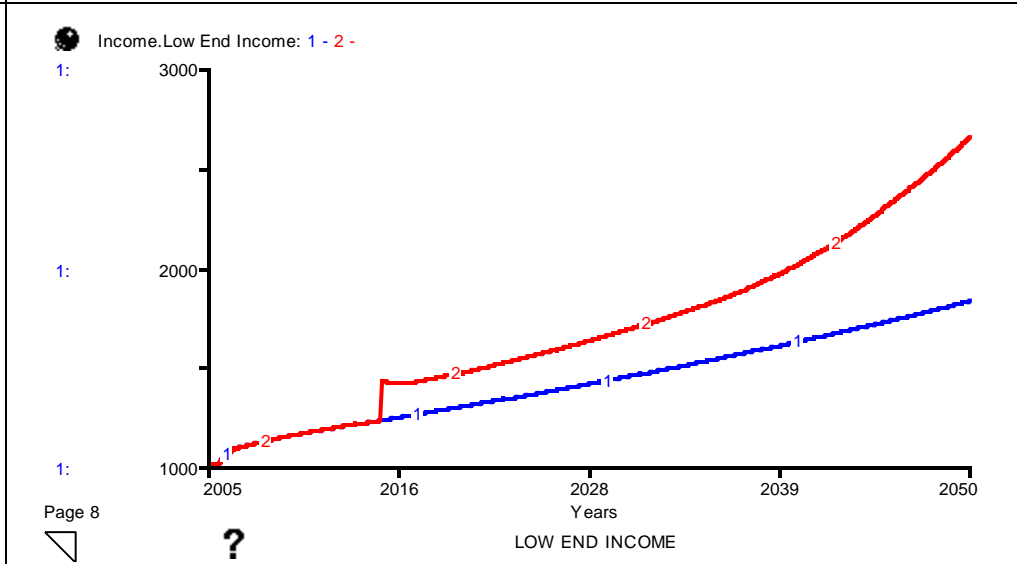
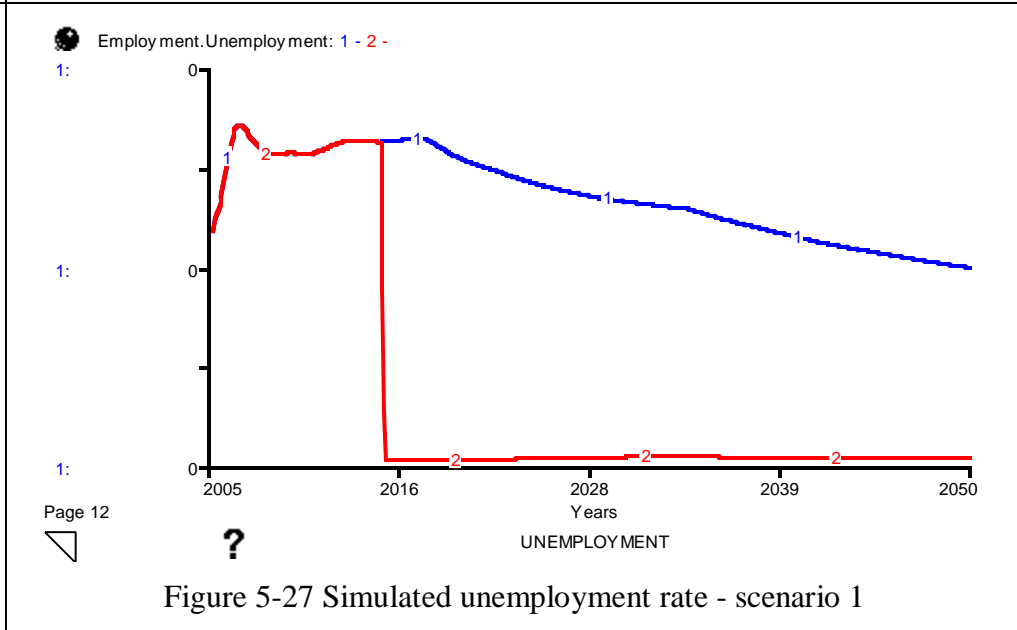
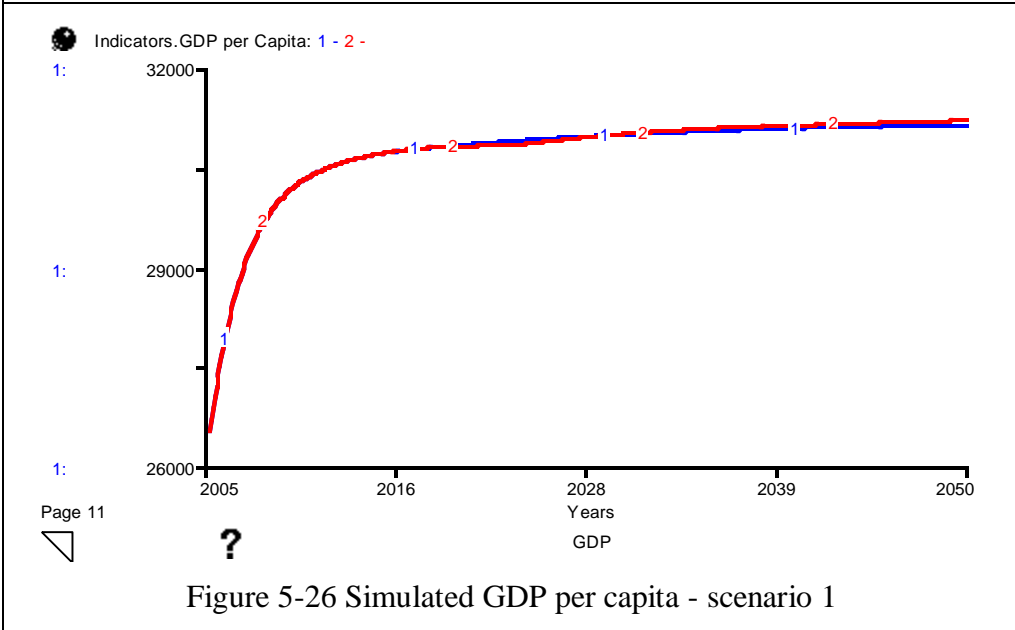
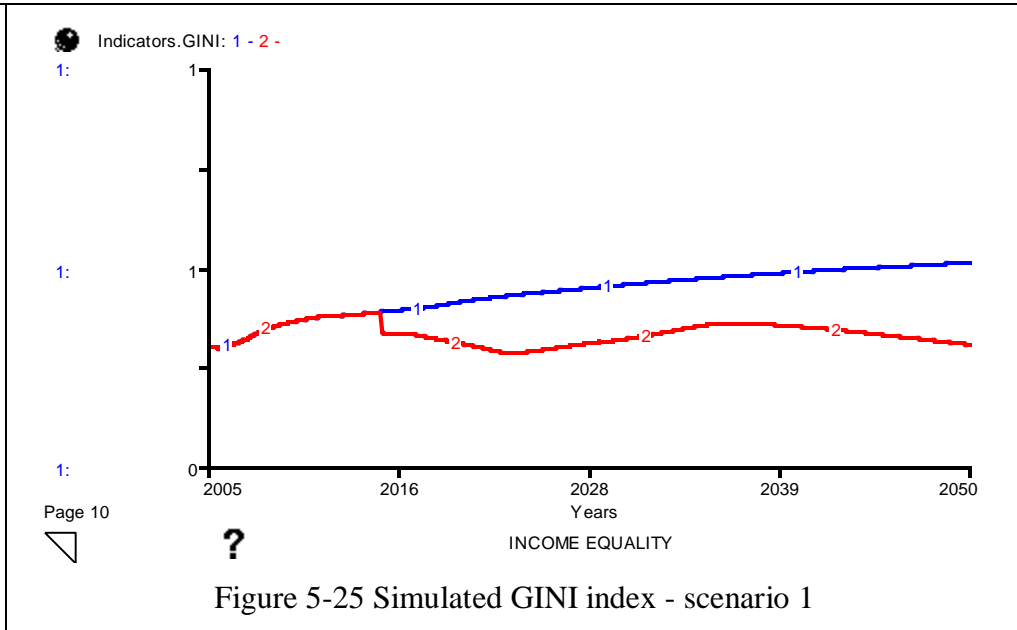
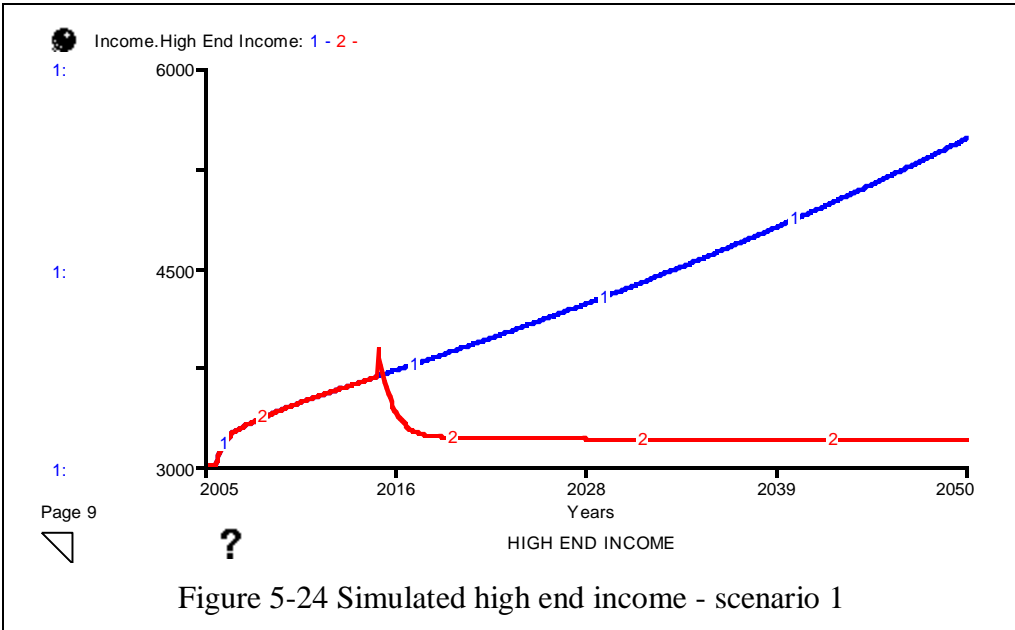


Figure 5-23 Simulated low end income - scenario 1



Maximum income is implemented through maximum income parameter which is used to calculate maximum allowed working hours for each income group based on their wages. Simulation results are then compared to the basic run in order to test the predictions made by the experts. The focus is on those indicators mentioned by at least three respondents, such as low end income and wages, working hours, and income equality. Simulation results compared to basic run are presented on Figure 5-16 to Figure 5-27. Blue lines are results of basic run and red lines of basic and maximum income policy run.

Policy settings:

- Basic Income=0+STEP(200,2015);
- Maximum Income=10000-STEP(7000,2015).

Policy results:

- Figure 5-16: Population decreases compared to the basic run because of increased emigration of the high end earners as predicted by the respondents in the consultation process;
- Figure 5-17: Jobs decrease compared to the basic run because of lower participation which causes lower capacity utilization. This causes reduction in industrial output which reduces available funds for investments in industrial capital and service capital used to determine the number of industrial and service jobs;
- Figure 5-18: Number of unemployed not participating people increases compared to the basic run because basic income policy makes employment less desirable since people can afford not working. This behavior is predicted by the respondents during consultation process.
- Figure 5-19: Low end wages increase compared to the basic run. Basic income increases the bargaining power of the low end employees and they are able to negotiate higher wages. In the long term wages seem to grow uncontrollably. This behavior was predicted by the experts in the consultation process.
- Figure 5-20: High end wages are decreased compared to the basic run because of the maximum income policy which limits the monthly income of high end earners. This reduces their bargaining power and their wages start to decrease. This behavior was predicted by the experts in the consultation process.

- Figure 5-21: Low end working hours decrease compared to the basic run because, as their wage increases, low end earners have to work less in order to earn their desired income. This behavior is predicted by the experts during the consultation process.
- Figure 5-22: High end working hours decrease compared to the basic run because of the maximum income policy, which limits the amount of hours they can work considering their current hourly wage. This behavior was predicted by the experts during the consultation process.
- Figure 5-23: Low end income increases compared to the basic run because of the increase in low end wages. The growth of income is slowed down because of the simultaneous decrease in the working hours but it still continues until the end of simulation. This behavior was predicted by the experts during consultation process.
- Figure 5-24: High end income decreases compared to the basic run because of the maximum income policy which puts a limit to the monthly income a person can receive. The income of high end earners quickly stabilizes slightly above the maximum income level. This behavior was predicted by the experts in the consultation process.
- Figure 5-25: GINI index decreases compared to the basic run which means that basic and maximum income policy improves income distribution as predicted by the experts during the consultation process. This happens because the differences between incomes of low end earners and high end earners decrease as a result of increasing income of the low end earners and decreasing income of the high end earners.
- Figure 5-26: GDP per capita does not change much compared to the basic run. In the short term there is a slight decrease in GDP caused by reduced participation in the labor force, which reduces capacity utilization and slightly reduces the industrial capital compared to the basic run. However, in the long run participation starts to increase again and GDP starts to increase and ends up slightly above the basic run value.
- Figure 5-27: Unemployment decreases substantially compared to the basic run. This behavior makes sense when two things are considered. First, unemployed people are given basic income which takes away their incentive to actively look for employment. Second, demand for labor still exists so everyone looking for job can easily find one.

Simulation results of basic and maximum income policy seem to be in line with experts' predictions. Implementing the basic income policy does increase low end wages, which

combined with stable high end wages (result of maximum income policy) improves income distribution and reduces working hours. Soon after the policy is implemented unemployment is reduced to 0. Some unemployed people will simply stop participating in the labor force and others will find job easier with less competition. In order to bring people back in to the labor force employers will continue to increase low end wages. One result which does not match predictions made by the experts is that implementing the policy did not slow down economic growth. In the short term the policy does slightly reduce GDP per capita, but in the long run GDP increases faster than in the basic run and ends up with slightly higher value.

### **5.2.2 Scenario 2 - Introducing work sharing policy**

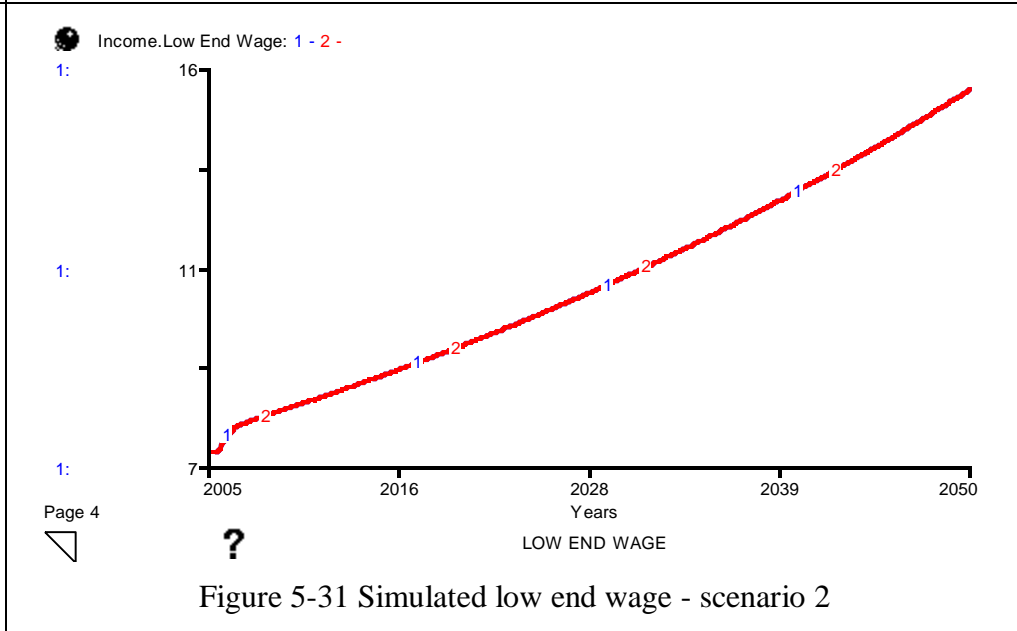
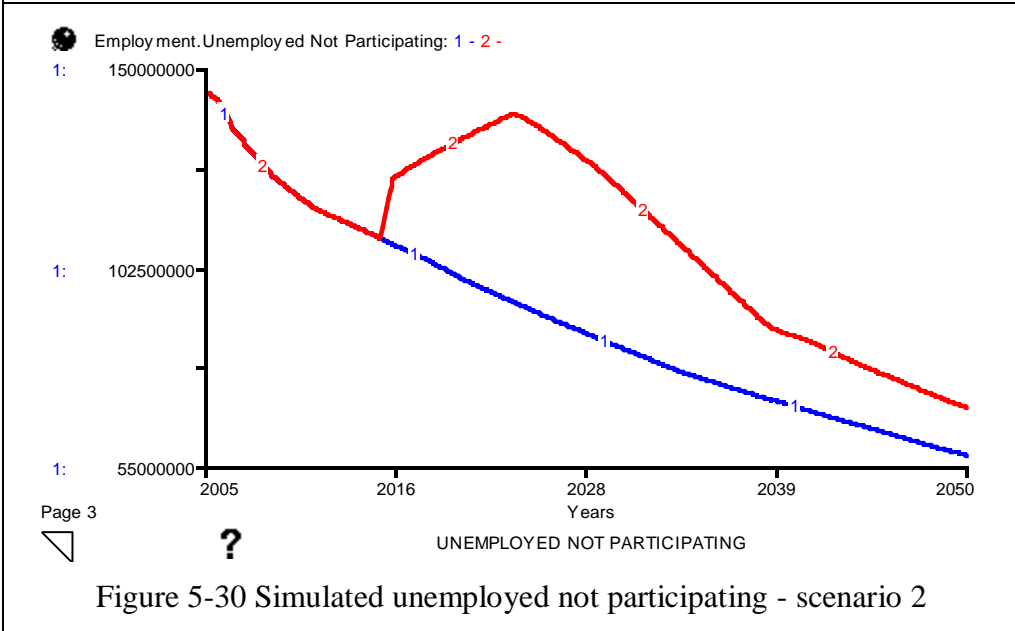
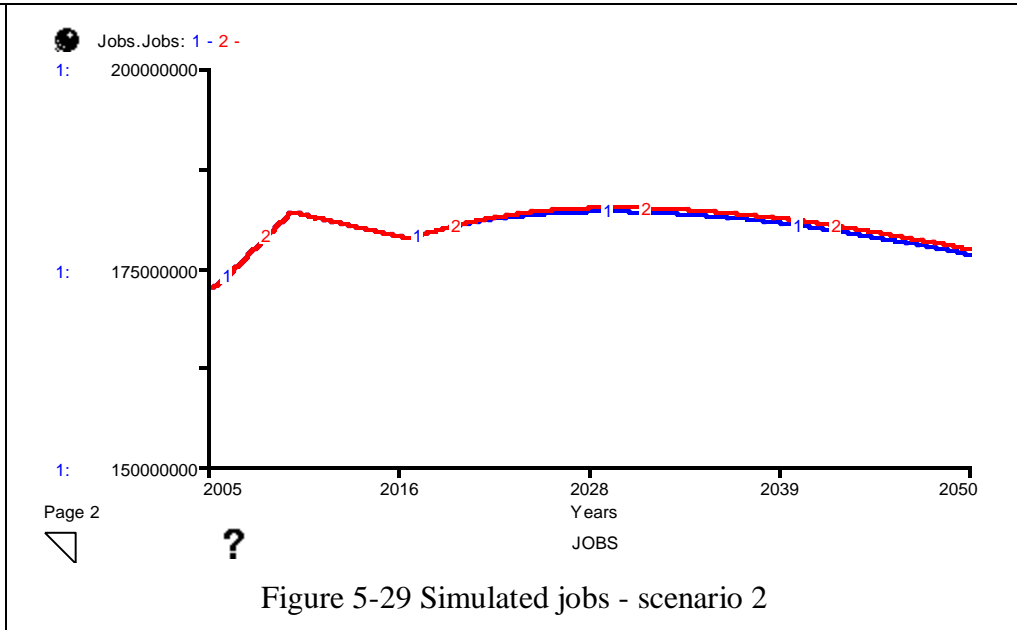
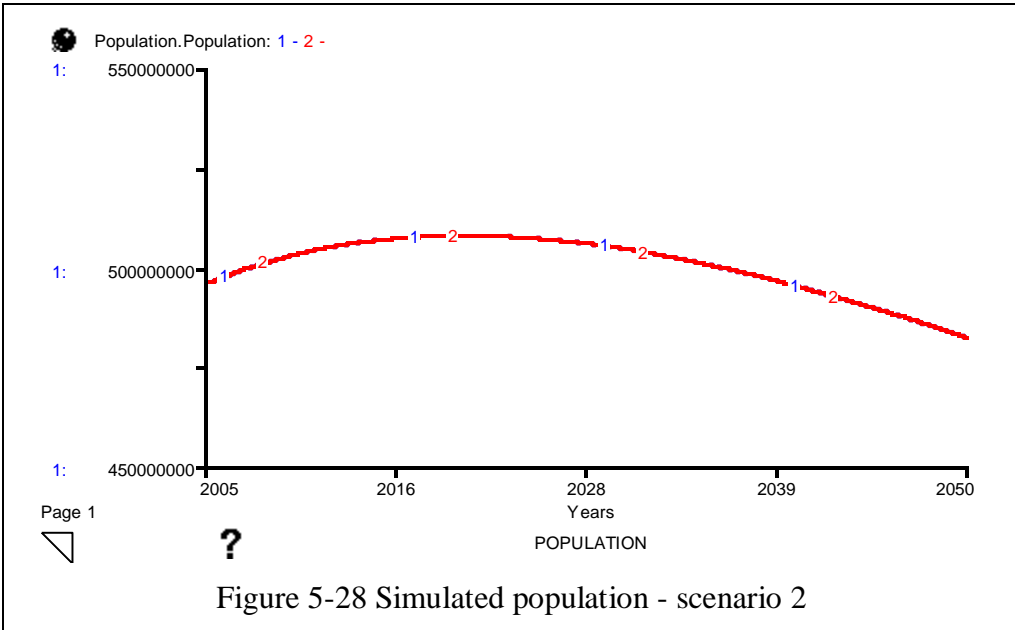
In this scenario, effects of implementing the work sharing policy are explored. The policy is implemented in the year 2015 and it stays in effect till the end of simulation time in the year 2050. It is implemented through the maximum allowed working hours variable which sets an upper limit to the amount of hours an employed person could work in a day. Simulation results are then compared to the basic run in order to test the predictions made by the experts. The focus is on those indicators mentioned by at least three respondents, such as working hours and employment. Simulation results compared to basic run are presented on Figure 5-28 to Figure 5-39. Blue lines are results of basic run and red lines of basic and maximum income policy run.

