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Business Informatics

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to the Faculty of Informatics
at the Vienna University of Technology

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The project could prove the strong influence of imitation at the micro-level on the pension system of Austria, projecting significant decreases of the average retirement age and the force of the business sectors, applying different retirement eligibility polices, that cause increased proportions of workforce exits before the national stipulation of 65 years. Subsequently, possible financing issues caused by decreased purchasing power and tax funding could be confirmed as economic effect. Additional findings show participation of rational agents, that could benefit from the accommodative sector policy and contribute to the proportion of premature retirements.

Abstract

The basic motivations for this work arose from the current situation regarding changes through pension reforms as well as different lectures from the institute for Mathematical Methods in Economics (ECON) concerning the social security system, computational economics and evolutionary economics. Demographic changes and individual dynamic behavior puts pressure on the government, leading to an enhanced pension model, aggravated access to earlier retirement and benefit adjustments. Many individuals do not want to accept these conditions and think about earlier retirement. But the factual time point is of course influenced by laws as well by the employer, the kind of employment in different sectors and, more important, imitative behavior of other individuals like the life partner or working colleagues through communication channels. Different models have been developed, evaluating effects caused by pension reform changes. People get aware of their social network and know the status as well as the retirement plans (reservations) of others. Some individuals change their mind if they get aware of plans of other people, what is described as imitative character and is a core social aspect of this model. Axtell and Epstein have defined different kind of human characters regarding the retirement plans, that will be applied in this model. Multiple small networks of agent-groups produce a dynamic network including transitive dependencies. The work focuses on this dynamic and wants to answer the question, how individual imitative behavior of agents as well as different sector policies are affecting retirement fractions and the purchasing power. Especially, the retirement time-points deferring from the stipulated level and the economic consequences are of major interest. A multi-agent based simulation is used to perform the experiments with individual local and group behavior under different global limitations and rules. Necessary data is obtained from the Statistik Austria and the Main Association of the Austrian Social Security Assurers. The project is aligned with the verification and validation framework, presented by Sargent (2005) to assure a valid conceptual model, that is transformed to the simulation model, applying techniques for correct programming design and module functionality, finally proving the operational validity, where the output results are measured against the problem statement. The results show an influence of individual imitative behavior on the micro-level to the early retirements caused by imitation (26%) as well as the overall early retirements up to 39% on the macro-level. Accommodative corporate behavior and different policies yield results of 52% early retirements caused by imitation and a total rate of premature retirements up to 79%, justifying its impact on the system. It could be demonstrated, that external influences on the individual as well as on the corporate level are significant and produce noticeable high fractions of premature workforce exits, that result in critical purchasing power reductions and may cause individual financial austerity as well as a system financing issue.

Kurzfassung

Die grundlegende Motivation für die Arbeit entstand aus der aktuellen Situation, welche sich in Änderungen durch Pensionsreformen ausdrücken, als gleich auch durch unterschiedliche Lehrveranstaltungen des Institutes für mathematische Methoden und Ökonomien betreffend Sozialversicherungssystemen, Compututational Economics sowie Evolutionary Economics. Demografische Veränderungen sowie auch individuelles Verhalten erzeugen neue Situationen, welche wiederum die Handlung von Reformverantwortlichen fordern. Aus diesem Grund wurde ein neues Pensionsberechnungsmodell etabliert, der Zugang zur Frühpension erschwert und Zusatzzahlungen angepasst. Ein Großteil der Bevölkerung will diese Bedinungen nicht akzeptieren und bildet eine reservation für eine vorzeitige Pensionierung, welche in dieser Arbeit eine zentrale Rolle einnimmt. Der tatsächliche Übergangszeitpunkt wird allerdings vom Arbeitgeber sowie auch von nationalen Gesetzen beeinflusst. Der Dienstgeber agiert branchenspezifisch und kann somit der Wunschvorstellung des Mitarbeiters zustimmen und eine indirekte Frühpensionierung ermöglichen. Somit sind die sozialen Netzwerke und Kommunikationskanäle, welche eine Person benutzt, um sich über die Reservation sowie Zustände anderer zu informieren und seine eigenen Reservation anzupassen, ein wesentliches Element. Diese Wahrnehmung wird von den Individuen jede Periode durchgeführt. Personen werden mit heterogener Charakteristik versehen, mit denen sie Entscheidungen anderer imitieren, unabhängig oder zufällig agieren. Epstein und Axtel haben in diesem Bereich bereits notwendige Erkenntnisse erzielt. Vor allem die unterschiedlichen Characteristika werden in dieer Arbeit übernommen. Dieser Strukturaufbau kann als ein dynamisches Netzwerk verstanden werden. Diese stehen im Fokus der Arbeit und soll die Veränderungen von wesentlichen Schlüsselparametern untersuchen und interpretieren. Zusätzlich wird die Auswirkung auf das durchschnittliche Antrittsalter, die Kaufkraftsumme und das Imitationsverhalten untersucht. Dies wird mit einer multi-agenten basierten Simulation mit Daten der Statistik Austria und des Hauptverbandes der Sozialversicherungsträger, realisiert und die Ergebnisse neben der Interpretation mit einem Evaluierungsrahmenwerk auf Gültigkeit überprüft. Die Ergebnisse zeigen einen Einfluss durch imitatives Verhalten auf der Mikro-Ebene an der Makro-Ebene durch einen gesteigerten Anteil an Frühpensionen durch Imitation bis 26% und gesamte Frühpensionen bis 39% an. Der Einfluss der Unternehmen ist ebenso beträchtlich mit Frühpensionen von bis zu 52% durch Imitation und bis zu 79% totale Frühpensionen, welche als signifikant zu werten sind. Das Model konnte so zeigen, dass Einflüsse auf der Individuellen sowie auf der Unternehmensebene zu Verlusten der Kaufkraft bis zu 22% und in weiterer Folge zu persönlicher finanzieller Einschränkung führen aber auch ein System-Finanzierungsproblem verursachen kann.