Policy settings:

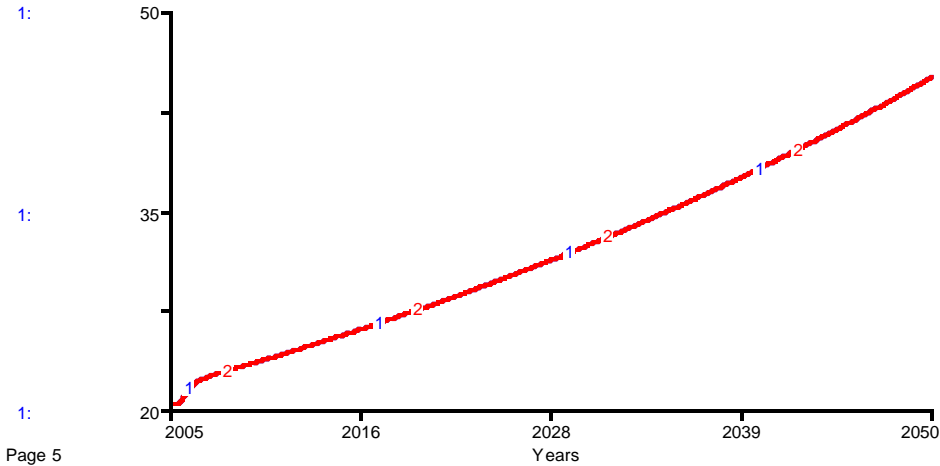
- Maximum LE Allowed Working Hours = IF TIME < 2015 THEN (Maximum Income/(Low End Wage\*Days per Month)) ELSE 4;
- Maximum ME Allowed Working Hours = IF TIME < 2015 THEN (Maximum Income/(Mid End Wage\*Days per Month)) ELSE 4;
- Maximum HE Allowed Working Hours = IF TIME < 2015 THEN (Maximum Income/(High End Wage\*Days per Month)) ELSE 4.

Policy results:

- Figure 5-28: Population changes in the same way as in the basic run;
- Figure 5-29: Jobs increase slightly compared to the basic run scenario because employers start to adjust working hours of new jobs according to the average working hours. Since the average working hours decline, more jobs with lower working hours are created to compensate.



Income.High End Wage: 1 - 2 -



Page 5

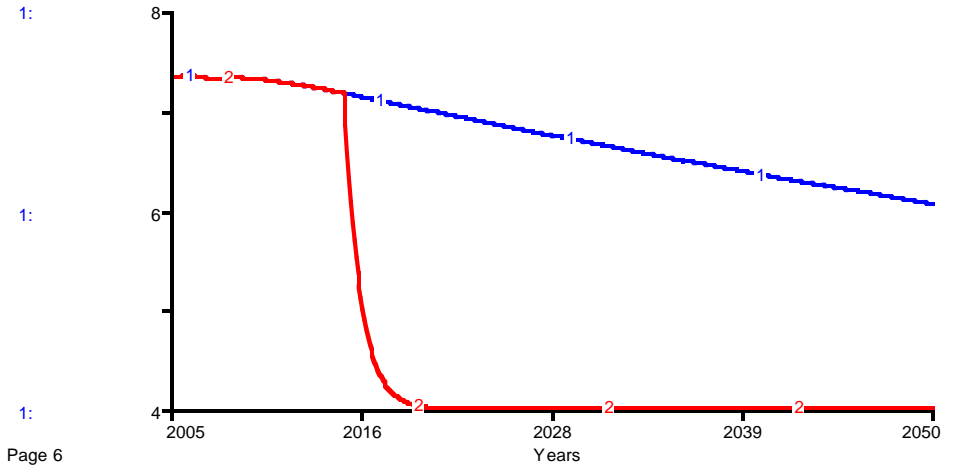


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HIGH END WAGES

Figure 5-32 Simulated high end wage - scenario 2

Income.LE Working Hours: 1 - 2 -



Page 6

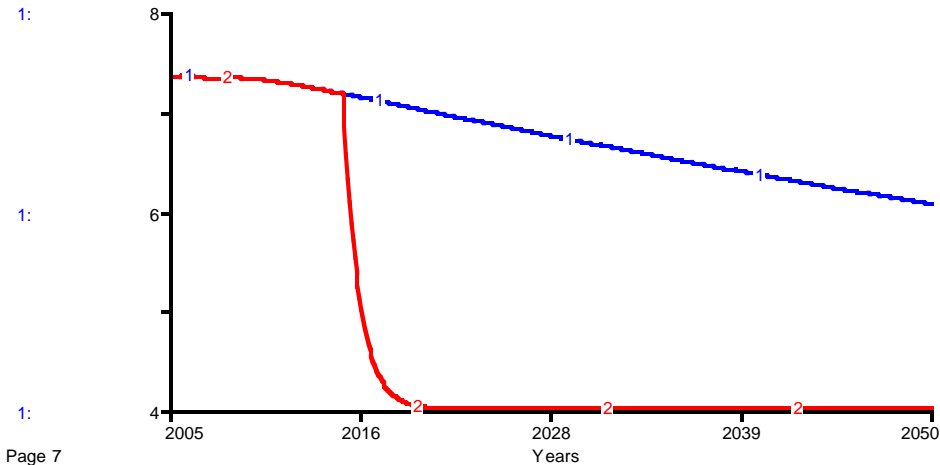


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LOW END WORKING HOURS

Figure 5-33 Simulated low end working hours - scenario 2

Income.HE Working Hours: 1 - 2 -



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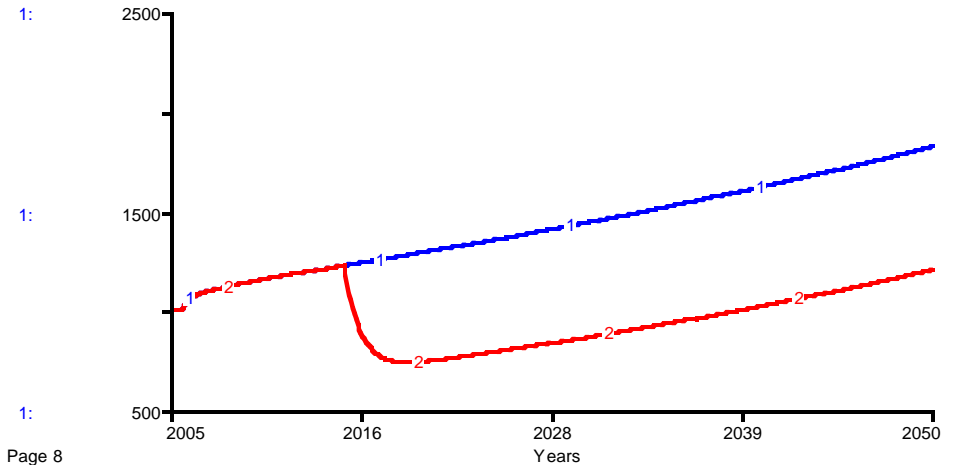


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HIGH END WORKING HOURS

Figure 5-34 Simulated high end working hours - scenario 2

Income.Low End Income: 1 - 2 -



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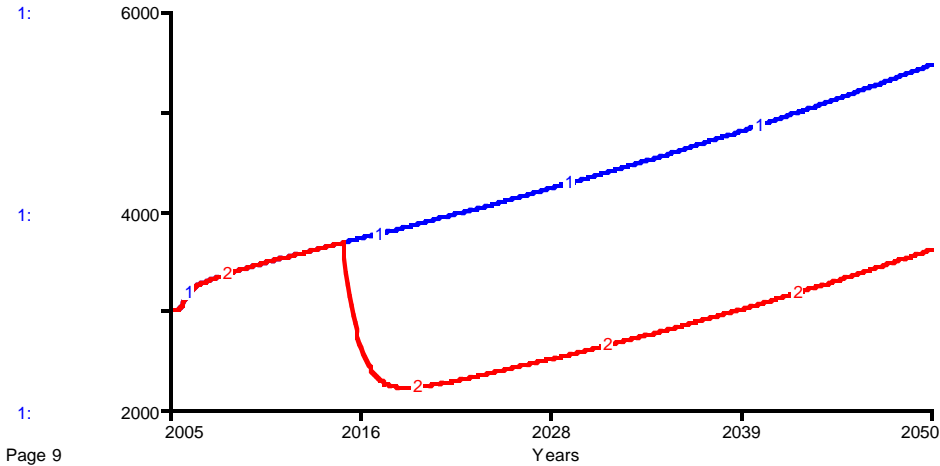


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LOW END INCOME

Figure 5-35 Simulated low end income - scenario 2

Income.High End Income: 1 - 2 -



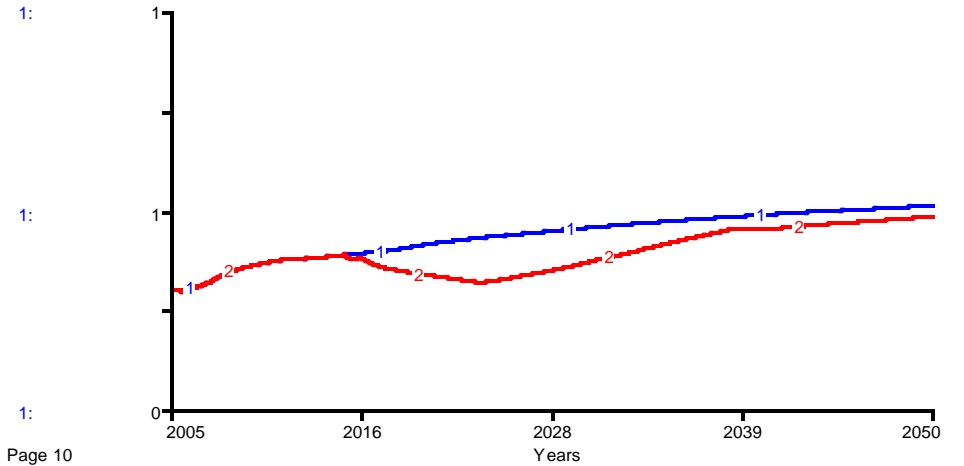
Page 9



HIGH END INCOME

Figure 5-36 Simulated high end income - scenario 2

Indicators.GINI: 1 - 2 -



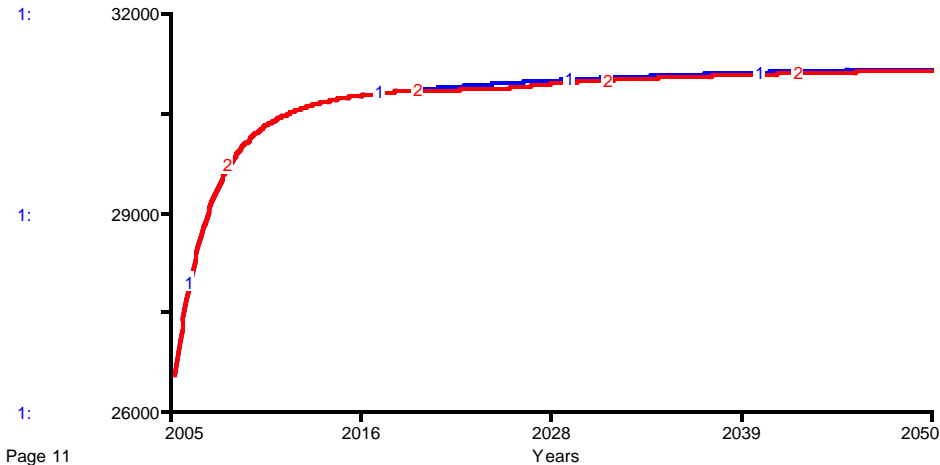
Page 10



INCOME EQUALITY

Figure 5-37 Simulated GINI index - scenario 2

Indicators.GDP per Capita: 1 - 2 -



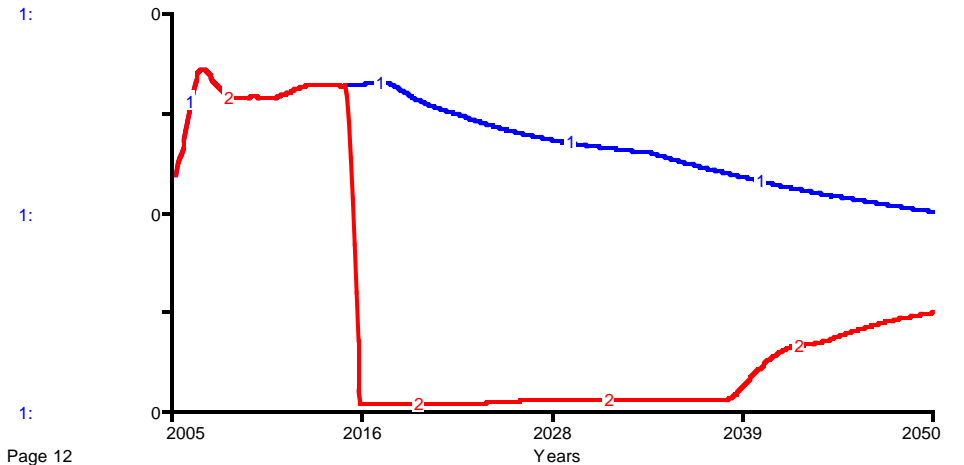
Page 11



GDP

Figure 5-38 Simulated GDP per capita - scenario 2

Employment.Unemployment: 1 - 2 -



Page 12



UNEMPLOYMENT

Figure 5-39 Simulated unemployment rate - scenario 2

- Figure 5-30: Unemployed not participating population increases compared to the basic run in the short term because the ratio between the average incomes of employed and unemployed people decline and employment becomes less desirable;
- Figure 5-31: Low end wages changes in the same way as in the basic run. This is contradictory to some of the predictions made by the experts suggesting that work sharing policy might increase wages. The reason why wages stay the same is because decrease in working hours is same for everyone so decreases in incomes are proportional for all income groups. Power balance does not change so wages continue to increase in the same way as in the basic run;
- Figure 5-32: High end wages changes in the same way as in the basic run. Explanation used in the previous policy result applies in this one as well;
- Figure 5-33: Low end working hours decrease compared to the basic run as a result of policy decision. This behavior is predicted by the experts during the consultation process;
- Figure 5-34: High end working hours decrease compared to the basic run as a result of policy decision. This behavior is predicted by the experts during the consultation process;
- Figure 5-35: Low end income decreases compared to the basic run because of decline in working hours. This behavior is predicted by the experts during the consultation process;
- Figure 5-36: High end income decreases compared to the basic run because of decline in working hours. This behavior is predicted by the experts during the consultation process;
- Figure 5-37: GINI index decreases compared to the basic run because the gap between employed and unemployed people's income reduces after implementation of work sharing policy which means that implementation of this policy improves income distribution. This behavior is predicted by the experts during the consultation process;
- Figure 5-38: GDP per capita exhibits very similar behavior in both policy and basic run. It decreases slightly in the short term after the policy is implemented but in the long term it ends up roughly the same value as in the basic run;
- Figure 5-39: Unemployment reduces substantially compared to the basic run. Reductions in working hours increase demand for labor and the hiring increases. At

the same time reducing the ratio between the average incomes of employed and unemployed people causes decline in participation.

Simulation results of work sharing policy partially align with predictions made by the experts during the consultation process. In particular, income inequalities decrease as predicted and reduced working hours in combination with decreasing labor force participation completely eliminate unemployment. However, hourly wages do not change differently than in the basic run. Once the wages increase to a high enough level unemployment rate starts to increase again, which indicated that being employed became more desirable and people started participating in the labor force again.

### **5.2.3 Scenario 3 - Introducing job guarantee policy**

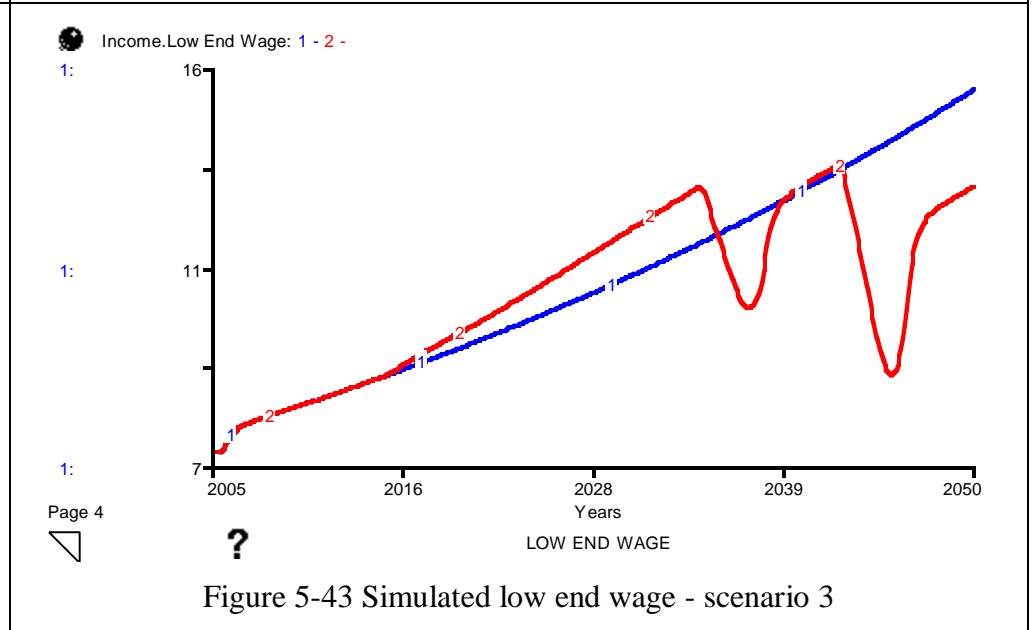
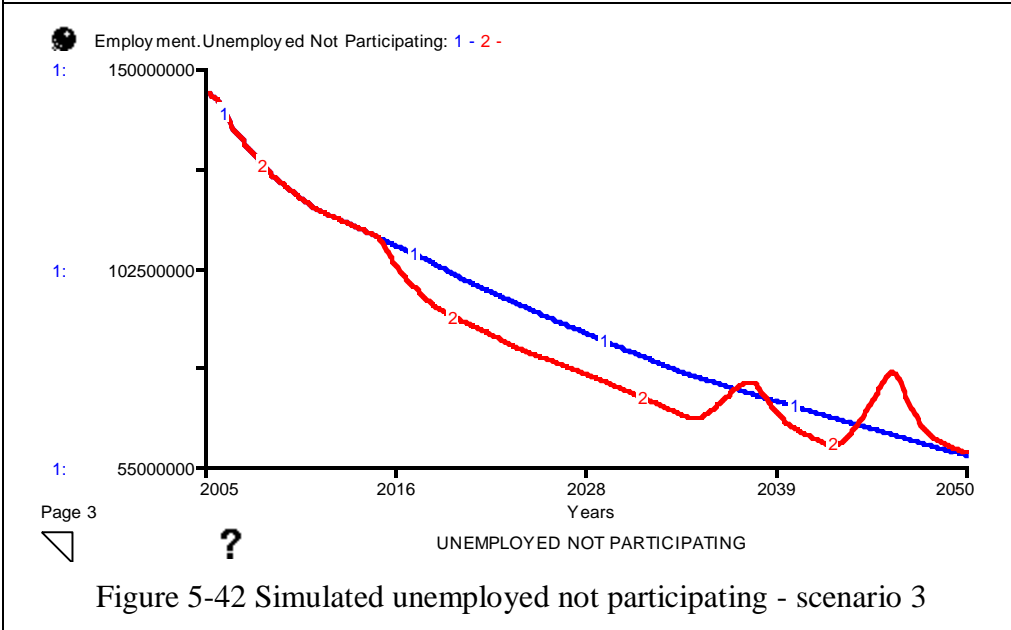
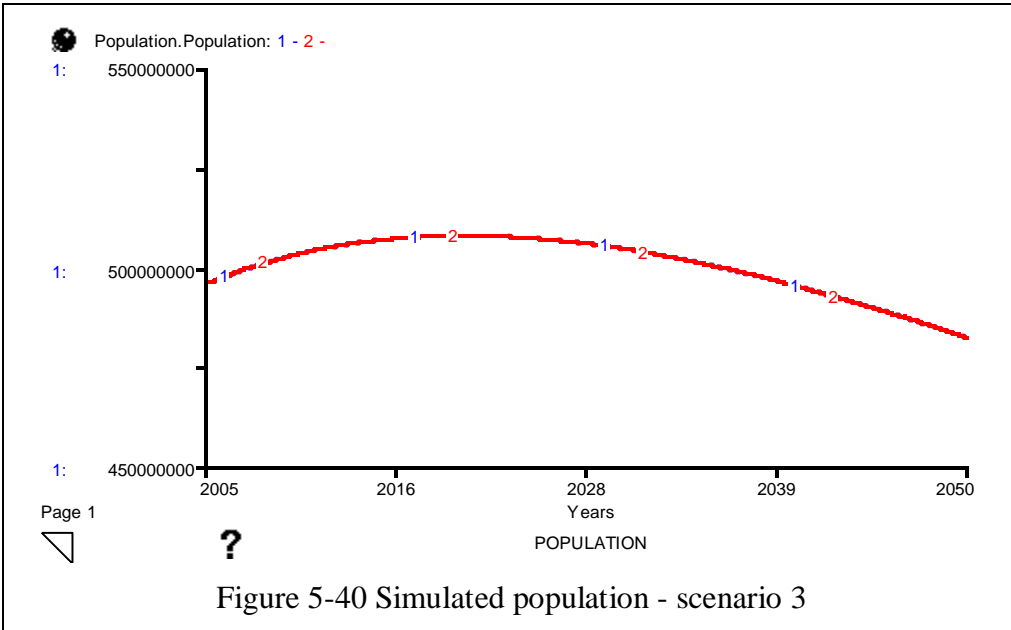
In this scenario, effects of implementing the job guarantee policy are explored. The policy is implemented in the year 2015 and it stays in effect till the end of simulation time in the year 2050. It is implemented by introducing a new stock to the existing model structure which will contain people employed in the job guarantee scheme. People move into the job guarantee stock from unemployed participating stock. The model assumes one of the basic principles of the job guarantee scheme which says that everyone looking for work will be provided work in a realistic amount of time by the government. From the job guarantee scheme it is possible to move into the employed stock. People that decide to move from the employed stock to the job guarantee stock have to go to unemployed participating stock first. Simulation results are compared to the basic run in order to test the predictions made by the experts. The focus is on those indicators mentioned by at least three respondents, such as wages and employment. Simulation results compared to basic run are presented on Figure 5-40 to Figure 5-51. Blue lines are results of basic run and red lines of basic and maximum income policy run.

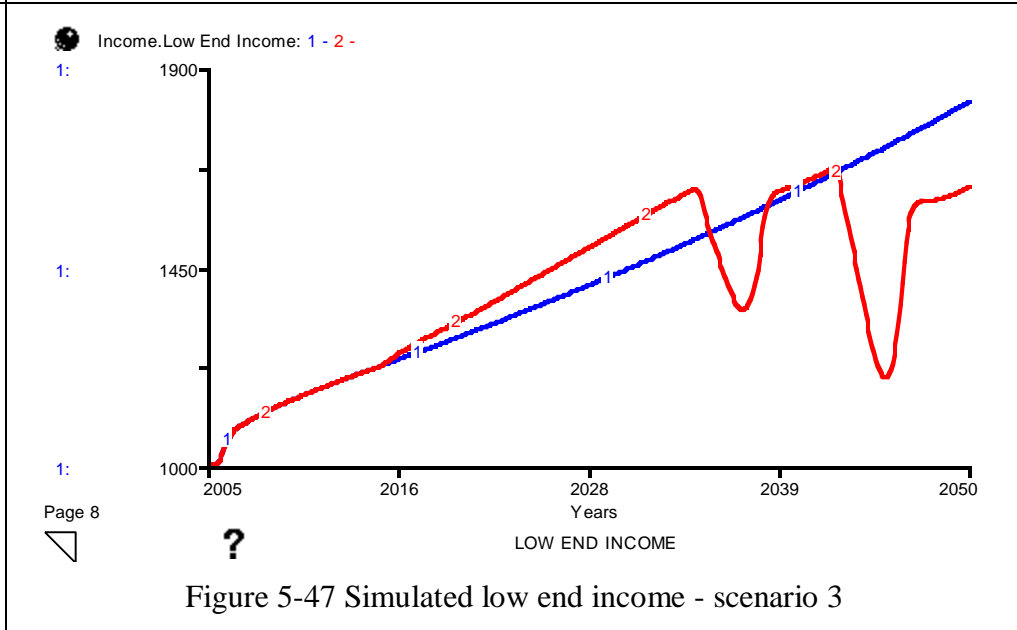
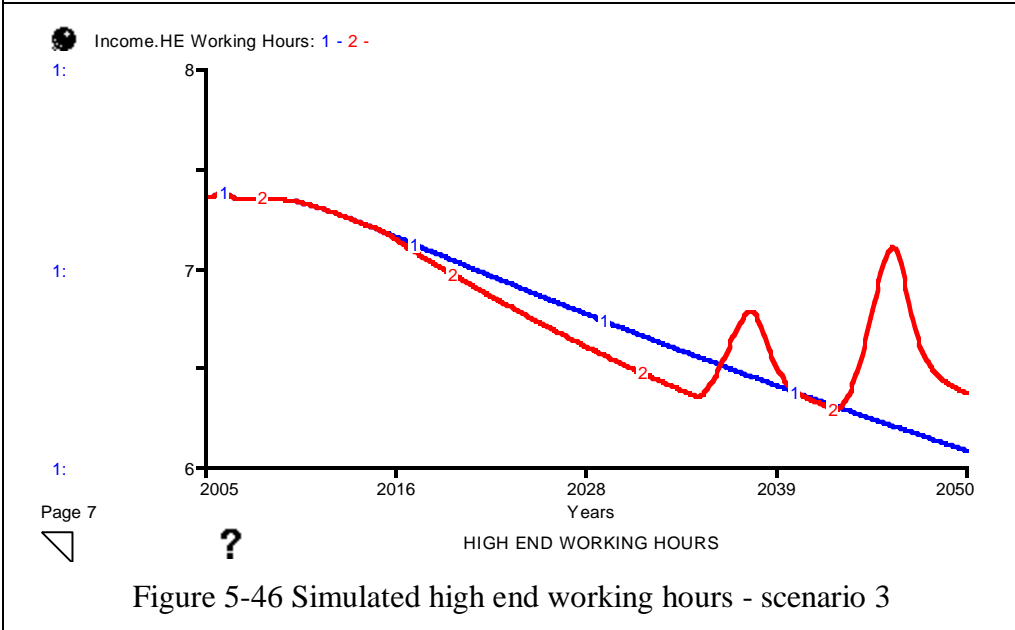
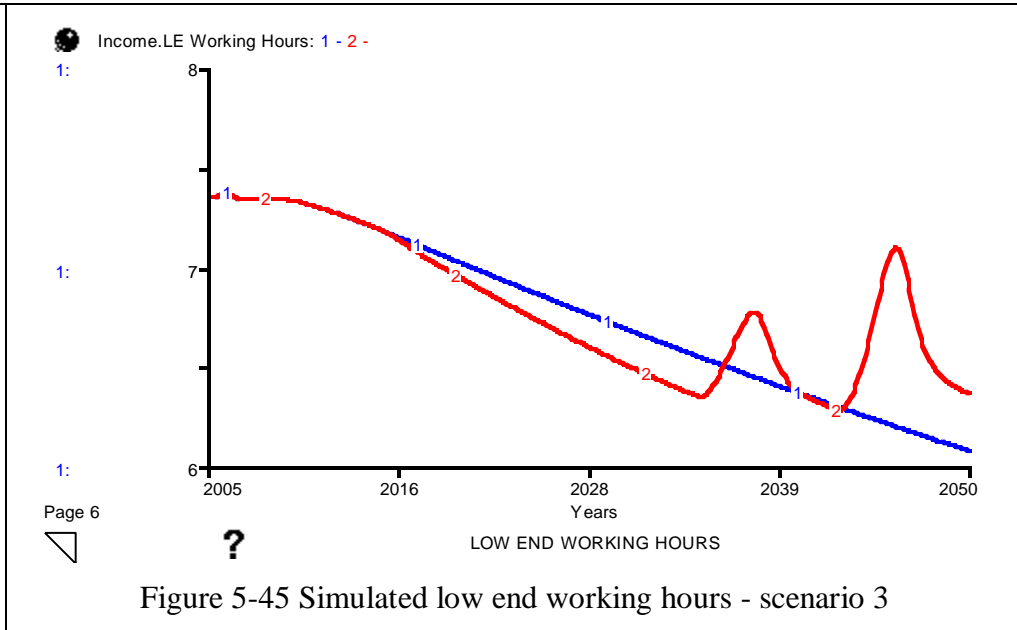
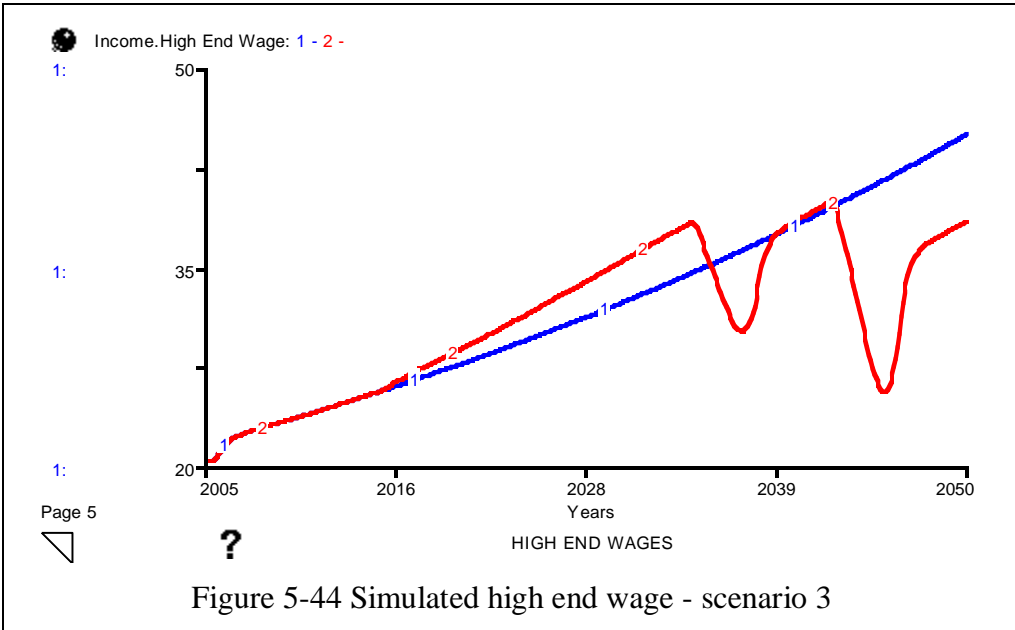
Policy settings:

- Hiring JG = IF TIME < 2015 THEN 0 ELSE (Unemployed Participating/ Employment AT);
- CHNG in Private Employment = IF TIME < 2015 THEN 0 ELSE (Employed\*Fraction of Employed Changing Employment).

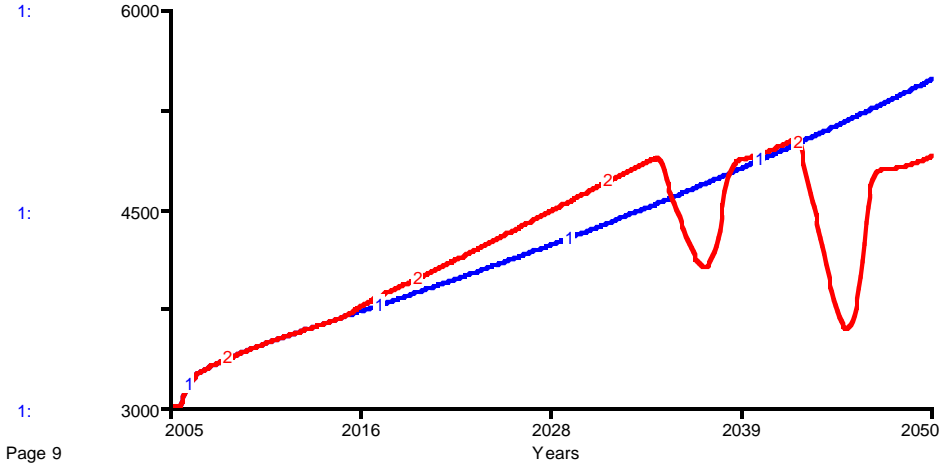
Policy results:

- Figure 5-40: Population changes in the same way as in the basic run.
- Figure 5-41: Jobs change in the same way as in the basic run.





Income.High End Income: 1 - 2 -



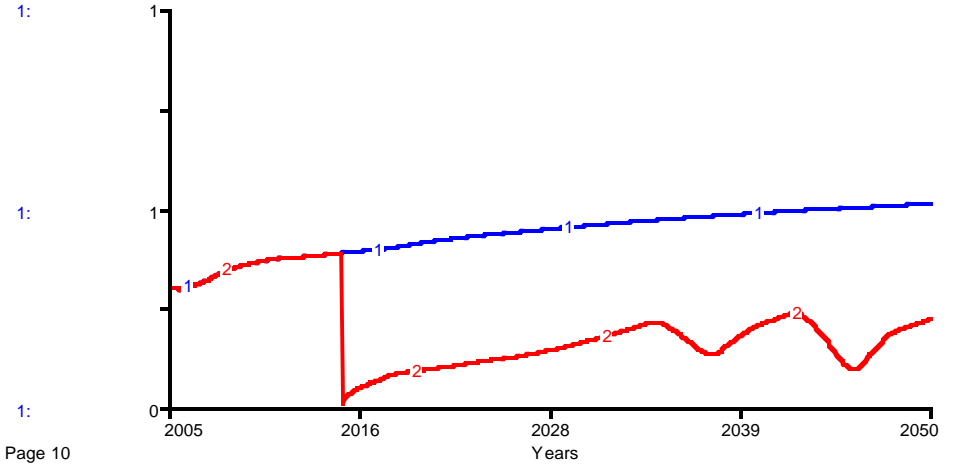
Page 9



HIGH END INCOME

Figure 5-48 Simulated high end income - scenario 3

Indicators.GINI: 1 - 2 -



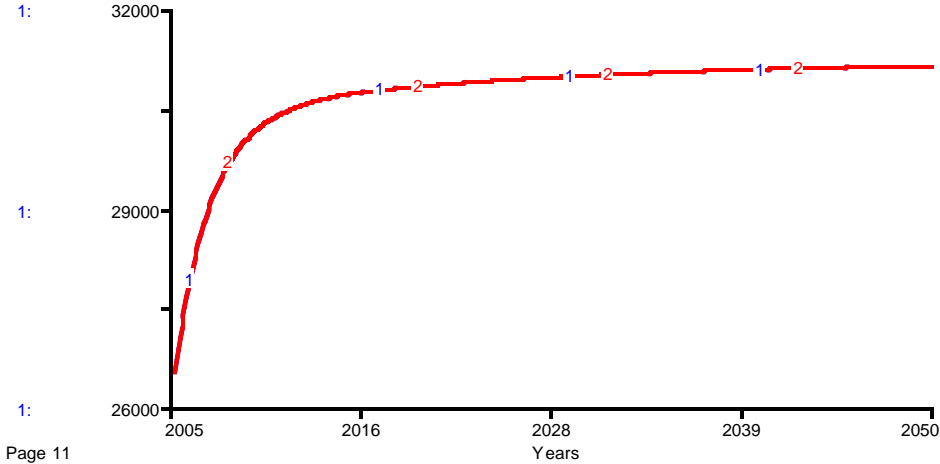
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INCOME EQUALITY

Figure 5-49 Simulated GINI index - scenario 3

Indicators.GDP per Capita: 1 - 2 -



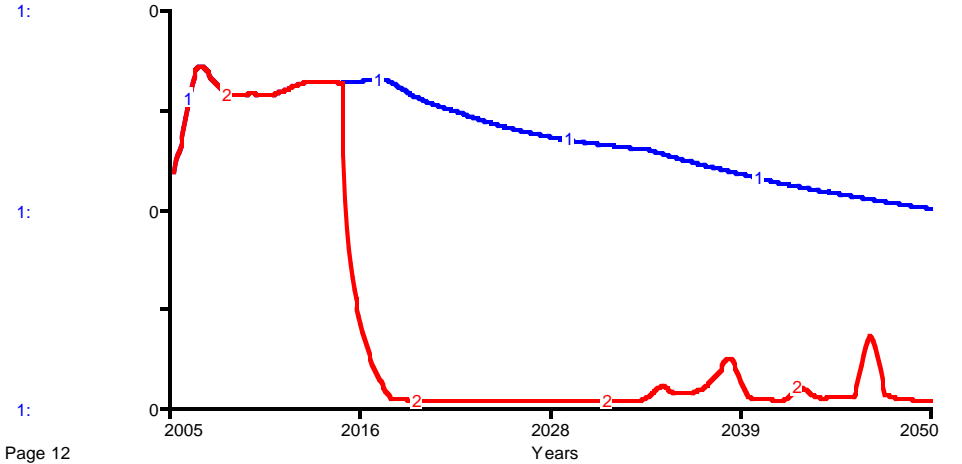
Page 11



GDP

Figure 5-50 Simulated GDP per capita - scenario 3

Employment.Unemployment: 1 - 2 -



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UNEMPLOYMENT

Figure 5-51 Simulated unemployment rate - scenario 3

- Figure 5-42: Unemployed not participating population decreases in the short term compared to basic run. As predicted by the experts, creating new public jobs for all unemployed people will increase participation and decrease the number of unemployed people not participating in the labor force. In the long the number of unemployed people not participating stabilizes at a value close to the basic run;
- Figure 5-43: Low end wages increase in the short term compared to the basic run. Unemployed population participating in the labor force is hired into the job guarantee scheme which forces private employers to increase wages in order to attract employees. However, in the long run wages start to decrease and oscillate. This happens because total number of private jobs starts to decrease and the number of employed people is too high. As a result of declining wages people start to move to public jobs again;
- Figure 5-44: High end wages also increase compared to the basic in the short term and decrease in the long term with oscillations similar to low end wages. Same explanation used in the previous policy result can be used to explain the behavior in this one;
- Figure 5-45: Low end working hours decrease in the short run compared to the basic run. This decrease happens as a result of increase in wages. Similarly when wages start to decrease and oscillate, working hours start to increase and oscillate;
- Figure 5-46: High end working hours also decrease in the short run compared to the basic run. This decrease happens as a result of increase in wages. Similarly when wages start to decrease and oscillate, working hours start to increase and oscillate;
- Figure 5-47: As a result of increasing wages, low end income increases compared to the basic run in the short term. When the wages start to decrease income follows.
- Figure 5-48: High end income exhibits the same type of behavior as the low end income and for all the same reasons;
- Figure 5-49: GINI index decreases substantially compared to the basic run. This happens because a large portion of unemployed population is employed in the job guarantee scheme and given higher income. As a result income is distributed more evenly across the population and equality increases. This behavior is predicted by the experts during the consultation process;
- Figure 5-50: GDP per capita changes in the same way as in the basic run;

- Figure 5-51: Unemployment decreases substantially compared to the basic run because government ensures that all unemployed participating people will be provided with work. This behavior is predicted by the experts during the consultation process.