Contents

CHAPTER 1

Introduction

1.1 Motivation

I would like to divide the motivation, where the first includes some private interests and the second some issues of administrative nature. The basic motivation arose out of different lectures on the Vienna University of Technology in the touching fields of science including sociological, juridically, economic but also computational areas. The university provided mandatory as well as free elective lectures striving various fields of interests. Social insurance law pointed out the current situation regarding calculation of pension benefits, claiming eligibility and how different cohorts apply to rules. Basic definitions were provided, regarding the implementation and interconnection of the pension system in the social security system and what strength and weaknesses exist. Also sociological issues were discussed in order to understand why insured individuals act heterogeneously and try to utilize social benefits. In the last module of the lecture, the exact calculation of the pension payments, the age at entry and feasible benefits or surcharges were discussed. History and ongoing developments as well as adaptations which had to be done in order to fit the pension system to demographic and political changes. Those fundamental questions, affecting the society were the inception for this master thesis, although the majority of the lecture was covered by legislative facts. Information economics should form the capability to understand and model economic processes, including information processes. It supported the understanding of the respond to social security statements and the implementation of information about the decision of others focusing economic choice. Evolutionary economics acquired information about new approaches in economic modeling and enabled new ways of thinking about processes. With the computational courses, students are able to get hands on newest simulation software and model social as well as economic models packed in easy implementation processes to bring formal structures to live and do numerous experiments using the full capacities of processor architecture. Additionally, some private observations were showing social processes during the retirement decision, leading to opportunistic changes, forcing earlier retirements, that consolidated the interests in this master thesis topic.

1.2 Structure

The work starts with an overview of major theories in several research fields to get a fundamental grasp, marking important facts and leading to the problem definition. In the chapter two, the information from chapter one is condensed to a problem statement with all details formulating a scientific question. How that question will be solved, is outlined in chapter three (Methodology). In chapter four, the Simulation Environment will roughly be explained leading to chapter five, where the state-of-the-art literature and acknowledgments are listed. I will explain the simulation model as well as the existing frameworks, verification and validation procedures, that are applied in chapter six (Validation and Verification). Chapter seven includes necessary information on the experiment conduction and execution leading the results, listed and reflected in chapter 8. The final chapters nine and ten, will evaluate and interpret the results subsequently associating a critical reflection and a final conclusion.

1.3 The Austrian Social Security System

The social security system as superordinate element is grown out of post-war ages with increasing labor force, where workers need to have a public financial insurance instance. There are 24 insurers, providing 24 health insurance, 7 general insurance and 4 casualty insurance institutions, which are responsible for two of all three types of social security [16, p. 93]. The System is administered by the Main Association of Austrian Social Insurance Companies (German: *Hauptverband der österreichischen Sozialversicherungsträger*) The social security contains four main sub insurance types, which are progressively restructured. The beginning of the social security system started in 1889, where employees could receive different types of welfare in form of social associations, support in case of destitution funded by the state or financial payments through the employer, where contributions as well as capitations have been defined in the contract. The very beginning took place in 1887-1889, where new social laws were established, primarily induced by the sinking physical condition of the Austrian population [16, p. 219]. A worker health, casualty and invalidity insurance was released where detailed contributions as well as limitations and rules for cure and death benefits were defined. Gert (1989) defines seven important periods in the development from 1889 to 1948+. And this was necessary, because in the following years, an ascended amount of industrial employee accidents was recognized. 1923 the system was transformed from a funded to a pay-as-you-go-system which it is until today [14, p. 19]. 1945 was the Community of Austrian Assocation of Social Insurances (german: *Arbeitsgemeinschaft der österreichischen Sozialversicherungsträger*) established, that is today the Main Association of the Austrian Social Security Insurance Companies [16, p. 228]. Gert states the development of this community as the most interesting phase in the history of the social security in Austria, but I do not want to go into detail. The more interested reader is recommended to read the related literature. The legal basis is the Common Social Security Act called ASVG *German: Allgemeines Sozialversicherungsgesetz*. In the following years, the ASVG got reformed on the basis of solidarity and assured autonomy for the insurance societies. It also includes three important principles, like the insurance principle, that everyone has to be insured automatically if the person is in an employment, independent of contractual items or time points [14, p. 28]. The second principle assures permanent immediate maintenance of medical or social nature at any time in first instance, not caring about the payment or the height of the contribution [14, p. 28]. The social principle is based on solidarity, expressing, that the level of maintenance is not proportional to the received obligation and everyone can receive individual treatment [14, p. 28]. Todays social security system is based on three pillars.

- The **Health insurance** is the core of the social security implementation, enabling sustainable population health and foster healthiness. It also includes important examinations for e.g. teenagers but also older adults and three levels of prevention (primary for healthy people to stay healthy, secondly, early diagnosis to prevent worse damage and thirdly for preventing long-term complication [14, p. 31]). The development of the health insurance implements optimal and economic treatment [14, p. 31] to keep this division of the social security system financially feasible. The performance of service has to be done under the current state of medical research applying the conventional medicine and has to be executed sufficient, adequate and indispensable[1]. I suggest, that demographic changes will force more concentration on the economic ascendancies in near future.