Simulation results of job guarantee policy seem to be in line with the experts' predictions, particularly in the short term. Private wages increase because of shortages in the labor force. Participation increases because everyone willing to work now has guaranteed employment. Unemployment is virtually eliminated. Income equality is increased and maintained. However, there are some problems with this policy in the long term. Private wages start to decrease and working hours start to increase to compensate and keep incomes at desired levels. The reduction in wages happens because their bargaining power decreases and because demand for employees decreases. As the number of people employed in the job guarantee scheme continues to increase the power of people employed in the private sector starts to decline which allows employers to reduce their wages. At the same time total number of available private jobs starts to decline which reduces demand for labor and causes employers to reduce wages. Once the number of privately employed become too low the wages increase to attract them from the job guarantee scheme. This process continues into the future and closely resembles behavior described in the literature, which predicts these oscillations of the labor force between the public and private sector.

#### **5.2.4 Scenario 4 - Introducing dematerialization policy**

In this scenario, the effects of implementing dematerialization policy are explored. The policy is implemented in the year 2015 and it stays in effect till the end of simulation time in the year 2050. It is implemented by reducing the investments in the industrial capital through the fraction of industrial output allocated to investment variable. In the basic run this variable is part of the bigger loop which determines its value. In the scenario run the loop is cut and the value is set manually after year 2015 in order to ensure the reduction of industrial output. Simulation results are compared to the basic run in order to test the predictions made by the experts. The focus is on economic and environmental indicators which are a good proxy to the indicators mentioned by the respondents. Simulation results compared to basic run are presented on Figure 5-52 to Figure 5-63. Blue lines are results of basic run and red lines of basic and maximum income policy run.

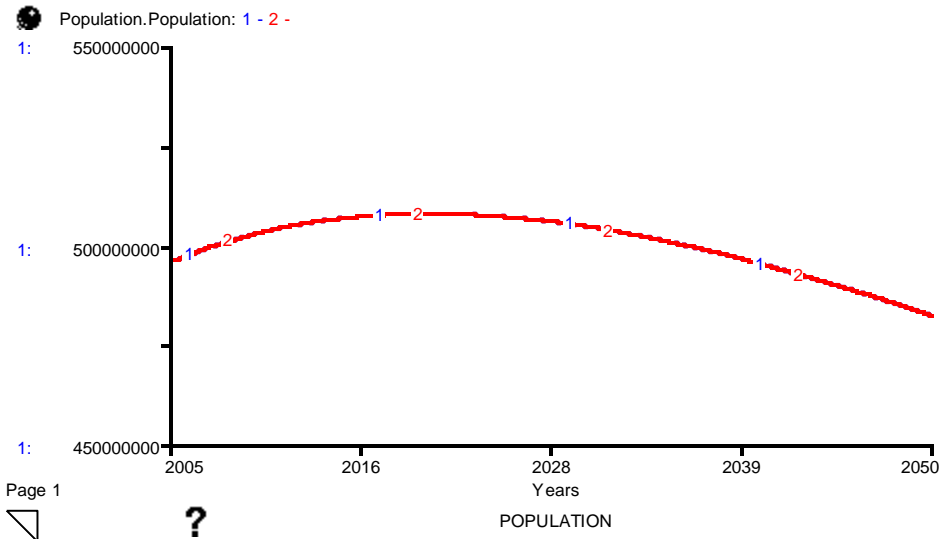


Figure 5-52 Simulated population - scenario 4

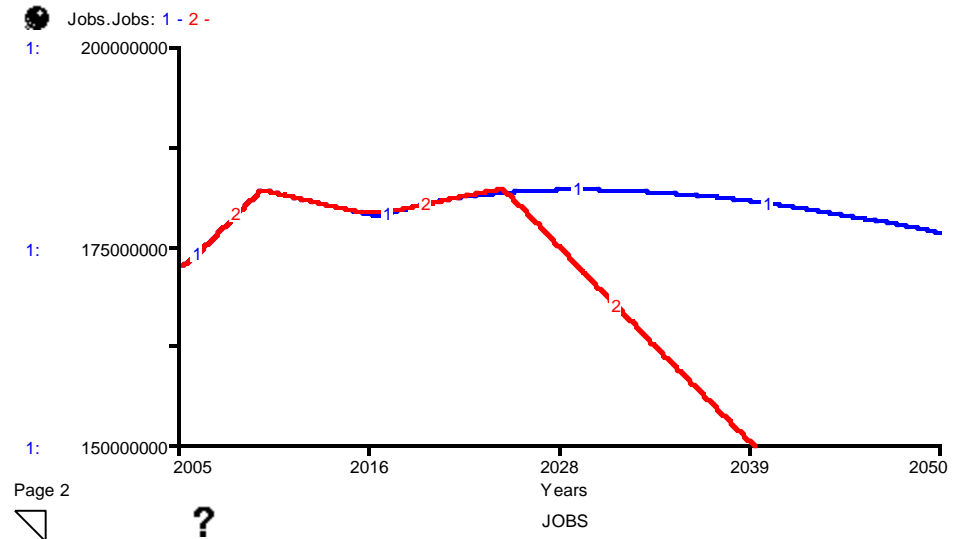


Figure 5-53 Simulated jobs - scenario 4

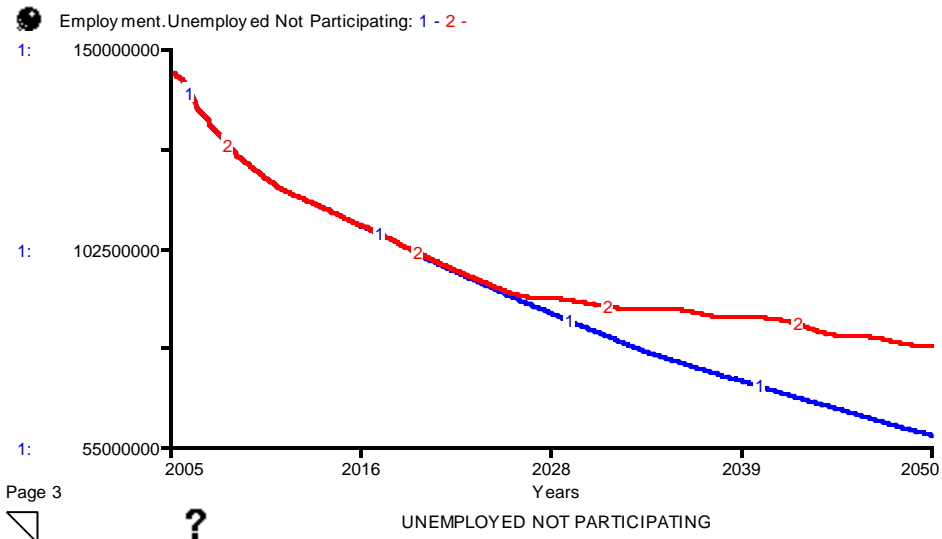


Figure 5-54 Simulated unemployed not participating - scenario 4

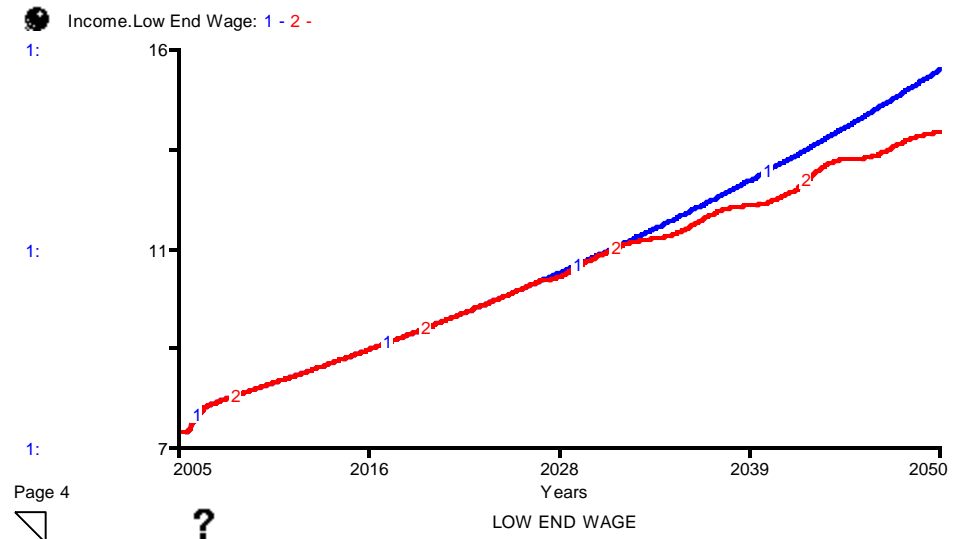


Figure 5-55 Simulated low end wage - scenario 4

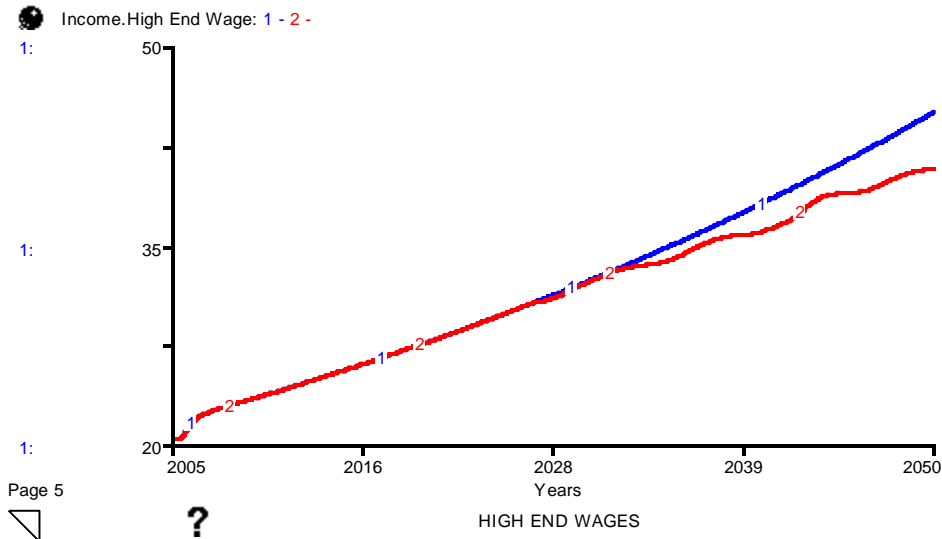


Figure 5-56 Simulated high end wage - scenario 4

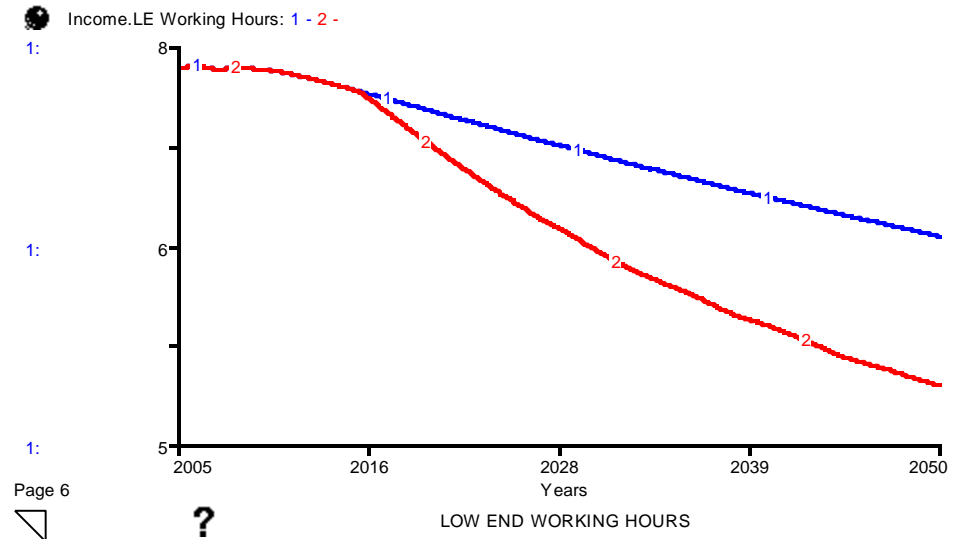


Figure 5-57 Simulated low end working hours - scenario 4

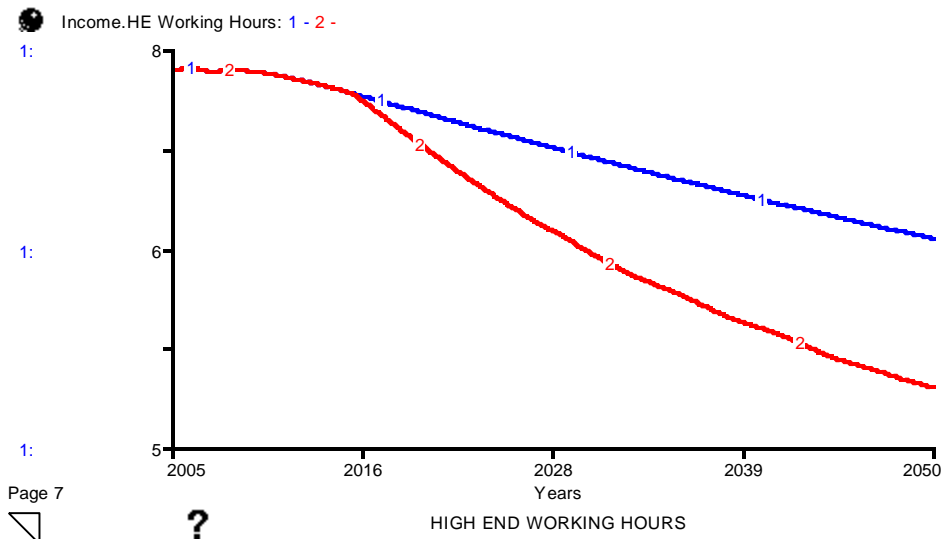


Figure 5-58 Simulated high end working hours - scenario 4

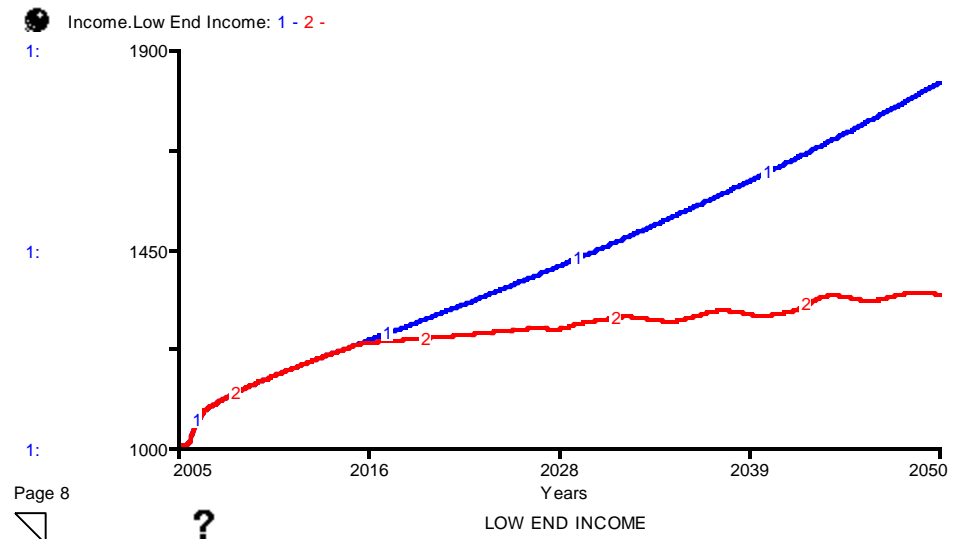


Figure 5-59 Simulated low end income - scenario 4

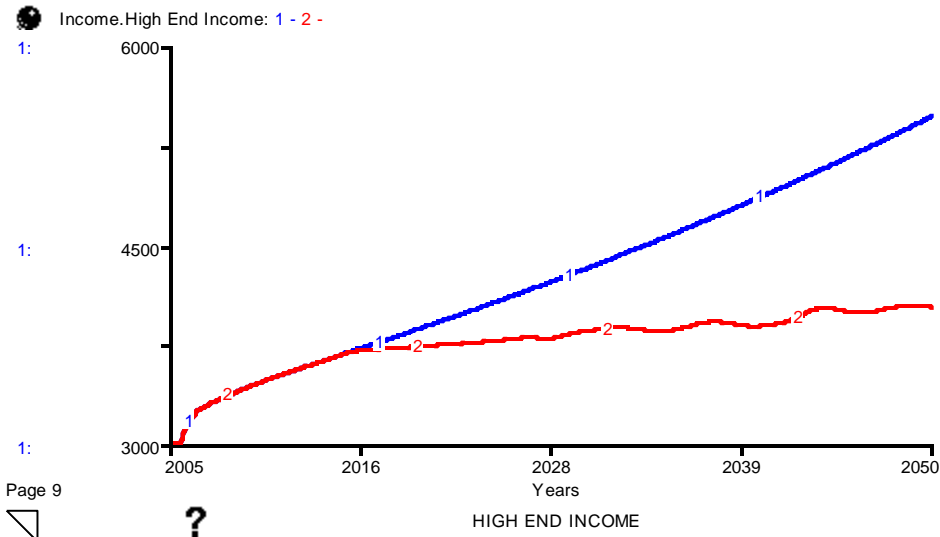


Figure 5-60 Simulated high end income - scenario 4

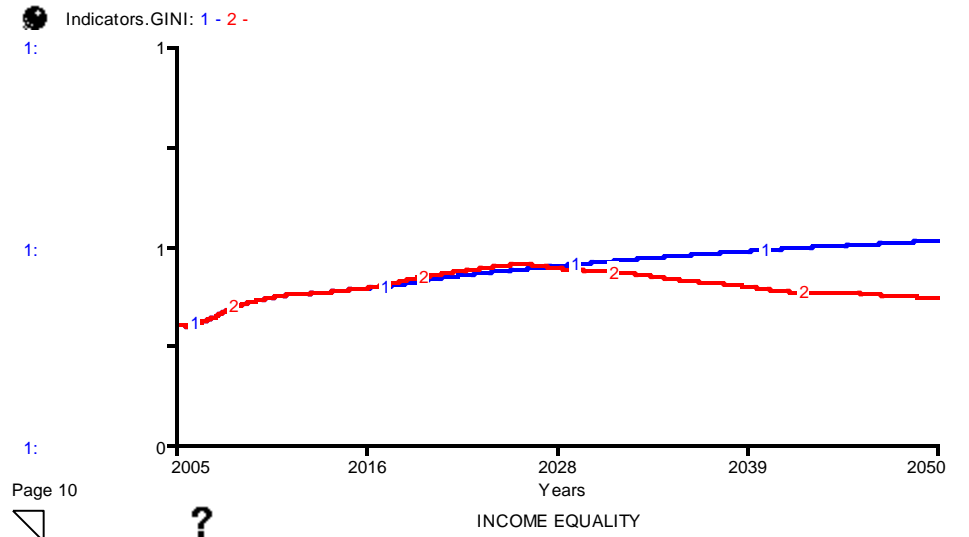


Figure 5-61 Simulated GINI index - scenario 4

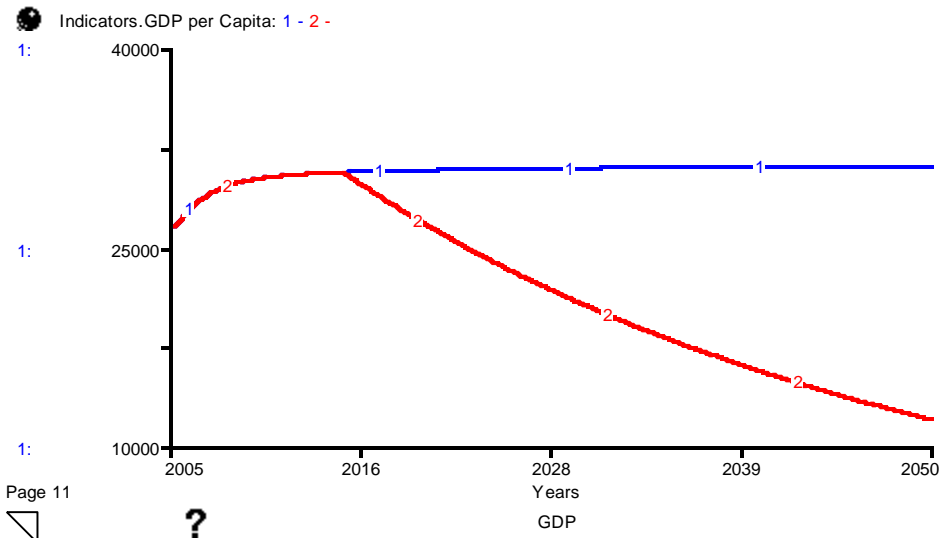


Figure 5-62 Simulated GDP per capita - scenario 4

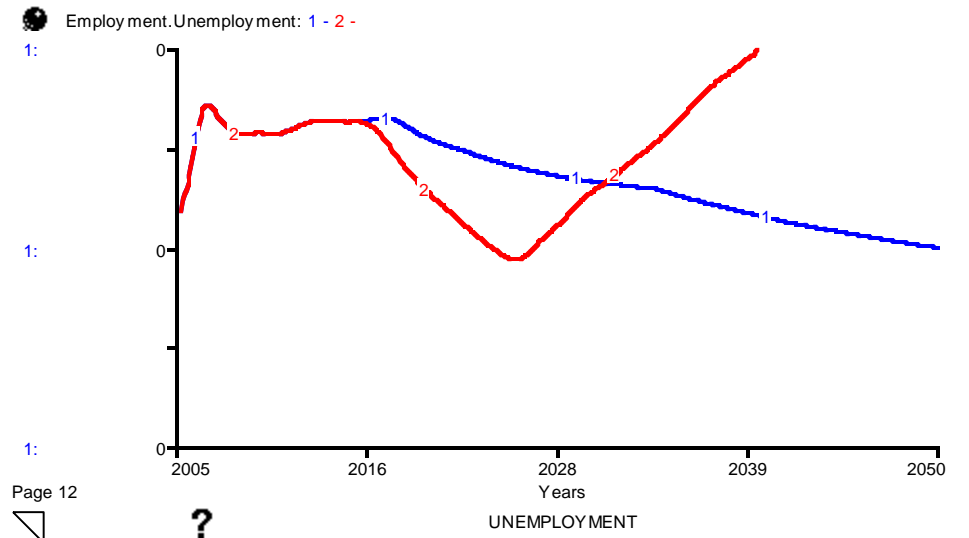


Figure 5-63 Simulated unemployment rate - scenario 4

#### Policy settings:

- Fraction of Industrial Output Allocated to Investment = IF TIME < 2015 THEN (1 - (Fraction of Industrial Output Allocated to Services + Fraction of Industrial Output Allocated to Consumption)) ELSE 0.15.

#### Policy results:

- Figure 5-52: Population changes in the same way as in the basic run;
- Figure 5-53: Number of available jobs stays the same in the short term compared to the basic run despite declining industrial and service capital. This happens because the number of workers required per unit of service and industrial capital increases as a result of declining output. In the long run this is not sustainable and the number of jobs available sharply declines;
- Figure 5-54: Unemployed not participating population increases compared to the basic run population because of the declining wages. As the dematerialization policy continues it is easier to find employees so the wages decrease. This makes employment less desirable so participation decreases;
- Figure 5-55: Low end wages decrease compared to the basic run because of reduced demand for labor caused by declining industrial capital;
- Figure 5-56: High end wages decrease compared to the basic run because of reduced demand for labor caused by declining industrial capital;
- Figure 5-57: Low end working hours decrease compared to the basic run because of declining average income of employed people. As the average income declines so does the desired income which allows people to work less;
- Figure 5-58: High end working hours decrease compared to the basic run because of declining average income of employed people. As the average income declines so does the desired income which allows people to work less;
- Figure 5-59: Low end income decreases compared to the basic run as a result of decreasing wages and working hours. Income still continues to increase but at a much slower rate than in the basic run;
- Figure 5-60: High end income decreases compared to the basic run as a result of decreasing wages and working hours. Income still continues to increase but at a much slower rate than in the basic run;

- Figure 5-61: GINI index increases slightly in the short term compared the basic run which means that the income inequalities increase. In the long run GINI index starts to decline, but unlike the other scenarios improved income distribution in this one is a result of everyone having less instead of more;
- Figure 5-62: GDP per capita decreases substantially compared to the basic run. This is a direct consequence of declining industrial output and industrial capital. This behavior was predicted by experts during the consultation process;
- Figure 5-63: Unemployment decreases in the short term compared to the basic run because of decrease in participation. As the number of jobs continues to decrease more employed people get fired and become unemployed. Because of that unemployment rate starts to increase rapidly in the long term.

Simulation results of dematerialization policy seem to be in line with experts' predictions. Working hours decrease and so do the average incomes of both low end and high end income groups. GDP also decreases and income equality slightly increases. The main difference between improvements in income distribution caused by implementation of dematerialization policy compared to previous ones is that these improvements are caused by the overall decline in incomes of all income groups. This reduces the difference between income groups which is referenced in the decrease of GINI index.

## 6 CONCLUSION

At the beginning of this thesis main research objectives and questions were identified. The main objectives were to identify common interpretations of the underlying causal structure of the main degrowth proposals, to use system dynamics modeling to make those interpretations explicit, and to see how this can be used to further expand the knowledge base and provide new evidence for degrowth claims. The four research questions were:

1. What are the most important, dynamically complex degrowth policy proposals which need to be explored using a systemic perspective?;
2. What is degrowth experts' perception of the underlying causal structure of these proposals?;
3. How can a system dynamics modeling approach be used to model and simulate a set of 'emblematic' degrowth proposals?;
4. How can these models be used to develop simulation scenarios which could test the foundational degrowth claims?.

To accomplish these objectives a four step research was conducted and results were presented in chapters 4 and 5. In the first step degrowth literature was extensively studied in order to select the most important dynamically complex degrowth policy proposals. In particular D'Alisa et al. (2015) book was an important source of concepts which could be used in this research. This book was screened according to the four criteria (dynamic nature, causal structure, controversy, and measurability), concepts were graded, and four of them were selected (basic and maximum income, work sharing, job guarantee, and dematerialization).

In the second step an online questionnaire was constructed and distributed to 45 experts who contributed in the D'Alisa et al. (2015) book. The answers collected provided an abundance of valuable information about the dynamic complexity of each of the four selected proposals. This information was processed, summarized, and presented in chapter 4. Causal loop diagrams were developed in order to visualize experts' knowledge about the underlying causal structure and predictions about the impacts these policies would have on socio-economic and environmental systems.

In the third step information collected by the means of literature review and experts' consultation was used to build a stock and flow model capable of testing some of the

predictions made by the experts. The model has four main sectors (population, jobs, employment, and income) and interactions between them are the source of dynamic complexity. The model initialized with the European Union data but it could easily be used for any single country or a region. EU data was used since it was easily accessible and the intention was to show that the model could be used in different settings and was not restricted to a single country.

In the fourth step the model was used to test four different scenarios to see if the simulated behavior matches predictions made by the experts during the consultation process. Simulation runs were compared to the basic run to compare short and long term behavior and to check for unintended consequences.

Basic run simulates the business as usual scenario. What happens if no degrowth policy is implemented? Population growth between 2005 and 2015 corresponds to available data and its development between 2015 and 2050 is consistent with current population projections. EU population is getting older, which means less births and an eventual decline in population. Decline in population will cause a decline in labor force which will slow down the economic growth. The model predicts that the growth will continue but at much slower rates than experienced before. This is also consistent with projections made by Piketty (2014). Decline in population and high performance economy will increase the wages and reduce the working hours of all employed people in all income groups. However, income increases will not be proportional. High end earners' income will grow much faster in absolute terms which will give rise to income inequalities in society. Overall, basic run predictions seem to be in line with predictions found in current economic and degrowth literature.

Results of basic and maximum income policy simulation were very consistent with predictions made by the experts. Introduction of basic income increases the power of low end earners, which improves their bargaining position and increases their wages. On the other hand maximum income restricts the income of high end earners, which reduces their bargaining power and encourages them to emigrate to countries with no maximum income. Basic and maximum income society would be one of higher income equality and no involuntary unemployment. Increased number of unemployed people not participating in the labor force might be concerning but implementing this policy had no major effect on the GDP, which indicates possibility of sustaining this society.

Results of work sharing policy simulation showed that this policy might have some surprising effects. Unlike the basic and maximum income, this policy did not cause high end earners'

emigration. Limiting working hours to four hours per day reduced the income proportionately. Even though high end earners saw their income drop, compared to other income group it stayed the same. This is the reason why growth of hourly wages stayed the same as in the basic run. Power balance did not change so the bargaining positions stayed the same. Work sharing society would also be a society of higher income equality and no unemployment, but it does not perform in these areas as good as basic and maximum income policy does. However, unlike basic and maximum income, work sharing policy does not cause high end earners' emigration and significantly reduces the working hours, allowing more free time for household and other activities.

Results of job guarantee policy simulation were very consistent with predictions made by the experts. Most importantly it seems that this policy is best suited in the short term and exhibits some problematic behaviors in the long run. Like work sharing policy it does not cause high end earners emigration and like previous policies it does not cause significant change in GDP. Unlike both basic and maximum income and work sharing policy this policy increases participation in the labor force because it offers a way of employment to everyone looking for work. Other two policies simply make it unnecessary for unemployed people to participate and look for work which reduces the unemployment. Also, unlike the other two policies this one causes increase in all wages and decrease in all working hours in the short term. Problematic behavior happens in the long run. Wages start to oscillate and decrease and people move back and forth between public and private employment. One of the respondents suggested that job guarantee policy should be a temporary measure which would help the transition to a low carbon economy. Results of this simulation would support that claim. Job guarantee society would be one of higher income equality, no unemployment, and even higher wages in the short term, however in the long term it would be necessary to find alternative way of managing employment.

Results of dematerialization policy simulation were consistent with predictions made by the experts. Implementing dematerialization would not have immediate negative impacts. Current stock of industrial capital is high enough to support the economy for a while, but eventually lack of investment in it will cause a decline in the job market. Unemployment will increase and wages will decrease along with the working hours and average incomes. Economic indicators will collapse as predicted by the experts which should also improve the environmental conditions. Dematerialization society would surely be one of significantly different lifestyle. It would be necessary to make drastic changes in society to ensure that

these measures do not affect human wellbeing negatively (simulation suggests a significant decline in human wellbeing).

Overall it can be said that all four policies tested have potential to positively influence socio-economic and environmental conditions but none of them is capable of fixing all problems on their own. Each one brings unintended consequences which could be hidden in the short term but could cause serious problems in the long term. System dynamics modeling can help identify the causes of those undesired behaviors. That way when and if they occur, policy makers will understand what is going on and will be able to adjust the policies accordingly. Supporters of degrowth can use this model to develop, test and communicate their own proposals to the public and policy makers. It could also be used as an educational tool to help students understand dynamic consequences of degrowth policies.

Future research should try to extend the model to include other important degrowth proposals, such as social enterprises which was highlighted by the experts during the consultation process as very important. This might be a start of a new degrowth “vocabulary”, which would include dynamic complexity of degrowth proposals in addition to theoretical overview. Obviously improvements in the model itself could be made. Many assumptions made in the model were made based on the answers received in the questionnaires, but other experts might have different opinions. These opinions could be implemented in the future version of the model. The model could also be used to test the effectiveness of these policies on national levels of both developed and developing nations. This would be a good way of testing the effectiveness of the proposals in different environments. Most importantly the results of this research could be used to further develop degrowth proposals in order to highlight their strengths and hide their weaknesses. One way of doing that could be development of composite policies which would consist of several different degrowth policies complementing each other in order to avoid long term problematic behavior.

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## APPENDIX A - Population sector modeling report

Formulations and comments	Units
<p>Population 0 to 14(t)=Population 0 to 14(2005)+</p> $\int_{2005}^t \text{Births}(s)ds + \text{Net Migration 0 to 14}(s)ds - \text{Maturation 14 to 15}(s)ds - \text{Deaths 0 to 14}(s)ds;$ <p>Population 0 to 14(2005)=Initial Population 0 to 14</p> <p>The stock of population 0 to 14 increases with Births and positive Net Migration 0 to 14, and decreases with Maturation 14 to 15 and Deaths 0 to 14. Maturation 14 to 15 moves people from Population 0 to 14 to Population 15 to 44. The initial number of people in stock Population 0 to 14 in year 2005 is 83.380.000. Data source: Calculated from World Bank population data and Eurostat age structure data.</p>	Person
<p>Population 15 to 44(t)=Population 15 to 44(2005)+</p> $\int_{2005}^t \text{Maturation 14 to 15} + \text{Net Migration 15 to 44}(s)ds - \text{Maturation 44 to 45}(s)ds - \text{Deaths 15 to 44}(s)ds;$ <p>Population 15 to 44(2005)=Initial Population 15 to 44</p> <p>The stock of population 15 to 44 increases with Maturation 14 to 15 and positive Net Migration 15 to 44, and decreases with Maturation 44 to 45 and Deaths 15 to 44. Maturation 44 to 45 moves people from Population 15 to 44 to Population 45 to 64. The initial number of people in stock Population 15 to 44 in year 2005 is 205.000.000. Data source: Calculated from World Bank population data and Eurostat age structure data.</p>	Person
<p>Population 45 to 64(t)=Population 45 to 64(2005)+</p> $\int_{2005}^t \text{Maturation 44 to 45} + \text{Net Migration 45 to 64}(s)ds - \text{Maturation 64 to 65}(s)ds - \text{Deaths 45 to 64}(s)ds;$ <p>Population 45 to 64(2005)=Initial Population 45 to 64</p> <p>The stock of population 45 to 64 increases with Maturation 44 to 45 and positive Net Migration 45 to 64, and decreases with Maturation 64 to 65 and Deaths 45 to 64. Maturation 64 to 65 moves people from Population 45 to 64 to Population 65 plus. The initial number of people in stock Population 45 to 64 in year 2005 is 128.515.000. Data source: Calculated from World Bank population data and Eurostat age structure data.</p>	Person
<p>Population 65 plus(t)=Population 65 plus(2005)+</p> $\int_{2005}^t \text{Maturation 64 to 65} + \text{Net Migration 65 plus}(s)ds - \text{Deaths plus}(s)ds;$ <p>Population 65 plus(2005)=Initial Population 65 plus</p> <p>The stock of population 65 plus increases with Maturation 64 to 65 and positive Net Migration 65 plus, and decreases with Deaths 65 plus. The initial number of people in stock Population 65 plus in year 2005 is 79.408.000. Data source: Calculated from World Bank population data and Eurostat age structure data.</p>	Person
<p>Births(t)=Total Fertility*Population 15 to 44(t)*0.5/Reproductive Lifetime</p>	Person/ Year
<p>Births is a rate at which people are born and added to the population. It is calculated by multiplying Population 15 to 44 with 0.5 to get the total number of women. Total number of women is multiplied with Total Fertility to get total number of children each women will on average give birth to. Total number of children is divided with</p>	

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Reproductive Lifetime to get the rate at which children are being born.

Maturation 14 to 15(t)=(Population 0 to 14(t)\*Ageing 0 to 14)/15 Person/  
Year

Maturation 14 to 15 is a rate at which people move from Population 0 to 14 to Population 15 to 44. It is calculated by multiplying Population 0 to 14 with Ageing 0 to 14 to get the total number of people which will mature. Total number of people which will mature is divided with 15 years to get the rate at which they mature.

Maturation 44 to 45(t)=(Population 15 to 44(t)\*Ageing 15 to 44)/30 Person/  
Year

Maturation 44 to 45 is a rate at which people move from Population 15 to 44 to Population 45 to 64. It is calculated by multiplying Population 15 to 44 with Ageing 15 to 44 to get the total number of people which will mature. Total number of people which will mature is divided with 30 years to get the rate at which they mature.

Maturation 64 to 65(t)=(Population 45 to 64(t)\*Ageing 45 to 64)/20 Person/  
Year

Maturation 64 to 65 is a rate at which people move from Population 45 to 64 to Population 65 plus. It is calculated by multiplying Population 45 to 64 with Ageing 45 to 64 to get the total number of people which will mature. Total number of people which will mature is divided with 20 years to get the rate at which they mature.

Deaths 0 to 14(t)=Population 0 to 14(t)\*Mortality 0 to 14 Person/  
Year

Deaths 0 to 14 is a rate at which people die in Population 0 to 14. It is calculated by multiplying Population 0 to 14 with Mortality 0 to 14 to get the rate at which people die.

Deaths 15 to 44(t)=Population 15 to 44(t)\*Mortality 15 to 44 Person/  
Year

Deaths 15 to 44 is a rate at which people die in Population 15 to 44. It is calculated by multiplying Population 15 to 44 with Mortality 15 to 44 to get the rate at which people die.

Deaths 45 to 64(t)=Population 45 to 64(t)\*Mortality 45 to 64 Person/  
Year

Deaths 45 to 64 is a rate at which people die in Population 45 to 64. It is calculated by multiplying Population 45 to 64 with Mortality 45 to 64 to get the rate at which people die.

Deaths 65 plus(t)=Population 65 plus(t)\*Mortality 65 plus Person/  
Year

Deaths 65 plus is a rate at which people die in Population 65 plus. It is calculated by multiplying Population 65 plus with Mortality 65 plus to get the rate at which people die.