- The **Public pension scheme** exists since 1889 as (German: *Alters-, Hinterbliebenden und Invaliditätsversicherung*) but was not anchored in the social security system and mainly used as invalidity and widow insurance. New reforms led to the elevation of the pension claim to 80 percent of the average income [16, p. 15] and implemented into the social security system. Today it is separated in three pillars [20, p. 7] that are explained subsequently. Holzmann (2001) states, that the first pillar is the public pension provision, that is administered by the seven big assurers and is responsible for the majority of insurance cases [20, p. 7]. Holzmann also remarks, that 86 percent of all employees are insured [20, p. 8]. With data from the Main Association of Austrian Social Insurance Companies[2] and the Statistik Austria [3], I can confirm that ratio for 2013 with a value of 87.7 percent. The important issue in Austria is, that officials are not insured in the same pension fund as the rest of the population and therefore other rules and stipulations are applied. Here, I see important connections from retirement time points to the sector affiliation. More details and the correlation to this thesis are given in the corresponding chapter on the model description. The second pillar contains the company pension provision, where the employer participates at the funding of an additional pension payment, that is invested in an external fund [20, p. 8]. The third financing type is of private nature, where people extend their regular pension additionally to the public guaranteed pension with private payments in financial products with good interests [20, p. 7]. In 1999, one million Austrian employees have signed such a private financing pension contract [20, p. 8]. Probably the tax deductibility of the dues, stated by Eckhart, 2009 [14, p. 82] may has influenced individual decisions.

[1] Information from lecture slides of Social Security Law, Walter Poeltner, BMASK, 2012

[2] http://www.hauptverband.at

[3] http://statistik.gv.at/web_de/statistiken/arbeitsmarkt/erwerbstaetige/062860.html

- The **Casualty insurance** has the legal duties to prevent occupational accidents and diseases, deliver occupational medical care and first aid for occupational accidents, enable rehabilitation and compensation [7]. The AUVA (German: *Allgemeine Unfallversicherungsanstalt*) - the Austrian Workers' Compensation Board) is the social insurance for occupational risks for more than 3.3 million employees and 1.4 million pupils and students. [7]

1.4 The pension system

After the general introduction to the social security system, I want to give some descriptive characteristics of the Austrian pension system, that are considerable in order to understand, how the simulation model is defined. It includes current parameters, advantages but also detriments. The pension insurance has been defined as essential part of the social security system in Austria and should protect every member against the risks of invalidity, old age and death, defined in the 189. national law 1955, Sept. 5th, ASVG §222[4] in accordance with the intergenerational contract [29, p. 45f] that also includes the pay-as-you-go financing principle. Prinz did an analysis, if there are asymmetries in this contract where generations evolve as winner or loser. But he also points out, that pension reforms are a hot and difficult issue, not because of the financing of the system but of equity of distribution and contribution [29, p. 29]. Analysis from Prinz state, that since the year 1970, citizen in Austria live three to four years longer, retiring only two years later or even six years earlier [29, p. 29]. Today, the investments for pension programs take nearly 15 percent of the gross domestic product [20, p. 6]. With progressive age, employees are thinking about an age, when to retire. Additionally, pension reforms stipulate an earliest possible retirement age, that has to be obtained. In February, 2014, 3.444.192 Austrian citizens were employed and pay national insurance contributions[5]. In comparison to the last decades, the labor market has become more volatile, forcing employees to change their affiliation more often and companies to dismiss employees. Very specific for the Austrian pension system is the constant high level of expenditure [20, p. 6], one of the highest worldwide. In the model, this will be projected in parameters concerning the retirement eligibility, that is different for each sector. Currently, men retire with 65 and women with 60 years age. Monthly insurance contributions are significant for special earlier or later retirement. Another difference can be drawn between private and public sector workers. Ivansits [21, p. 30] consolidates this imbalance trough social-philosophic positions. For public sector workers, an own national social insurance company is responsible, although they are governed by the same rules and limitations as all other citizens. This imbalance could not be solved until today. The majority of them is also not allowed to work longer than the maximum retirement age, but are able to retire earlier. Holzmann also stated, that male clerks could retire with 60 (until 2003) and from 2003 on with only 61.5, where private sector employers did not have this option [20, p. 13]. In the private sector, employees are mainly not eligible to retire before but have the possibility to work longer than this level under the indulgence of the employer. Prinz explains the higher income of officials with the ratio of occupational to retirement time, which shifts continuously to the benefit of the free time phase.

[4] http://www.jusline.at/222._Leistungen_der_Pensionsversicherung_ASVG.html

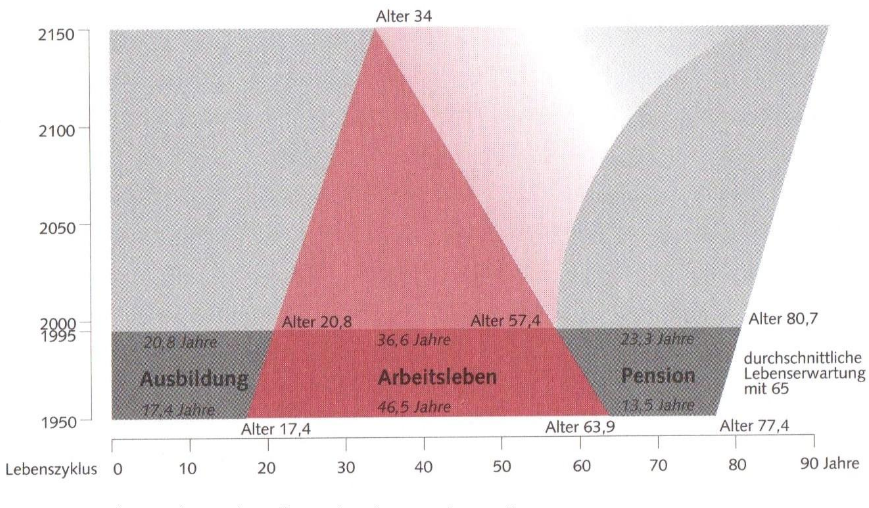
[5] http://www.hauptverband.at

In contrast to private sector workers, officials are not dismissed and have only casualties in job because of illness [29, p. 324]. This is prospected to not change significantly in the future. [29, p. 324] Under critical reflection it needs to be mentioned, that the development of such a system needs to apply a big interconnected network of different stakeholders, trying to enforce their interests effective, quick and without high expenditure. But as shown, the system is driven by numerous historical grown parameters and can not easily be manipulated in a long term sight. Diamond and Barr [5, p. 3f] state objectives of a pension system

- Consumption smoothing projecting the wish to live with a balanced path of consumption during the whole life cycle.
- Relief poverty for those, who were not able to save enough money although they were gainfully active the entire life.
- Insurance against low income to be able to live at old age with an adequate economic status.
- Redistribution in a social acceptable manner.