Net Migration 0 to 14(t)=Total Migration\*Percentage Migrating 0 to 14 Person/  
Year

Net Migration 0 to 14 is a rate at which people migrate in or out of Population 0 to 14. It is calculated by multiplying Total Migration with Percentage Migrating 0 to 14 to get the rate at which people migrate.

Net Migration 15 to 44(t)=Total Migration\*Percentage Migrating 15 to 44 Person/

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	Year
Net Migration 15 to 44 is a rate at which people migrate in or out of Population 15 to 44. It is calculated by multiplying Total Migration with Percentage Migrating 15 to 44 to get the rate at which people migrate.	
Net Migration 45 to 64(t)=Total Migration*Percentage Migrating 45 to 64	Person/ Year
Net Migration 45 to 64 is a rate at which people migrate in or out of Population 45 to 64. It is calculated by multiplying Total Migration with Percentage Migrating 45 to 64 to get the rate at which people migrate.	
Net Migration 65 plus(t)=Total Migration*Percentage Migrating 65 plus	Person/ Year
Net Migration 65 plus is a rate at which people migrate in or out of Population 65 plus. It is calculated by multiplying Total Migration with Percentage Migrating 65 plus to get the rate at which people migrate.	
Total Migration=Population*Normal Migration Rate-High End Emigration	Person/ Year
Total Migration represents a total number of people migrating in or out of population. It is calculated by multiplying Population with Normal Migration Rate and subtracting High End Emigration.	
Population=Population 0 to 14+Population 15 to 44+population 45 to 64+ +Population 65 plus	Person
Population represents a total number of people. It is calculated by adding together all of the Population stocks.	
Deaths Working Age Population=Deaths 15 to 44(t)+Deaths 45 to 64(t)	Person/ Year
Deaths Working Age Population is the total number of people age 15 to 64 dieing per year. It is calculated by adding together Deaths 15 to 44 and Deaths 45 to 64.	
High End Emigration=High End Employed*Fraction HE Emigrating	Person/ Year
High End Emigration represents a total number of people emigrating because of the policy effects. It is calculated by multiplying High End Employed with fraction of high end earners emigrating.	
Ageing 0 to 14=1-Mortality 0 to 14	Unitless
Ageing 0 to 14 is a percentage of people in Population 0 to 14 which are going to move to Population 15 to 44. It is calculated by subtracting Mortality 0 to 14 from 1.	
Ageing 15 to 44=1-Mortality 15 to 44	Unitless
Ageing 15 to 44 is a percentage of people in Population 15 to 44 which are going to move to Population 45 to 64. It is calculated by subtracting Mortality 15 to 44 from 1.	
Ageing 45 to 64=1-Mortality 45 to 64	Unitless
Ageing 45 to 64 is a percentage of people in Population 45 to 64 which are going to move to Population 65 plus. It is calculated by subtracting Mortality 45 to 64 from 1.	

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Reproductive Lifetime=30	Year
The number of years women can give births. Data source: World 3 model.	
Total Fertility=1.5	Unitless
Average number of children a women gives birth to during her Reproductive Lifetime. Data source: Eurostat	
Mortality 0 to 14=0.001	per Year
Percentage of Population 0 to 14 which will die. Data source: World 3 model.	
Mortality 15 to 44=0.0008	per Year
Percentage of Population 15 to 44 which will die. Data source: World 3 model.	
Mortality 45 to 64=0.006	per Year
Percentage of Population 45 to 64 which will die. Data source: World 3 model.	
Mortality 65 plus=0.04	per Year
Percentage of Population 65 plus which will die. Data source: World 3 model.	
Percentage 0 to 14 Migrating=0.15	Unitless
Percentage of Population 0 to 14 migrating in or out of population. Data source: Eurostat (estimate based on graphical data in Figure 5-2).	
Percentage 15 to 44 Migrating=0.5	Unitless
Percentage of Population 15 to 44 migrating in or out of population. Data source: Eurostat (estimate based on graphical data in Figure 5-2).	
Percentage 45 to 64 Migrating=0.3	Unitless
Percentage of Population 45 to 64 migrating in or out of population. Data source: Eurostat (estimate based on graphical data in Figure 5-2).	
Percentage 65 plus Migrating=0.05	Unitless
Percentage of Population 65 plus migrating in or out of population. Data source: Eurostat (estimate based on graphical data in Figure 5-2).	
Normal Migration Rate=0.0015	per Year
Percentage of total population moving in or out of population. Data source: Eurostat	
Fraction of HE Emigrating=	
GRAPH(HE Income Ratio/HE Normal Income Ratio)	per Year
(0, 0.25) (0.2, 0.2) (0.4, 0.15) (0.6, 0.1) (0.8, 0.05) (1, 0) (1.2, 0)	
Graphical function connecting High End Income to Percentage of High End Employed Emigrating. This connection was established during the consultation process by respondents 1, 2 and 5. The values are estimated using best judgement.	

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## APPENDIX B - Jobs sector modeling report

Formulations and comments	Units
<p>Arable Land(t)=Arable Land(2005)+</p> $\int_{2005}^t \text{Land Development Rate}(s)ds - \text{Land Removal}(s)ds;$ <p>Arable Land(2005)=Initial Arable Land</p> <p>The stock of arable land decreases with Land Removal for Urban and Industrial Use. Land Removal for Urban and Industrial Use moves land from Arable Land to Urban &amp; Industrial Land. The initial surface of land in the stock Arable Land in 2005 is 190.179.239 hectares. Data source: calculated using World Bank land area data and Eurostat land cover, land use and landscape data.</p>	Hectares
<p>Urban and Industrial Land(t)=Urban and Industrial Land(2005)+</p> $\int_{2005}^t \text{Land Removal}(s)ds ;$ <p>Urban and Industrial Land(2005)=Initial Urban and Industrial Land</p> <p>The stock of urban and industrial land increases with Land Removal for Urban and Industrial Use. The initial surface of land in the stock Urban and Industrial Land in 2005 is 37.151.293 hectares. Data source: calculated using World Bank land area data and Eurostat land cover, land use and landscape data.</p>	Hectares
<p>Industrial Capital(t)=Industrial Capital(2005)+</p> $\int_{2005}^t \text{Industrial Capital Investment}(s)ds - \text{Industrial Capital Depreciation}(s)ds;$ <p>Industrial Capital(2005)=Initial Industrial Capital</p> <p>The stock of industrial capital increases with Industrial Capital Investment and decreases with Industrial Capital Depreciation. The initial value of capital in the stock Industrial Capital in 2005 is 13.234.700.000.000 Euros. Data source: calculated using World Bank GDP per capita and population data, and World 3 graphical function for calculating GDP per capita from industrial output per capita.</p>	Euros
<p>Service Capital(t)=Service Capital(2005)+</p> $\int_{2005}^t \text{Service Capital Investment}(s)ds - \text{Service Capital Depreciation}(s)ds;$ <p>Service Capital(2005)=Initial Service Capital</p> <p>The stock of service capital increases with Service Capital Investment and decreases with Service Capital Depreciation. The initial value of capital in the stock Service Capital in 2005 is 4.963.030.000.000 Euros. Data source: calculated using World 3 graphical function for calculating service output per capita from industrial output per capita.</p>	Euros
<p>Delayed Labor Utilization Fraction(t)=Delayed Labor Utilization Fraction(2005)+</p> $\int_{2005}^t \text{CHNG in DLUF}(s)ds ;$ <p>Delayed Labor Utilization Fraction(2005)=1</p> <p>The stock representing informational delay in labor utilization fraction increases with CHNG in Delayed Labor</p>	Unitless

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Utilization Fraction. The initial fraction in the stock Delayed Labor Utilization Fraction is set at 1.

$\text{Land Removal}(t) = \text{MAX}(0, (\text{Urban and Industrial Land Required} - \text{Urban \& Industrial Land}(t)) / \text{Urban and Industrial Development Time})$       Hectares/  
Year

Land Removal for Urban and Industrial Use is a rate at which arable land is turned into urban and industrial land. If the required urban and industrial land is smaller than current urban and industrial land then the Land Removal for Urban and Industrial Use will be 0. If it is higher then the difference is divided with Urban and Industrial Development Time to get the rate which land will be developed.

$\text{Industrial Capital Investment}(t) = \text{Industrial Output} * \text{Fraction of Industrial Output Allocated to Investment}$       Euros/  
Year

Industrial Capital Investment is a rate at which new industrial capital is created. It is calculated by multiplying Industrial Output with Fraction of Industrial Output Allocated to Investment to get the rate at which new capital is created.

$\text{Industrial Capital Depreciation}(t) = \text{Industrial Capital}(t) / \text{Average Life of Industrial Capital}$       Euros/  
Year

Industrial Capital Depreciation is a rate at which industrial capital depreciates. It is calculated by dividing the Industrial Capital stock with the Average Life of Industrial Capital to get the rate at which the industrial capital depreciates.

$\text{Service Capital Investment}(t) = \text{Industrial Output} * \text{Fraction of Industrial Output Allocated to Services}$       Euros/  
Year

Service Capital Investment is a rate at which new service capital is created. It is calculated by multiplying Service Output with Fraction of Industrial Output Allocated to Services to get the rate at which new capital is created.

$\text{Service Capital Depreciation}(t) = \text{Service Capital}(t) / \text{Average Life of Service Capital}$       Euros/  
Year

Service Capital Depreciation is a rate at which service capital depreciates. It is calculated by dividing the Service Capital stock with the Average Life of Service Capital to get the rate at which the service capital depreciates.

$\text{CHNG in Delayed Labor Utilization Fraction}(t) = (\text{Labor Utilization Fraction} - \text{Delayed Labor Utilization Fraction}(t)) / \text{Labor Utilization Fraction Delay Time}$       per Year

Change in delayed labor utilization fraction is a rate at which Delayed Labor Utilization Fraction changes. It is calculated by subtracting indicated Labor Utilization Fraction and Delayed Labor Utilization Fraction stock to get the discrepancy. This is then divided with Labor Utilization Fraction Delay Time to get the rate of change.

$\text{Jobs} = \text{Jobs Agriculture} + \text{Jobs Industry} + \text{Jobs Service}$       Job

Jobs is a total number of available jobs in all sectors. It is calculated by adding together Potential Jobs Agriculture, Potential Jobs Industry, and Potential Jobs Service.

$\text{Potential Jobs Agriculture} = \text{Arable Land}(t) * \text{Jobs per Hectare}$       Job

Potential Jobs Agriculture is a total number of available jobs in the agriculture sector. It is calculated by multiplying Arable Land stock with Jobs per Hectare.

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Potential Jobs Industry=Industrial Capital(t)*Jobs per Industrial Capital Unit*Job Industry Multiplier	Job
<p>Potential Jobs Industry is a total number of available jobs in the industry sector. It is calculated by multiplying Industrial Capital stock with Jobs per Industrial Capital Unit. This number is multiplied with a Job Industry Multiplier which is adapted from the World 3 model.</p>	
Potential Jobs Service=Service Capital(t)*Jobs per Service Capital Unit*0.0003	Job
<p>Potential Jobs Service is a total number of available jobs in the service sector. It is calculated by multiplying Service Capital stock with Jobs per Service Capital Unit. This number is multiplied with a Job Service Multiplier which is adapted from the World 3 model.</p>	
Urban and Industrial Land Demand=Population*Urban and Industrial Land Required per Capita	Hectares
<p>Urban and Industrial Land Demand is a total land surface required to support the existing population. It is calculated by multiplying Population with Urban and Industrial Land Required per Capita.</p>	
Industrial Output=(Industrial Capital(t)*(1-Fraction of Industrial Capital Allocated for Obtaining Resources))*Capacity Utilization Fraction/Industrial Capital Output Ratio	Euros/ Year
<p>Industrial Output is the total industrial production. It is calculated by multiplying Industrial Capital stock with fraction of industrial capital NOT allocated to obtaining resources, and capacity utilization fraction to get total amount of industrial capital used for industrial production. This is divided with Industrial Capital Output Ratio to get the Industrial Output.</p>	
Industrial Output per Capita=Industrial Output/Population	Euros/ Person- Year
<p>Industrial Output per Capita is the total industrial output per person. It is calculated by dividing Industrial Output with Population.</p>	
Fraction of Industrial Output Allocated to Investment=1-(Fraction of Industrial Output Allocated to Consumption+Fraction of Industrial Output Allocated to Services)	Unitless
<p>Fraction of Industrial Output Allocated to Investment is the percentage of industrial output which is invested in development of new industrial capital. It is calculated by adding together Fraction of Industrial Output Allocated to Consumption, Fraction of Industrial Output Allocated to Agriculture, and Fraction of Industrial Output Allocated to Services to get the total fraction of industrial output NOT allocated to investment. This is then subtracted from 1 to get the actual fraction allocated to investment.</p>	
Service Output=(Service Capital(t)*Capacity Utilization Fraction)/Service Capital Output Ratio	Euros/ Year
<p>Service Output is the total service production. It is calculated by multiplying Service Capital stock with Capacity Utilization Fraction to get the total amount of service capital used service production. This is divided with Service Capital Output Ratio to get the Service Output.</p>	
Service Output per Capita=Service Output/Population	Euros/ Person- Year
<p>Service Output per Capita is the total service output per person. It is calculated by dividing Service Output with</p>	

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Population.	
Labor Utilization Fraction=(Jobs*People per Job)/Labor Force	Unitless
Labor Utilization Fraction is the ratio of available Jobs and the Labor Force. It is calculated by multiplying Jobs with Employees per Job to get the total number of potential employees. This is divided with Labor Force to get the Labor Utilization Fraction.	
Jobs per Hectare=0.056	Job/ Hectares
Jobs per Hectare is the number of agricultural jobs available for every hectare of arable land. Data source: calculated using the World Bank population and employment data.	
Job Industry Multiplier=0.001	Unitless
Job Industry Multiplier is a constant used to calculate the number of available jobs in the industry sector. Data source: World 3 model.	
Job Service Multiplier=0.000205	
Job Service Multiplier is a constant used to calculate the number of available jobs in the service sector. Data source: adapted from World 3 model.	
Urban and Industrial Development Time=10	Year
Urban and Industrial Development Time is an average time required to close the gap between the desired urban and industrial land area and the actual urban and industrial land area. Data source: World 3 model.	
Fraction of Industrial Capital Allocated for Obtaining Resources=0.05	Unitless
Fraction of Industrial capital Allocated for Obtaining Resources is a percentage of industrial capital used to obtain new resources. Data source: World 3 model.	
Average Life of Industrial Capital=14	Year
Data source: World 3 model.	
Average Life of Service Capital=14	Year
Data source: Estimate based on World 3 model	
Industrial Capital Output Ratio=3	Year
Industrial Capital Output Ratio is a ratio of industrial capital used to produce an output over a period of time. Data source: World 3 model.	
Service Capital Output Ratio=1	Year
Service Capital Output Ratio is a ratio of service capital used to produce an output over a period of time. Data source: World 3 model.	
Labor Utilization Fraction Delay Time=2	Year
Labor Utilization Fraction Delay Time is the time required to adjust the Labor Utilization Fraction. Data source: World 3 model.	
Desired Industrial Output per Capita=8000	Euros/

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	Person- Year
Industrial Output per Capita Desired is a desired value of industrial output per person. Desired value is the same as initial value for the industrial output per capita.	
Employees per Job=1	Person/ Job
Employees per Job is the number of people each job is intended for assuming standard work day. It was not used in World 3 model because the unit for Jobs used was Person. In this model unit for Jobs is Job so this variable had to be added to make the model consistent in terms of units.	
Fraction of Industrial Output Allocated to Services=GRAPH(Service Output per Capita/ Indicated Service Output per Capita (0, 0.3)(0.5, 0.2)(1, 0.1)(1.5, 0.05)(2, 0)	Unitless
Fraction of Industrial Output Allocated to Services is a graphical function connecting Service Output per Capita to the fraction of industrial output used to develop service capital. The function uses ratio between actual and indicated service output per capita. Data source: World 3 model.	
Indicated Service Output per Capita=GRAPH(Industrial Output per Capita) (0, 200) (1000, 1500) (2000, 3200) (3000, 5000) (4000, 6100) (5000, 7250) (6000, 8250) (7000, 9000) (8000, 10000)	Euros/ Person- Year
Indicated Service Output per Capita is a graphical function connecting Industrial Output per capita to desired value of service output per capita. Data source: World 3 model.	
Urban and Industrial Land Required per Capita=GRAPH(Industrial Output per Capita) (0, 0.005) (1000, 0.008) (2000, 0.015) (3000, 0.025) (4000, 0.04) (5000, 0.055) (6000, 0.07) (7000, 0.08) (8000, 0.09)	Hectares/ Person
Graphical function connecting industrial output per capita with urban and industrial land required per capita. As the industrial output per capita increases, so does the amount of urban and industrial land required to support the population. Data source: World 3 model.	
Fraction of Industrial Output Allocated to Consumption=GRAPH(Industrial Output per Capita/Industrial Output per Capita Desired) (0, 0.3) (0.2, 0.32) (0.4, 0.34) (0.6, 0.36) (0.8, 0.38) (1, 0.43) (1.2, 0.73) (1.4, 0.77) (1.6, 0.81) (1.8, 0.82) (2, 0.83)	Unitless
Graphical function connecting the ratio between actual and desired industrial output per capita with fraction of industrial output allocated to consumption. As the ratio increases, so does the fraction of industrial output allocated to consumption. Data source: World 3 model.	
Jobs per Industrial Capital Unit=GRAPH(Industrial Output per Capita) (250, 0.37) (1000, 0.18) (1750, 0.12) (2500, 0.09) (3250, 0.07) (4000, 0.06) (4750, 0.05) (5500, 0.047)	Job/ Euros
Graphical function connecting industrial output per capita with jobs per industrial capital unit. If the industrial output per capita increases jobs per industrial capital unit decrease. Data source: World 3 model.	

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Jobs per Service Capital Unit=GRAPH(Service Output per Capita)

(250, 1.1) (1000, 0.6) (1750, 0.35) (2500, 0.2) (3250, 0.15) (4000, 0.145)

Job/

(4750, 0.14) (5500, 0.135) (6250, 0.130) (7000, 0.125) (7750, 0.12) (8500, 0.116)

Euros

(9250, 0.113) (10000, 0.111) (10750, 0.11) (11500, 0.099) (12250, 0.098) (13000, 0.097)

Graphical function connecting service output per capita with jobs per service capital unit. If the service output per capita increases jobs per service capital unit decrease. Data source: World 3 model.

Capacity Utilization Fraction=GRAPH(Delayed Labor Utilization Fraction)

Unitless

(1, 1) (3, 0.9) (5, 0.7) (7, 0.3) (9, 0.1) (11, 0.1)

Graphical function connecting delayed labor utilization fraction with capacity utilization fraction. If the delayed labor utilization fraction increases, the capacity utilization fraction decreases. Data source: World 3 model.