1.5 Demography

I would like to start this section with a figure (1.1) presented by Prinz, Marin, 1999 [29, p. 110, Abb.1], showing, that education, occupation and retirement are connected and that longer apprenticeship times lead to a later entrance into workforce. If the retirement age is fixed, the



Source: Prinz, Marin; Pensionsreformen (1999); p. 110, bottom figure

Figure 1.1: Correlation of life cycle and affiliation

shortened working period forces a reduction in insurance contributions, exerting pressure on the budget and leads to further consolidation. And finally, the demographic shift may prolong disbursement periods. At the beginning of humanity, the life expectation was 30 years [15, p. 4]. Since 1970, individuals live in average three to four years longer, start to work two years later and up to six years shorter and receive seven years longer pension benefits [29, p. 29]. Mahlberg, Freund, Curaesma and Prskawetz (2011) projected an increase of the proportion 65+ of the population from 17.4 to 24.1 percent [25, p. 1]. They also state, that the life expectancy will rise about 3 months every year [25, 1]. Figure 1.2 shows a demographic comparison between 1992 and 2030. On the top, the enlargement of the 60+ age society and the consequential increasing number of withdrawals is visible. How this problem is projected in the model, will be discussed in chapter two.

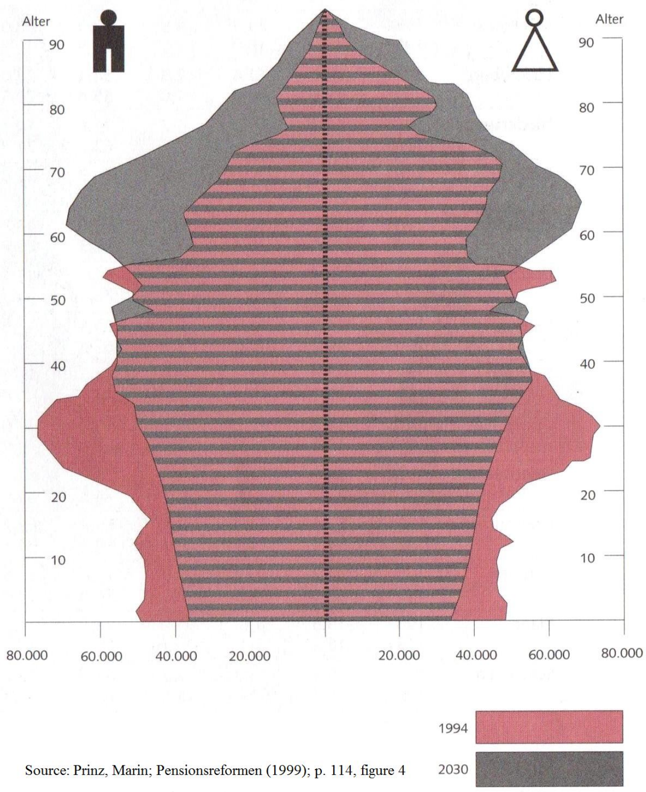


Figure 1.2: Demographic forecast

1.6 Aging and Accumulation

The shifting size of the two groups 15-65 and 65+ includes several difficulties that are described by Hanappi [18, p. 3] that arise from the financing of inter-generational transfer payments, that put pressure on the economically active generation. They face an increasing opposition of retirees, whose life expectation is growing faster [18, p. 3]. A key factor in the game of different generational levels is the public administration, that implements reforms in order to avoid budgetary problems [18, p. 3] and will also be part of the model consideration explained in the corresponding section.

1.7 Corporate Culture

Another important stakeholder besides the government, are the companies exerting their influence on the retirements. And this does not mean, that firms can send employees directly into the retirement, without caring about national regularities. It basically covers the changes in corporate behavior and what pathways for employees exist nowadays to retire virtually earlier than usually possible. As Gassmann and Reepmeyer state 2006, economy has build up an image over the last decades that should be juvenile and fresh for products and develop services only exclusive for the target group of 14-49 age people [15, p. 9]. People over 50 seem not to be interesting as target group although it is economically obvious, that the potential customer class has gray hair [15, p. 10]. And the size of this group will increase in near future. Nearly the same holds for the employees. Young and mid-age people are mostly welcome in all companies. High unemployment rates at old-age and pre-retirement stage may explain, why people are mostly not welcome, although they have experience and special potential. The reasons are complex and will be discussed in the section one of chapter two. Two different approaches have been developed if old people leave the labor market, which are characterized by Radl [30, p. 44]. In the pull approach, economic models treat the decision of the retirement as in-temporal and discrete between the states work and pension [30, p. 44]. It is the result of a decision process, where the individual check continuously what outcome can by achieved with the current income and compares this with an utility of staying in the workforce [30, p. 44]. *The model focuses on the opportunity cost of retiring or, equivalently, on the value of retaining the option to retire at a later date* [33, p. 1158]. The rational choice perspective can not be used to analyze the social stratification in terms of retirement time points [30, p. 45]. The second approach is the push-approach, which explains the retirement transition as free decision made by the employee [30, p. 45]. As Radl states in his article, old and unemployed people are in this situation because the chances of reemployment at old age are low [30]. He mentioned, that the employers are seen as the prevailing instance for the moment of the transition from work to retirement and states, that it depends on the size and the sector, if and how intensive companies agree to earlier retirements [30, p. 45]. Teipen states 2003, that the influence of the labor union in the company additionally determines the usage of such processes [35]. Phillipson and Smith have recognized, that an earlier retirement is only possible, if there is a certain form of control of the individual [27, p. 55]. Szinovacz and Davey explain the majority of early retirements through the push-approach as subjective negative con-notated process [34]. In this section, two major ways have been noticed, where individuals leave the workforce. Either voluntary, exactly knowing of financial benefits. Or working in the public sector, may being forced through company austerity programs or personal circumstances, where early retiring processes have not evolved or are only weak. The effects and the correlations to this topic are explained in the second section of chapter two.