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## APPENDIX C - Employment sector modeling report

Formulations and comments	Units
$\text{Unemployed Participating}(t) = \text{Unemployed Participating}(2005) + \int_{2005}^t \text{New Adults Looking for a Job}(s) ds + \text{CHNG in Participation}(s) ds - \text{CHNG in Employment}(s) ds - \text{Deaths Unemployed}(s) ds - \text{Retirement Unemployed Participating}(s) ds - \text{Hiring JG}(s) ds;$ $\text{Unemployed Participating}(2005) = \text{Initial Unemployed Participating}$ <p>The stock of unemployed people participating in the labor force increases with addition of new adults looking for a job and a positive change in participation. It decreases with a positive flow of change in employment, deaths, retirement, and hiring to job guarantee scheme. The initial number of unemployed participating people in 2005 is 16.845.253 people. Data source: calculated using Eurostat population data and World Bank employment and unemployment data.</p>	Person
$\text{Unemployed Not Participating}(t) = \text{Unemployed Not Participating}(2005) + \int_{2005}^t \text{New Adults Not Looking for a Job}(s) ds - \text{CHNG in Participation}(s) ds - \text{Deaths Unemployed}(s) ds - \text{Retirement Unemployed Participating}(s) ds;$ $\text{Unemployed Not Participating}(2005) = \text{Initial Unemployed Not Participating}$ <p>The stock of unemployed people not participating in the labor force increases with addition of new adults not looking for a job. It decreases with a positive flow of change in participation, deaths and retirement. The initial number of unemployed not participating people in 2005 is 144.242.492 people. Data source: calculated using Eurostat population data and World Bank employment and unemployment data.</p>	Person
$\text{Employed}(t) = \text{Employed}(2005) + \int_{2005}^t \text{CHNG in Employment}(s) ds + \text{CHNG in Private Employment}(s) ds - \text{Deaths Employed}(s) ds - \text{Retirement Employed}(s) ds - \text{Economic Emigration}(s) ds;$ $\text{Employed}(2005) = \text{Initial Employed}$ <p>The stock of employed people increases with positive flows of change in employment and change in private employment. It decreases with deaths, retirement and economic emigration. The initial number of employed people in 2005 is 172.427.255 people. Data source: calculated using Eurostat population data and World Bank employment data.</p>	Person
$\text{Retired}(t) = \text{Retired}(2005) + \int_{2005}^t \text{Retirement Unemployed Participating}(s) ds + \text{Retirement Unemployed Not Participating}(s) ds + \text{Retirement Employed}(s) ds + \text{Retirement JG}(s) ds - \text{Deaths Retired}(s) ds;$ $\text{Retired}(2005) = \text{Initial Retired}$ <p>The stock of retired people increases with retirement of unemployed and employed people, and it decreases with deaths. The initial number of retired people in 2005 is 79.408.000 people, which is the same number as the initial</p>	Person

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value of people age 65 plus.

Job Guarantee(t)=Job Guarantee(2005)+

$$\int_{2005}^t \text{Hiring JG(s)ds} - \text{CHNG in Private Employment(s)ds} - \text{Deaths JG(s)ds} - \text{Retirement JG(s)ds};$$

Person

Retirement JG(s)ds;

Job Guarantee(2005)=0

The stock of people employed in job guarantee scheme increases with hiring and decreases with a positive flow of change in private employment, deaths and retirement. The initial number of people employed in the job guarantee scheme is 0 since this is a policy proposal.

New Adults Looking for a Job(t)=Maturation 14 to 15(t)\*Normal Participation Rate Person/  
Year

New Adults Looking For a Job is a rate at which people are added to the stock of unemployed people participating in the labor force. It is calculated by multiplying number of people maturing from age 14 to age 15 with a normal participation rate.

New Adults Looking Not for a Job(t)=Maturation 14 to 15(t)\*  
(1-Normal Participation Rate) Person/  
Year

New Adults Not Looking For a Job is a rate at which people are added to the stock of unemployed people not participating in the labor force. It is calculated by multiplying number of people maturing from age 14 to age 15 with a normal participation rate subtracted from 1.

CHNG in Participation(t)=((Indicated Participation Rate-Real Participation Rate)\*  
Working Age Population)/Participation AT Person/  
Year

CHNG in Participation is a rate at which people move between the stocks of unemployed participating and unemployed not participating people. It is calculated by subtracting indicated and real participation rates to get the discrepancy. This number is multiplied with working age population to calculate the total number of people which needs to move from one stock to the other. This is divided with Participation AT to get the rate at which they move.

Deaths Unemployed Participating(t)=(Unemployed Participating(t)/Working Age  
Population)\*Deaths Working Age Population Person/  
Year

Deaths Unemployed Participating is the rate at which unemployed participating people die. It is calculated by dividing the stock of unemployed participating people with total number of working age people to get the fraction of all working age people dying in the unemployed participating population. This is then multiplied with Deaths Working Age Population to get the rate at which people die.

Deaths Unemployed Not Participating(t)=(Unemployed Not Participating(t)/Working  
Age Population)\*Deaths Working Age Population Person/  
Year

Deaths Unemployed Not Participating is the rate at which unemployed not participating people die. It is calculated by dividing the stock of unemployed not participating people with total number of working age people to get the fraction of all working age people dying in the unemployed not participating population. This is then multiplied with Deaths Working Age Population to get the rate at which people die.

Deaths Employed(t)=(Employed(t)/Working Age Population)\*Deaths Working Age  
Population Person/  
Year

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Deaths Employed is the rate at which Employed people die. It is calculated by dividing the stock of Employed people with total number of working age people to get the fraction of all working age people dying in the Employed population. This is then multiplied with Deaths Working Age Population to get the rate at which people die.

Deaths Retired(t)=Deaths 65 plus(t) Person/  
Year

Deaths Retired is the rate at which retired people die. It is the same as the rate at which people aged 65 plus die.

Retirement Unemployed Participating(t)=(Unemployed Participating(t)/Working Age Population)\*Maturation 64 to 65(t) Person/  
Year

Retirement Unemployed Participating is the rate at which unemployed participating people retire. It is calculated by dividing the stock of unemployed participating people with total number of working age people to get the fraction of all working age people retiring in the unemployed participating population. This is then multiplied with Maturation 64 to 65 to get the rate at which people retire.

Retirement Unemployed Not Participating(t)=(Unemployed Not Participating(t)/Working Age Population)\*Maturation 64 to 65(t) Person/  
Year

Retirement Unemployed Not Participating is the rate at which unemployed not participating people retire. It is calculated by dividing the stock of unemployed not participating people with total number of working age people to get the fraction of all working age people retiring in the unemployed not participating population. This is then multiplied with Maturation 64 to 65 to get the rate at which people retire.

Retirement Employed(t)=(Employed(t)/Working Age Population)\*Maturation 64 to 65(t) Person/  
Year

Retirement Employed is the rate at which employed people retire. It is calculated by dividing the stock of employed people with total number of working age people to get the fraction of all working age people retiring in the employed population. This is then multiplied with Maturation 64 to 65 to get the rate at which people retire.

Economic Emigration(t)=High End Emigration Person/  
Year

Economic Emigration is the rate at which high end earners emigrate as a result of policies. It is the same value as high end emigration.

CHNG in Employment(t)=Perceived Employees Demand/ Employment AT Person/  
Year

CHNG in Employment is a rate at which people move between unemployed participating and employed stocks. It is calculated by dividing perceived employees demand with employment adjustment time.

Hiring JG(t)=IF TIME<2015 THEN (Unemployed Participating(t)/Employment AT)\* JG SWITCH Person/  
Year

Hiring JG is a rate at which unemployed participating people are added to the job guarantee scheme. It is calculated by dividing the stock of unemployed participating people with employment adjustment time. This flow is active only when job guarantee policy is active.

Deaths JG(t)=(Job Guarantee(t)/Working Age Population)\*Deaths Working Age Population Person/

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	Year
<p>Deaths JG is the rate at which people employed in job guarantee scheme die. It is calculated by dividing the stock of job guarantee people with total number of working age people to get the fraction of all working age people dying in the job guarantee population. This is then multiplied with Deaths Working Age Population to get the rate at which people die.</p>	
Retirement JG(t)=(Job Guarantee(t)/Working Age Population)*Maturation 64 to 65(t)	Person/ Year
<p>Retirement JG is the rate at which people employed in job guarantee scheme retire. It is calculated by dividing the stock of job guarantee people with total number of working age people to get the fraction of all working age people retiring in the job guarantee population. This is then multiplied with Maturation 64 to 65 to get the rate at which people retire.</p>	
CHNG in Private Employment(t)=IF TIME<2015 THEN 0 ELSE (Employed(t)*Fraction of Employed Changing Employment)*JG SWITCH	Person/ Year
<p>CHNG in Private Employment is a rate at which people move between stocks of job guarantee and employed people. It is calculated by multiplying the stock of employed people with fraction of employed changing employment. This flow is only active when job guarantee policy is active.</p>	
Working Age Population=Unemployed Participating(t)+Unemployed Not Participating(t)+Employed(t)+Job Guarantee(t)	Person
<p>Working Age Population is the total number of people age 15 to 64. It is calculated by adding together stocks of unemployed participating, unemployed not participating, employed and job guarantee people.</p>	
Labor Force=Employed(t)+Unemployed Participating(t)+Job Guarantee(t)	Person
<p>Labor Force is the total number of people working or looking for work. It is calculated by adding together stocks of employed, unemployed participating and job guarantee people.</p>	
Low End Employed=Employed(t)*Low End Percentage	Person
<p>Low End Employed is the total number of employed people working in low paying jobs. It is calculated by multiplying the stock of employed people with percentage of low end employed.</p>	
Mid End Employed=Employed(t)*Mid End Percentage	Person
<p>Mid End Employed is the total number of employed people working in mid paying jobs. It is calculated by multiplying the stock of employed people with percentage of mid end employed.</p>	
High End Employed=Employed(t)*High End Percentage	Person
<p>High End Employed is the total number of employed people working in high paying jobs. It is calculated by multiplying the stock of employed people with percentage of high end employed.</p>	
Indicated Participation Rate=Normal Participation Rate*Effect of Mean Income on Participation*Effect of Working Hours on Participation	Unitless
<p>Indicated Participation Rate is a participation rate corrected with effects of mean income and working hours. It is calculated by multiplying Normal Participation Rate with Effect of Mean Income on Participation and Effect of Working Hours on Participation.</p>	
Real Participation Rate=Labor Force/Working Age Population	Unitless

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Low End Percentage=0.17	Unitless
Percentage of people working in low end jobs. Data source: World Bank data on share of low end earners in the total employed population.	
Mid End Percentage=0.78	Unitless
Percentage of people working in mid end jobs. Data source: estimated.	
High End Percentage=0.05	Unitless
Percentage of people working in high end jobs. Data source: estimated.	
Normal Participation Rate=0.57	Unitless
Standard participation rate based on the historic data. Data source: World Bank labor participation data.	
Participation AT=0.5	Year
Participation AT is the time required to move people between the unemployed participating and unemployed not participating stocks. Data source: estimated.	
Normal Employment AT=0.5	Year
Normal Employment AT is the standard time required to move people between the unemployed participating and employed stocks. Data source: estimated.	
JG SWITCH=1	Unitless
Policy switch that activates job guarantee policy.	
Effect of Working Hours on Participation=GRAPH(Average Working Time)	
(0, 1.21) (1, 1.17) (2, 1.14) (3, 1.12) (4, 1.1) (5, 1.07)	Unitless
(6, 1.05) (7, 1.03) (8, 1) (9, 0.98) (10, 0.96)	
Effect of Working Hours on Participation is a graphical function connecting average working hours with participation. This connection was established during consultation process by respondents 3 and 5. Higher the average working hours lower the participation in the labor force.	
Effect of Mean Income on Participation=GRAPH(Employed Mean Income/	
Unemployed Mean Income)	
(0, 0.55) (0.625, 0.56) (1.25, 0.58) (1.875, 0.61) (2.5, 0.63) (3.125, 0.67)	Unitless
(3.75, 0.7) (4.375, 0.74) (5, 0.78) (5.625, 0.83) (6.250, 0.9) (6.875, 1)	
(7.5, 1.1) (8.125, 1.15) (8.750, 1.19) (9.375, 1.23) (10, 1.25)	
Effect of Mean Income on Participation is a graphical function connecting mean income to participation in the labor force. This connection was established during consultation process by respondents 1 and 5. If the mean income of employed people increases compared to unemployed people people will be more likely to participate in the labor force.	
Effect of Unemployment on Employment AT=GRAPH(Unemployment)	
(0, 1.4) (0.05, 1.3) (0.1, 1) (0.15, 0.75) (0.2, 0.5) (0.25, 0.5)	Unitless
Effect of Unemployment on Employment AT is a graphical function connecting availability of unemployed labor force with time required to hire or fire people. If the unemployment is low it is more difficult to find	

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employees so the hiring proces is slower. Also employers are more reluctant to fire employees since it may be hard to find new ones in the future. On the other side if the unemployment is high it is easier to find new employees and to fire existing ones so the adjustment time is lower.

Fraction of Employed Changing Employment=GRAPH(Attractiveness of JG Scheme)

(0.3, 0.031) (0.34, 0.028) (0.38, 0.025) (0.42, 0.017) (0.46, 0.01) (0.5, 0) per Year

(0.54, -0.01) (0.58, -0.017) (0.62, -0.025) (0.66, -0.028) (0.7, -0.031)

Fraction of Employed Changing Employment is a graphical function connecting attractiveness of job guarantee employment with movement between the job guarantee and employment stocks. This relationship was establishe during the consultation process by respondentes 3 and 5.

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## APPENDIX D - Income sector modeling report

Formulations and comments	Units
$\text{Low End Wage}(t) = \text{Low End Wage}(2005) + \int_{2005}^t \text{CHNG in LE Wage}(s) ds;$	Euros/
$\text{Low End Wage}(2005) = \text{Initial Low End Wage}$	Hour
<p>The stock of Low End Wage changes with CHNG in LE Wages. Initial wage for low end earners is 6.8 Euros per hour. Data source: Estimated using Eurostat income distribution data and World Bank employment data.</p>	
$\text{Mid End Wage}(t) = \text{Mid End Wage}(2005) + \int_{2005}^t \text{CHNG in ME Wage}(s) ds;$	Euros/
$\text{Mid End Wage}(2005) = \text{Initial Mid End Wage}$	Hour
<p>The stock of Mid End Wage changes with CHNG in ME Wages. Initial wage for mid end earners is 13.6 Euros per hour. Data source: Estimated using Eurostat income distribution data and World Bank employment data.</p>	
$\text{High End Wage}(t) = \text{High End Wage}(2005) + \int_{2005}^t \text{CHNG in HE Wage}(s) ds;$	Euros/
$\text{High End Wage}(2005) = \text{Initial High End Wage}$	Hour
<p>The stock of High End Wage changes with CHNG in HE Wages. Initial wage for mid end earners is 20.4 Euros per hour. Data source: Estimated using Eurostat income distribution data and World Bank employment data.</p>	
$\text{LE Working Hours}(t) = \text{LE Working Hours}(2005) + \int_{2005}^t \text{CHNG in LE Working Hours}(s) ds;$	Hour/
$\text{LE Working Hours}(2005) = \text{Initial LE Working Hours}$	Day-Person
<p>The stock of low end working hours changes with CHNG in LE Working Hours. Initial working hours for low end earners is 7.365 hours per day. Data source: calculated using World Bank employment data.</p>	
$\text{ME Working Hours}(t) = \text{ME Working Hours}(2005) + \int_{2005}^t \text{CHNG in ME Working Hours}(s) ds;$	Hour/
$\text{ME Working Hours}(2005) = \text{Initial ME Working Hours}$	Day-Person
<p>The stock of mid end working hours changes with CHNG in ME Working Hours. Initial working hours for mid end earners is 7.365 hours per day. Data source: calculated using World Bank employment data.</p>	
$\text{HE Working Hours}(t) = \text{HE Working Hours}(2005) + \int_{2005}^t \text{CHNG in HE Working Hours}(s) ds;$	Hour/
$\text{HE Working Hours}(2005) = \text{Initial HE Working Hours}$	Day-Person
<p>The stock of mid end working hours changes with CHNG in ME Working Hours. Initial working hours for mid end earners is 7.365 hours per day. Data source: calculated using World Bank employment data.</p>	
$\text{CHNG in LE Wage}(t) = (\text{Indicated LE Wage} - \text{Low End Wage}) / \text{Wage AT}$	Euros/
	Hour-Year
<p>CHNG in LE Wage is a rate at which the low end wages change. It is calculated by subtracting the stock of Low</p>	

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End Wage from Indicated LE Wage. This value is then divided with adjustment time to get the rate of change.

$$\text{CHNG in ME Wage}(t)=\frac{\text{Indicated ME Wage}-\text{Mid End Wage}}{\text{Wage AT}} \quad \begin{array}{l} \text{Euros/} \\ \text{Hour-Year} \end{array}$$

CHNG in ME Wage is a rate at which the mid end wages change. It is calculated by subtracting the stock of Mid End Wage from Indicated ME Wage. This value is then divided with adjustment time to get the rate of change.

$$\text{CHNG in HE Wage}(t)=\frac{\text{Indicated HE Wage}-\text{High End Wage}}{\text{Wage AT}} \quad \begin{array}{l} \text{Euros/} \\ \text{Hour-Year} \end{array}$$

CHNG in HE Wage is a rate at which the high end wages change. It is calculated by subtracting the stock of High End Wage from Indicated HE Wage. This value is then divided with adjustment time to get the rate of change.

$$\text{CHNG in LE Working Hours}(t)=\frac{\text{Indicated LE Working Hours}-\text{HE Working Hours}}{\text{Working Hours AT}} \quad \begin{array}{l} \text{Hour/} \\ \text{Day-Person-} \\ \text{Year} \end{array}$$

CHNG in LE Working Hours is a rate at which the low end working hours change. It is calculated by subtracting the stock of LE Working Hours from Indicated LE Working Hours. This value is then divided with adjustment time to get the rate of change.

$$\text{CHNG in ME Working Hours}(t)=\frac{\text{Indicated ME Working Hours}-\text{ME Working Hours}}{\text{Working Hours AT}} \quad \begin{array}{l} \text{Hour/} \\ \text{Day-Person-} \\ \text{Year} \end{array}$$

CHNG in ME Working Hours is a rate at which the mid end working hours change. It is calculated by subtracting the stock of ME Working Hours from Indicated ME Working Hours. This value is then divided with adjustment time to get the rate of change.

$$\text{CHNG in HE Working Hours}(t)=\frac{\text{Indicated HE Working Hours}-\text{HE Working Hours}}{\text{Working Hours AT}} \quad \begin{array}{l} \text{Hour/} \\ \text{Day-Person-} \\ \text{Year} \end{array}$$

CHNG in HE Working Hours is a rate at which the high end working hours change. It is calculated by subtracting the stock of HE Working Hours from Indicated HE Working Hours. This value is then divided with adjustment time to get the rate of change.

$$\text{Employed Mean Income}=\frac{\text{Low End Income}*\text{Low End Employed}(t)+\text{Mid End Income}*\text{Mid End Employed}(t)+\text{High End Income}*\text{High End Employed}(t)+\text{Job Guarantee}(t)*\text{JG Income}}{\text{Low End Employed}+\text{Mid End Employed}+\text{High End Employed}+\text{Job Guarantee}} \quad \begin{array}{l} \text{Euros/} \\ \text{Month-} \\ \text{Person} \end{array}$$

Employed Mean Income is the average monthly income of all employed people. It is calculated by dividing total income with total number of employed people.

$$\text{Low End Income}=\text{Low End Wage}(t)*\text{Low End Working Hours}(t)*\text{Days per Month}+\text{Basic Income} \quad \begin{array}{l} \text{Euros/} \\ \text{Month-} \\ \text{Person} \end{array}$$

Low End Income is the average monthly income of low end earners. It is calculated by multiplying Low End Wage with Low End Working Hours to get a daily income. This is multiplied with the number of days an employed person works in a single month to get the monthly income. If the basic income policy is enforced this is added to the the total sum.

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Mid End Income=Mid End Wage(t)*Mid End Working Hours(t)*Days per Month+	Euros/
Basic Income	Month- Person

Mid End Income is the average monthly income of mid end earners. It is calculated by multiplying Mid End Wage with Mid End Working Hours to get a daily income. This is multiplied with the number of days an employed person works in a single month to get the monthly income. If the basic income policy is enforced this is added to the the total sum.

High End Income=High End Wage(t)*High End Working Hours(t)*Days per Month+	Euros/
Basic Income	Month- Person

High End Income is the average monthly income of high end earners. It is calculated by multiplying High End Wage with High End Working Hours to get a daily income. This is multiplied with the number of days an employed person works in a single month to get the monthly income. If the basic income policy is enforced this is added to the the total sum.

Indicated LE Wage=Normal LE Wage*Effect of LE Power on Wages*Effect of Demand	Euros/
on Wages	Hour

Indicated LE Wage is the average monthly income of low end earners corrected with effects of power and demand. It is calculated by multiplying Normal LE Wage with effects of power and demand on wages.