1.8 Social Connectedness

This subsection wants to explain, how individuals communicate within social networks and how this can influence the time point of workforce exit, basically examined by Lancee and Radl, 2012 [24]. They have used data from the German Socioeconomic Panel Study from the years 1985 to 2009 and applied event history analysis to study the extent of social connectedness in terms of retirement timing. What is interesting in this article, although there are numerous studies on social relations, is the focus on the effects of connections in later stages of a working life. Lancee and Radl point out, that there is only little research, that examines this influence on the timing of retirement through social networks [24, p. 481]. Social relations play an important role and cause great diversity of orientations [4]. They also found out, that a high level of social participation results in strong leisure orientation leading to more free time, people can spend with family and friends. Social connectedness refers to the quality and the amount of personal interactions in its small network. In the social literature it is common practice to distinguish between formal and informal participation. Mutchler et al. 2003 [26] defines participants as family, friends and neighbors. Lancee and Radl were not able to focus on the connectedness in terms of coworkers relationship, because data was not available. This would have been interesting, but the information about informal connections is usable enough for the purpose of this thesis. Kohli and Künemund (2008) have noticed, that older age groups have smaller networks than younger people, but this fact does not conclude anything about the effects, how this connectedness influences the retirement processes [23]. Lancee and Radl are also noticing, that workers with a social network of over average size are rating private life more than workers with only few connections [24, p. 482]. And secondly they acknowledged, when people get older, time is stronger perceived as limited and therefore people value emotional goals and activities [24, p. 482] more then rationally, in contrast to the rational-choice theory. They also assume, that *formal participation may lead to early exit from work* [24, p. 483], what is essential for my work to prove, how many individuals are actually suggestible and will change their reservation according to former policies. Lancee and Radl additionally list the complementarity hypothesis [24, p. 483], showing, that voluntary work enhances opportunities on the labor market in the long term, implementing the continuity theory. In conclusion, Lancee and Radl find out, that *a higher contact frequency with relatives and friends, informal participation lead to anticipated withdrawal from the labor market* [24, p. 485] and express their perceptions in the figure 1.3 [24, p. 487, fig 1]. They conclude, that changes in the social network occur more often after retirement than before and the level of informal participation is relatively stable over life and does not significantly change in the years before retirement, what is observable in figure 1.3. It is also important to differ between retirement as transition or as state, what has been defined by Bosse and Aldwin, 1993 [9]. The definition of structure and size is the aim of the next chapter.

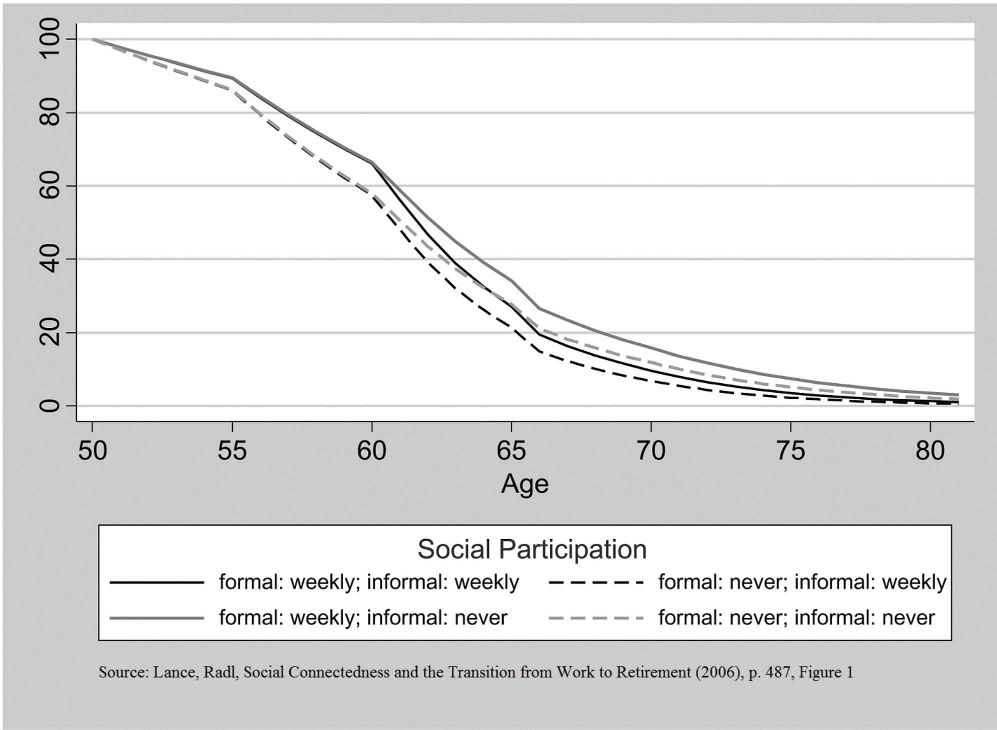


Figure 1.3: Condensed perception of Lancee and Radl (2006)