Indicated ME Wage=Normal ME Wage*Effect of ME Power on Wages*Effect of Demand	Euros/
on Wages	Hour

Indicated ME Wage is the average monthly income of mid end earners corrected with effects of power and demand. It is calculated by multiplying Normal ME Wage with effects of power and demand on wages.

Indicated HE Wage=Normal HE Wage*Effect of HE Power on Wages*Effect of Demand	Euros/
on Wages	Hour

Indicated HE Wage is the average monthly income of high end earners corrected with effects of power and demand. It is calculated by multiplying Normal HE Wage with effects of power and demand on wages.

Normal LE Wage=SMTH1(Low End Wages(t),5,Low End Wages(t))	Euros/
	Hour

Normal LE Wage is the average monthly income expected by the low end earners. It is calculated by smoothing Low End Wages over period of 5 years.

Normal ME Wage=SMTH1(Mid End Wages(t),5,Mid End Wages(t))	Euros/
	Hour

Normal ME Wage is the average monthly income expected by the mid end earners. It is calculated by smoothing Mid End Wages over period of 5 years.

Normal HE Wage=SMTH1(High End Wages(t),5,High End Wages(t))	Euros/
	Hour

Normal HE Wage is the average monthly income expected by the high end earners. It is calculated by smoothing High End Wages over period of 5 years.

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LE Income Ratio=Low End Income/Employed Mean Income	Unitless
LE Income Ratio is a ratio between Low End Income and mean income of employed people. It is used as a proxy to power of employees. It is calculated by dividing Low End Income with Employed Mean Income.	
ME Income Ratio=Mid End Income/Employed Mean Income	Unitless
ME Income Ratio is a ratio between Mid End Income and mean income of employed people. It is used as a proxy to power of employees. It is calculated by dividing Mid End Income with Employed Mean Income.	
HE Income Ratio=High End Income/Employed Mean Income	Unitless
HE Income Ratio is ratio between High End Income and mean income of employed people. It is used as a proxy to power of employees. It is calculated by dividing High End Income with Employed Mean Income.	
LE Normal Income Ratio=INIT(LE Income Ratio)	Unitless
LE Normal Income Ratio is the normal value of LE Income Ratio. Its value is the initial value of LE Income Ratio.	
ME Normal Income Ratio=INIT(ME Income Ratio)	Unitless
ME Normal Income Ratio is the normal value of ME Income Ratio. Its value is the initial value of ME Income Ratio.	
HE Normal Income Ratio=INIT(HE Income Ratio)	Unitless
HE Normal Income Ratio is the normal value of HE Income Ratio. Its value is the initial value of HE Income Ratio.	
Indicated LE Working Hours=MIN(Normal LE Working Hours*Effect of Productivity on LE Working Hours,Maximum LE Allowed Working Hours)	Hour/ Day-Person
Indicated LE Working Hours is the working time of low end earners corrected with effect of productivity on working hours. It is calculated as a MIN function where a smaller value between Maximum LE Allowed Working Hours and Normal LE Working Hours multiplied with Effect of Productivity is chosen.	
Indicated ME Working Hours=MIN(Normal ME Working Hours*Effect of Productivity on ME Working Hours,Maximum ME Allowed Working Hours)	Hour/ Day-Person
Indicated ME Working Hours is the working time of mid end earners corrected with effect of productivity on working hours. It is calculated as a MIN function where a smaller value between Maximum ME Allowed Working Hours and Normal ME Working Hours multiplied with Effect of Productivity is chosen.	
Indicated HE Working Hours=MIN(Normal HE Working Hours*Effect of Productivity on HE Working Hours,Maximum HE Allowed Working Hours)	Hour/ Day-Person
Indicated HE Working Hours is the working time of high end earners corrected with effect of productivity on working hours. It is calculated as a MIN function where a smaller value between Maximum HE Allowed Working Hours and Normal HE Working Hours multiplied with Effect of Productivity is chosen.	
Normal LE Working Hours=INIT(LE Working Hours(t))	Hour/ Day-Person
Normal LE Working Hours is the working time expected by the low end earners. Its value is the initial value of LE Working Hours.	

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Normal ME Working Hours=INIT(ME Working Hours(t))	Hour/ Day-Person
Normal ME Working Hours is the working time expected by the mid end earners. Its value is the initial value of ME Working Hours.	
Normal HE Working Hours=INIT(HE Working Hours(t))	Hour/ Day-Person
Normal HE Working Hours is the working time expected by the high end earners. Its value is the initial value of HE Working Hours.	
LE Productivity=GDP per Capita/Low End Income	Day
LE Productivity is a ratio between GDP per Capita and Low End Income. If the ratio increases so does the need for LE Working Hours. If it decreases working hours also decrease. It is calculated by dividing GDP per Capita with Low End Income.	
ME Productivity=GDP per Capita/Mid End Income	Day
ME Productivity is a ratio between GDP per Capita and Mid End Income. If the ratio increases so does the need for ME Working Hours. If it decreases working hours also decrease. It is calculated by dividing GDP per Capita with Mid End Income.	
HE Productivity=GDP per Capita/High End Income	Day
HE Productivity is a ratio between GDP per Capita and High End Income. If the ratio increases so does the need for HE Working Hours. If it decreases working hours also decrease. It is calculated by dividing GDP per Capita with High End Income.	
Normal LE Productivity=INIT(LE Productivity)	Day
Normal LE Productivity is the initial value of LE Productivity.	
Normal ME Productivity=INIT(ME Productivity)	Day
Normal ME Productivity is the initial value of ME Productivity.	
Normal HE Productivity=INIT(HE Productivity)	Day
Normal HE Productivity is the initial value of HE Productivity.	
Maximum LE Allowed Working Hours=Maximum Income/(Low End Wage(t)* Days per Month)	Hour/ Day-Person
Maximum LE Allowed Working Hours is the maximum number of hours LE employee is allowed to work in a day. It is calculated by dividing Maximum Income with low end monthly wage.	
Maximum ME Allowed Working Hours=Maximum Income/(Mid End Wage(t)* Days per Month)	Hour/ Day-Person
Maximum ME Allowed Working Hours is the maximum number of hours ME employee is allowed to work in a day. It is calculated by dividing Maximum Income with mid end monthly wage.	

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Maximum HE Allowed Working Hours=Maximum Income/(High End Wage(t)* Days per Month)	Hour/ Day-Person
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Maximum HE Allowed Working Hours is the maximum number of hours HE employee is allowed to work in a day. It is calculated by dividing Maximum Income with high end monthly wage.

Unemployed Mean Income=(Unemployed Participating*Unemployed Participating Income+Unemployed Not Participating*Unemployed Not Participating Income)/ (Unemployed Participating+Unemployed Not Participating)	Euros/ Month- Person
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Unemployed Mean Income is the average monthly income of unemployed people age 15 to 64. It is calculated by dividing total income of unemployed people with total number of all unemployed people.

Unemployed Participating Income=500+Basic Income	Euros/ Month- Person
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Unemployed Participating Income is an average monthly income of unemployed people who are participating in the labor force. It is set at 500 Euros and increases by the amount of basic income if the basic income policy is implemented.

Unemployed Not Participating Income=250+Basic Income	Euros/ Month- Person
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Unemployed Not Participating Income is an average monthly income of unemployed people who are not participating in the labor force. It is set at 250 Euros and increases by the amount of basic income if the basic income policy is implemented.

Pensions=1333+Basic Income	Euros/ Month- Person
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Pensions is an average monthly income of retired people. It is set as 1333 Euros per month, which corresponds to 70% of the initial mean income of employed people, and it increases by the amount of basic income if the basic income policy is implemented.

JG Income=JG Wages*JG Working Hours*Days per Month+Basic Income	Euros/ Month- Person
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JG Income is an average monthly income of people employed in the job guarantee scheme. It is calculated by multiplying JG Wages with JG Working Hours to calculate daily income. This is multiplied with the number of days worked in a month to calculate monthly income. If the basic income policy is active it is added to the total sum. This variable is only active if the job guarantee policy is active.

Normal Employees Demand=INIT(Perceived Employees Demand)	Person
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Normal Employees Demand is the initial number of employees needed by the agriculture, industry and service sectors.

Wage AT=0.5	Year
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Wage AT is the time required to adjust the wages to desired values. Data source: estimate.

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Working Hours AT=1	Year
Working Hours AT is the time required to adjust the working hours to desired values. Data source: estimate.	
Basic Income=0+STEP(200,2015)	Euros/ Month- Person
Basic Income is a policy measure which guarantees a certain income to all people. In this model it is set at 200 Euros per month once the policy is activated.	
Maximum Income=10000-STEP(7000,2015)	Euros/ Month- Person
Maximum Income is a policy measure which limits the amount of money an individual can receive in a month. In this model it is set 3000 Euros per month once the policy is activated.	
JG Wages=15	Euros/ Hour
JG Wages is the hourly wage of people employed by the job guarantee scheme. In this model it is set at 15 Euros per hour. This parameter is only active if the job guarantee policy is active.	
JG Working Hours=4	Hour/ Day-Person
JG Working Hours is the number of hours worked in a day by the people employed in the job guarantee scheme. In this model it is set at 4 hours per day. This parameter is only active if the job guarantee policy is active.	
Days per Month=20	Day/ Month
Days per month is a total number of days in a month an employee spends working.	
Effect of Demand on Wages=GRAPH(Perceived Employees Demand/Normal Employees Demand	
(0, 0.9) (1, 1) (2, 1.04) (3, 1.05) (4, 1.06) (5, 1.068)	Unitless
(6, 1.075) (7, 1.083) (8, 1.09) (9, 1.09) (10, 1.09)	
Effect of Demand on wages is a graphical function connecting demand for employees with wages. This connection was established during the consultation process by respondent 3. If the demand for employees increases the wages also increase.	
Effect of LE Power on Wages=GRAPH(LE Income Ratio/LE Normal Income Ratio)	
(0, 0.865) (0.2, 0.87) (0.4, 0.88) (0.6, 0.9) (0.8, 0.95) (1, 1)	Unitless
(1.2, 1.05) (1.4, 1.1) (1.6, 1.12) (1.8, 1.13) (2, 1.135)	
Effect of LE Power on Wages is a graphical function connecting power of low end employees with wages. This connection was established during the consultation process by respondent 2. If the power of employees increases the wages also increase.	
Effect of ME Power on Wages=GRAPH(ME Income Ratio/ME Normal Income Ratio)	Unitless

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(0, 0.865) (0.2, 0.87) (0.4, 0.88) (0.6, 0.9) (0.8, 0.95) (1, 1)

(1.2, 1.05) (1.4, 1.1) (1.6, 1.12) (1.8, 1.13) (2, 1.135)

Effect of ME Power on Wages is a graphical function connecting power of mid end employees with wages. This connection was established during the consultation process by respondent 2. If the power of employees increases the wages also increase.

Effect of HE Power on Wages=GRAPH(HE Income Ratio/HE Normal Income Ratio)

(0, 0.865) (0.2, 0.87) (0.4, 0.88) (0.6, 0.9) (0.8, 0.95) (1, 1)

Unitless

(1.2, 1.05) (1.4, 1.1) (1.6, 1.12) (1.8, 1.13) (2, 1.135)

Effect of HE Power on Wages is a graphical function connecting power of high end employees with wages. This connection was established during the consultation process by respondent 2. If the power of employees increases the wages also increase.

Effect of Productivity on LE Working Hours=GRAPH(LE Productivity/LE Normal

Productivity)

(0, 0.5) (0.2, 0.6) (0.4, 0.7) (0.6, 0.8) (0.8, 0.9) (1, 1)

Unitless

(1.2, 1.1) (1.4, 1.2) (1.6, 1.3) (1.8, 1.4) (2, 1.5)

Effect of Productivity on LE Working Hours is a graphical function connecting income of low end employees to the number of hours worked in a day. This connection was established during the consultation process by respondents 1, 2 and 5.

Effect of Productivity on ME Working Hours=GRAPH(ME Productivity/ME Normal

Productivity)

(0, 0.5) (0.2, 0.6) (0.4, 0.7) (0.6, 0.8) (0.8, 0.9) (1, 1)

Unitless

(1.2, 1.1) (1.4, 1.2) (1.6, 1.3) (1.8, 1.4) (2, 1.5)

Effect of Productivity on ME Working Hours is a graphical function connecting income of mid end employees to the number of hours worked in a day. This connection was established during the consultation process by respondents 1, 2 and 5.

Effect of Productivity on HE Working Hours=GRAPH(HE Productivity/HE Normal

Productivity)

(0, 0.5) (0.2, 0.6) (0.4, 0.7) (0.6, 0.8) (0.8, 0.9) (1, 1)

Unitless

(1.2, 1.1) (1.4, 1.2) (1.6, 1.3) (1.8, 1.4) (2, 1.5)

Effect of Productivity on HE Working Hours is a graphical function connecting income of high end employees to the number of hours worked in a day. This connection was established during the consultation process by respondents 1, 2 and 5.

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## APPENDIX E - Indicator sector modeling report

Formulations and comments	Units
GDP per Capita=GRAPH(Industrial Output per Capita) (0, 600) (1000, 3000) (2000, 6000) (3000, 9000) (4000, 12500) (5000, 16000)	Euros/ Person-Year
GDP (Gross Domestic Product) is defined as an aggregate measure of production equal to the sum of gross values added of all resident, institutional units engaged in production. GDP is commonly used measure of the economic performance of a country or a region. It is calculated as a graphical function connecting industrial output per capita to GDP per capita. Data source: World 3 model.	
Human Welfare Index=(Life Expectancy Index+Education Index+GDP Index)/3	Unitless
Human Welfare Index is a composite statistic of life expectancy, education and per capita income which is commonly used to rank countries into four tiers of human development. It is calculated by adding together values of Life Expectancy Index, Education Index and GDP Index and dividing the sum with 3.	
Life Expectancy Index=0.9	Unitless
Life Expectancy Index is a statistic which grades countries and regions according to their life expectancy. In this model life expectancy is assumed to be constant at around 80 years and the World 3 model is used to obtain the value of Life Expectancy Index.	
Education Index=GRAPH(GDP per Capita) (0, 0) (5000, 0.81) (10000, 0.88) (15000, 0.92) (20000, 0.95) (25000, 0.98) (30000, 0.99) (35000, 1)	Unitless
Education Index is a statistic which grades countries and regions according to their education. It is calculated as a graphical function connecting GDP per Capita with education. Data source: World 3 model.	
GDP Index=LOG10(GDP per Capita/Reference Low GDP)/LOG10(Reference High GDP/Reference Low GDP)	Unitless
GDP Index is a statistic which grades countries and regions according to the gross domestic product per capita. It is calculated dividing logarithmic value of GDP to reference low GDP ratio with logarithmic value of reference high to reference low GDP ratio.	
Reference Low GDP=120	Euros/ Person-Year
Data source: World 3 model.	
Reference High GDP=47540	Euros/ Person-Year
Data source: World 3 model.	
GINI=IF JG SWITCH=0 THEN ((7/5)-((1/(15*Total Mean Income))*(1*High End Income+2*Mid End Income+3*Pensions+4*Low End Income+5*Unemployed Participating Income+6*Unemployed Not Participating Income))) ELSE (IF TIME<2015 THEN ((7/5)-((1/(15*Total Mean Income))*(1*High End Income+2*Mid End Income+3*Pensions+4*Low	Unitless

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$$\frac{\text{End Income} + 5 * \text{Unemployed Participating Income} + 6 * \text{Unemployed Not Participating Income}}{\text{ELSE } (((8/6) - (1/(15 * \text{Total Mean Income})) * (1 * \text{High End Income} + 2 * \text{Mid End Income} + 3 * \text{Pensions} + 4 * \text{Low End Income} + 5 * \text{JG Income} + 6 * \text{Unemployed Participating Income} + 7 * \text{Unemployed Not Participating Income}))))}$$

GINI Index is a measure of statistical dispersion intended to represent the income distribution and is commonly used as a measure of inequality. A GINI Index of 0 represents perfect equality where everyone has the same income. GINI Index of represent perfect inequality where one person hold all the income and everyone else have none. The calculation method used in this model is suggested by Jasso (1979).

$$\text{Total Mean Income} = \frac{(\text{Low End Employed} * \text{Low End Income} + \text{Mid End Employed} * \text{Mid End Income} + \text{High End Employed} * \text{High End Income} + \text{Unemployed Participating} * \text{Unemployed Participating Income} + \text{Unemployed Not Participating} * \text{Unemployed Not Participating Income} + \text{Retired} * \text{Pensions} + \text{Job Guarantee} * \text{JG Income})}{(\text{Low End Employed} + \text{Mid End Employed} + \text{High End Employed} + \text{Unemployed Participating} + \text{Unemployed Not Participating} + \text{Retired} + \text{Job Guarantee})}$$
Unitless

Total Mean Income is the average income of the entire population above 15 years of age. It is calculated by dividing total income of the entire population above age 15, with total number of people above age 15.

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## **APPENDIX F - Questionnaire**

Thank you for deciding to participate in this research. Your knowledge is of great value to us and your contribution deeply appreciated.

The questionnaire includes 4 sections designed to gather your input on the dynamics of the following degrowth actions/strategies: basic and maximum income, dematerialization, job guarantee, and work sharing. If you strongly feel about another policy/strategy please add it in the optional question at the end.

The estimated time per question is 3-5 minutes.

### **BASIC AND MAXIMUM INCOME**

Imagine that this policy is implemented in the near future in a developed country

Initial changes:

Describe what would be the initial effects of the policy. How would it change the system in the short term (e.g., 5 years from now) and which indicators could be used to track these changes? What do you anticipate the behavior of those indicators to be like?

Long term changes:

Describe what would be the desired long term effects of the policy (e.g., in 20 years time). Again, please explain how would these changes be measured and which indicators would be used. What behavior do you anticipate?

Unintended consequences:

Describe the potential unintended consequences. What can go wrong? What can go better than expected?

### **WORK SHARING**

Imagine that this policy is implemented in the near future in a developed country

Initial changes

Describe what would be the initial effects of the policy. How would it change the system in the short term (e.g., 5 years from now) and which indicators could be used to track these changes? What do you anticipate the behavior of those indicators to be like?

Long term changes

Describe what would be the desired long term effects of the policy (e.g., in 20 years time). Again, please explain how would these changes be measured and which indicators would be used. What behavior do you anticipate?

Unintended consequences

Describe the potential unintended consequences. What can go wrong? What can go better than expected?

## JOB GUARANTEE

Imagine that this policy is implemented in the near future in a developed country

Initial changes

Describe what would be the initial effects of the policy. How would it change the system in the short term (e.g., 5 years from now) and which indicators could be used to track these changes? What do you anticipate the behavior of those indicators to be like?

Long term changes

Describe what would be the desired long term effects of the policy (e.g., in 20 years time). Again, please explain how would these changes be measured and which indicators would be used. What behavior do you anticipate?

Unintended consequences

Describe the potential unintended consequences. What can go wrong? What can go better than expected?

## DEMATERIALIZATION

Imagine that this strategy is implemented in the near future in a developed country

Initial changes

Describe what would be the initial effects of the strategy. How would it change the system in the short term (e.g., 5 years from now) and which indicators could be used to track these changes? What do you anticipate the behavior of those indicators to be like?

Long term changes

Describe what would be the desired long term effects of the strategy (e.g., in 20 years time). Again, please explain how would these changes be measured and which indicators would be used. What behavior do you anticipate?

Unintended consequences

Describe the potential unintended consequences. What can go wrong? What can go better than expected?

OTHER

If you would like to recommend a different policy please do so below. Write the name of the policy and like in previous questions imagine if the policy was implemented in a developed country.

Name of the policy

Initial changes

Describe what would be the initial effects of the policy/strategy. How would it change the system in the short term (e.g., 5 years from now) and which indicators could be used to track these changes? What do you anticipate the behavior of those indicators to be like?

Long term changes

Describe what would be the desired long term effects of the policy/strategy (e.g., in 20 years time). Again, please explain how would these changes be measured and which indicators would be used. What behavior do you anticipate?

Unintended consequences

Describe the potential unintended consequences. What can go wrong? What can go better than expected?