CHAPTER 2

Problem Definition

In chapter one I gave a brief overview about the relevant topics. In the subsections, numerous problem statements have been expressed, which will be focused in the following sections dealing with the components of the scientific question. Afterwards, the solution process will be projected. The first challenges of the social security system emerged through disputes of competence and to achieve broad and safe insurance for everyone. But in the last decades, the requisitions for the system have changed. As stated in chapter one, an increase of individuals in the cohorts 60+ coming from the high-birthrate periods of the post-war era and the economic development has been noticed. Additionally, following side effects are considerable. A better medical treatment pushes the average life time contentiously upward. Austria has a high level of income, what is expected to rise in near future. Up to now, many employees used the opportunity to retire earlier. In combination with a longer life expectation, the prospective financing of the system is quite doubtful. A significant amount of the population receives an over-average pension. Individuals use their networks to notice possible advantages they could use to retire earlier than usually possible. Companies are obviously not interested to keep elder, high-paid employees, which results in higher unemployment rates or special agreements. These are all problem components of the pension system in the current decade. I have already mentioned social networks, communication and the use of the information for optimized recalculation. Radl explored and visualized the diverse pathways to retirement [31, p. 232, fig. 7.1], explaining, that heterogeneous policies lead to different results in the same environment with equal legal stipulations. The study was performed in Germany, but the results are recognized as comparable to Austria. The first pathway is the ideal process for all individuals, retiring regular at the stipulated age. But usually, many are forced to follow the second path through unemployment at an age before the stipulated level. The forth pathway is even more interesting to observe, where people can benefit from private agreements between the employer and the insurance company and virtually retire before 65 and receive the regular pension with the stipulated retirement age.

2.1 Components

In this section, I want to focus on the parameters, that are part of the problem statement. First, a representative subset of the population has to be assumed. The set consists out of n individuals, shifting from one to the subsequent cohort, including necessary parameters and characteristics. They are situated in a branch with heterogeneous attributes and build up a social network of diverse size but uniform structure. An individual needs to set up a calculated retirement age in correspondence to the income and a $retirementReservationAge$, that is initially based on the income, but can be influenced by others within the social network. If an individual performs imitation, depends on the person type. Legal minimum and maximum thresholds need to be introduced, based on the framework of the ASVG and APG. And finally, the way of communication needs to be defined, distinguishing between three different counterpart groups, where o is the requesting agent and i one of the linked agents:

- Group *Retired*: Only listen to all friends and coworkers in the age range of $age(i_n) \leq age(o) + 10$, which have already retired.
- Group *Working*: Adjust reservation age based only on information of economically active people in a box $age(i_n) \geq age(o) - 10$.
- Group *Dual*: Listen to both groups, 1 and 2 in a box $age(o) - 5 \leq age(i_n) \leq age(o) + 5$.

2.2 Scientific Question

The work focuses on the effects of individual imitation based on communication through social networks and wants to answer the question, how individuals that perform imitation, situated in different economic sectors have significant influence on the average retirement age and purchasing power.

2.3 Expected Results

The focus is on the ratio of all retired agents that have performed a successful imitation with the social network and a premature retirement. These agents are expected to be in a minority of maximum thirty percent assuming a strict employer policy. The effect on the purchasing power loss as well as the decrease of the average retirement is expected to be under ten percent. With a wider, more liberal, eligibility range, increased fractions of early retirements and stronger decrease of the average retirement age as well as a higher loss of purchasing power will be assumed, but not clearly estimated.

2.4 Solution Process

This question will be answered with an multi-agent based simulation using the Software NetLogo, which is free available and easy to use. Every period is defined as a year. Agents are randomly assigned to a sector/business over the entire lifetime and can retire in reconciliation with the sector as well as also legal stipulations. All agents will create individual social networks, but only agents of imitative character will communicate with others to update their reservation level. If the agent age gets close to the retirement age, they will try to retire at the reservation age moment. It depends on the sector, if the process is successful. The visualization in NetLogo will be built up two dimensional, where on the x-axes represent different sectors and the y-axes the age cohorts between 50 and 100. The simulation model will be verified with the model verification approach from Sargent [32]. Finally, the results from the simulation will be validated operationally, to ensure correct functionality in order to the real system. Finally, the results will be evaluated in the last two chapters.

CHAPTER 3

Methodology

As described in the last chapter, the problem statement will be transformed in a conceptual model, that is then implemented as a multi-agent-based simulation model The successive section deals with economic and social models, followed by mentionable simplifications and assumptions, including the description of the simulation model with all parameters, variables and functions derived from the chapter one and two. Additionally, some network modeling approaches are presented, followed by the most important method, the verification and validation framework for simulation models defined by Sargent (2005).

3.1 Agent-based Modeling

Multi-agent based simulation has evolved as very popular for social experiments in the last years. Nigel Gilbert describes the idea of agent-based modeling as *new analytical method for the social sciences, enabling users to build models with entities and individual interactions, that are directly represented* [17, p. 1]. He also mentions, that *it offers the possibility of modeling individual heterogeneity, decision rules of agents, that are situated in a virtual space* [17, p. 1]. In this case, the space will represent Austria with its inhabitants. With other modeling approaches, it would not be that easy to implement rudimentary individual and dynamic behavior on a micro level. Gilbert ascribes this form of modeling to the Computational Social Science, what is definitely true, but I would also draw a connection to the Computational Economics, where economic scenarios are depicted and executed in an agent based model framework. For this work, a social virtual reality is created with a simplified approach, where a network of individuals, serving as nodes, and communication channels, represented through edges, is modeled as circle of acquaintances, which has previously been described as social network. Bonabeau (2002) confirms the application in his article of Agent-based modeling, stating, that *it applies to cases, where people are influenced by their social context, that is, what others around them do.* [8, p. 7285] These models are then formulated through computer program code, where input parameter and outputs through variables are implemented. Gilbert also lists an example with consuming agents, where the purchasing of a friend will influence the buying behavior of the friends agent, pointing out, that *the mutual reinforcement is easy to model with the agent-based approach* [17, p. 2]. He also draws a connection between scientific social network modeling and computer games, being very close to computational modeling with better graphics and less social theory and states that, *The model has to represent the reality, existing phenomenon, that is called the target of the model* [17, p. 4]. It reflects the relationships between target features and enables the user to discover properties of the target by an investigation of the model [17, p. 4]. Different kind of models have been elaborated, where scale models are mostly preferred. They are a reduced version of the real world system with few complexity and level of detail neglected for the sake of feasibility. What I want to highlight in Gilbert's deliberations is, that *Such models are useful because well-established results from the analogy can be carried over and applied to the target, but of course the validity of these depends on the adequacy of the analogy* [17, p. 5]. Possible model errors are not apparent in first instance and the model has to be validated to the real world at best. An other important element in the agent-based simulation is the agent, interacting with the environment and represents individuals in a virtual world. Their primary functions, in concurrence to Gilbert are to *react to the computational environment, that is an simplified reflection of the real world, where the social actors, interact with other agents, pass messages to each other and act according to the information and execute actions in order to predefined rules* [17, p. 5]. The simulation environment is seen as neutral medium, where imitation occurs, but they can be adjusted to external environment conditions (like borders or maximum ages). Gilbert stated, that *Another option is to have no spatial representation at all but to link agents together into a network in which the only indication of an agent's relationship to other agents is the list of the agents to which it is connected by network links* [17, p. 6]. Finally I want to point out some features of agent-based modeling, stated by Gilbert [17, p. 14f] and Bonabeau [8, p. 7280]. Agents are heterogeneous, differing to the usual conditions, where firms deal with a typical form and agents follow the same rule sets. But this homogeneous character may imply some difficulties, finding the right analytical solution. Bounded Rationality is applied to agent based simulations with a set of rules to let agents optimize utility or well being and is different to models, where individuals act randomly or irrationally. There can be an ontological correspondence between the agents of the computational simulation model and the actors of the real world, simplifying the design and interpretation process. The companion or participative modeling approach is used for multi-agent models as support for negotiation, decision making or for training. The *companion modeling* approach includes a creation of a multi-agent system with informants [17, p. 13]. They are interviewed about their understanding of the situation, from where a computer model is created. Environmental representation includes physical barriers, agents may need to overcome boundaries, that lead to local or global resource depletion. The interactions of agents are the most important benefit. They are technically the transfer of messages (data) from one agent to another and can have a heterogeneous structure. In this thesis, the exchange of information will mainly focus on the reservation levels. Gilbert also states, that *Agent-based models are able to simulate learning at both the individual and population levels.* [17, p. 16]

In contrast to the listed benefits of agent-based simulation I want to discuss some alternative approaches beside the mentioned techniques. Microsimulation can be seen as opportunity, where a small system like a household can be simulated with an underlying large database, where rules are used to update the members behavioral space. Gilbert states, that *this form has been used to access the distribution implications of changes in social security, personal tax as well as pension* [17, p. 17]. Brown and Harding concluded, that microsimulation can add big contribution in the evaluation of private sectors as well as public policies [10]. This sounds well suitable for this kind of work, but we want to use the micro level not only to observe changes in the macro level, but also between individuals. And as already mentioned, a large database is needed, that is not available in that extent. I agree with the advantages of Gilbert, arguing, that the developer of the system does not have to assume something hypothetical, but from a real world observed sample. But microsimulations are accompanied with some disadvantages like obtaining reliable and correct estimations for the transition matrices, agents rely on to change from one state to another, e.g. aging [17, p. 17]. And, more problematic, agents are defined as isolated and are not allowed to have any transaction or communication between the agents, what is crucial for this work. The second possible framework deals with System Dynamics, where a model expresses the *cause-and-effect relationships between variables, but agents are not represented directly.* [17, p. 18]. It can model a system of interacting components using feedback loops, sources and sinks, where products can flow from one direction to another and can handle causal links, that are directed. A disadvantage is, that it can not deal with big populations but includes the advantage, that it can deal with agents, that have similar characteristics and behavior. It allows the user, to implement atoms, that can be seen as breeds and easily be duplicated. But it has elaborated to be more useful in simulations for traffic or production processes, because the standard package already includes the atoms for such structures.

3.2 Sargents Modeling Framework

Sargent introduces verification and validation methods. It is important to mention, that *Every new simulation project presents a new and unique challenge* [32, p. 9] and *no algorithm exists to determine what techniques or procedures to use*. [32, p. 9]. Sargent remarks, that all models have to be developed for a specific purpose, answering a variety of questions. The validity has to be assured in respect to the problem statement. Because a model may be valid for one set of experimental conditions and invalid in others, it is required, that the output variables, that are relevant are correctly identified and have an required amount of accuracy. He also states, that it is often time consuming to prove, if a model is absolutely valid in the whole domain. Therefore it will not be attempted, but the validation for the intended application will be performed. The process will mainly be executed subjective decision based, because the independent verification and validation needs third party stakeholder, who implement their qualitative attribute measures for validity. The scoring model [32, p. 2], mentioned by Sargent will not be applied, because Sargent argues plausibly, why this method has certain flaws. Sargent recommends the simple version of the model development process in terms of model verification and validation, that are illustrated in figure 3.1.

- The **Problem Entity** represents a real world issue.

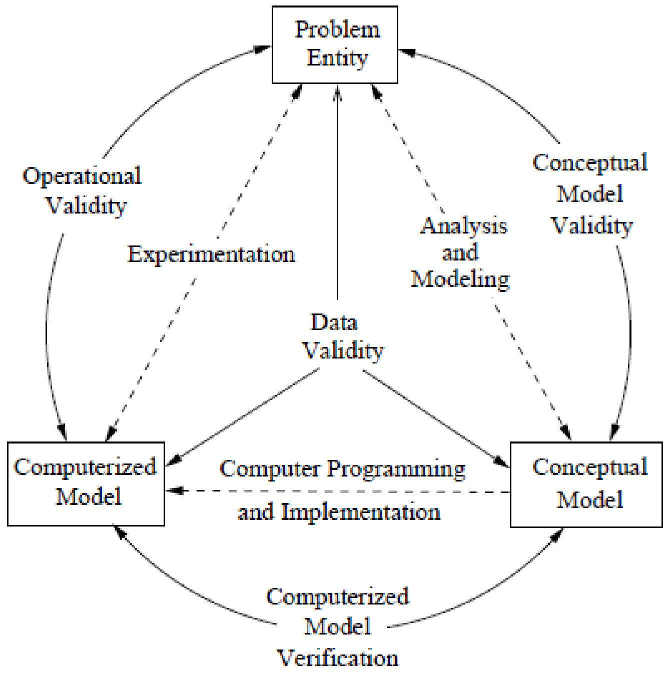


Figure 3.1: Simplified Version of the Modeling Process, Sargent (2005, p. 3)

- The **Conceptual Model** is the through analysis and modeling phase developed and a logical, mathematical or verbal represented solution.
- The **Computerized Model** is the code representation of the conceptual model.
- **Conceptual Model Validity** proves, if the underlying concepts of the conceptual model are correct for the problem entity.
- The **Computerized Model Verification** assures, that the implementation of the conceptual model is correct.
- The **Operational Validity** assures, that the output of the simulation, and the underlying computerized model is correct and provides sufficient accuracy for the purpose.
- Optionally, the **Data Validity** ensures, that the data quality is sufficient for model building, evaluating and testing.

In this passage I want to evaluate different validation techniques, explained by Sargent [32, p. 3] and also want to discuss the usability for my work. He differs between subjective, objective or mixed techniques, that are generally applied.

1. With the *Animation Technique*, the behavior of the model is visualized in time dependency. This results are used for validation to observe anomalies or failures e.g. strong volatilities. Because the simulation software allows graphical (histograms, plots) as well as numerical (monitor) outputs, this validation method is possible, but some experiments showed the weak annotation and scaling of the Netlogo plots.

2. The *Event Validity* compares special events, that occur with those of the real world system. This approach is usable, e.g. to simulate an elevation of the minimum retirement age and observe the consequences on the purchasing power, turn of the imitation process or maximize the network to abnormal values. Assumptions and Simplifications could lead to problems regarding the comparability with real world data.

3. *Extreme Condition Tests* would be a possible validation technique, driving the network size to an extreme low or high value and observe the system output parameter.

4. For the usage of *Face Validity*, the objective can be presented to an associate of the institute of ECON, which are knowledgeable about the economic and social processes.

5. *Historical Data Validation* does not seem useful, because there has not been done such a simulation like it is performed in this thesis, although a lot of data is available in sub domains.

6. The *Multistage Validation* is rated as too extensive for this small project although it contains powerful validation approaches.

7. The *Parameter Variability-Sensitivity Analysis* is evaluated as the best validation method in correspondence to the simulation software, because the integrated experiment tools allow exactly the stated procedure of changing the values of the input and internal parameters to determine the effect upon the model's output.

8. *Traces* are useful in the context to follow single agents, when getting older and transitioning through the different states. It is easily applicable, especially through the implemented trace and show functions of the simulation software.

9. The *Fixed Values* technique uses easy calculated values to compare them against model output variables with fixed inputs and will be applied to check the reliability of the procedures that distribute parameters like income or calculated retirement age and the agent type fractions.

Now I want to combine the simplified modeling approach with the validation techniques in connection with my topic and underlying elements in correspondence to figure 3.1.

- Conceptual Model Validity [32, p. 4]: The validation proofs, if the model is an accurate representation of the real system. If aspects are missing, the process needs to be repeated until the model accuracy is acceptable. Sargent also mentions, that all sub-models and the overall model have be evaluated to check if they are correct and reasonable for the intended purpose. Is the structure appropriate, logical and are causal relationships used correctly. If errors are found, the conceptual model must be revised and the validation process needs to be performed again. That implies for my model, to prove, if concepts of aging, income, reservation level calculation, income distribution, social network building, transition between the states, calculation of detail and overall output variables are correct.

- Computerized Model Verification [32, p. 5]: This technique should help to ensure, that the program is correct, means, that the design and the development procedures in the fields of software engineering are used for implementation. These include object-oriented and top-down design, structured programming and program modularity. When bugs have been removed, the program must be tested to be accurate and correct. To do that, the simulation procedures can be tested static or dynamic, but the static testing includes a walk-through examination within a development team, that is not available, therefore the dynamic testing method will be selected. In the simulation code, there are basically no functions, and procedures can only be tested with the command center output to verify functionality step by step. Tests with assertions are not possible. The testing bottom-up way is possible, starting with the sub procedures and input-output tests and at last the top procedure.

- Data Validity [32, p. 4]: Sargent recommends the data validation process, but mentions the costly and time consuming characteristic. Therefore it will only optionally be applied, because the source of data is specified as trustful.

- Operational Validity [32, p. 5]: Is concerned with the validity of the model output. Sargent differs between observable and non-observable systems using a subjective or objective approach. The simulation software provides visualization of the model as well as data export functionality for further analysis, therefore the subjective approach is applicable through graphical display. Scale-Robustness and appropriate measures have to be strictly obeyed. The objective approach compares results with statistical tests and procedures what will be the goal to be applied to the system. Sergant indicates, that the statistical method must satisfy the underlying assumptions of the used technique [32, p. 7]. The model range accuracy should be held as small as possible. Then the hypothesis test is used either to prove, that the model is valid for the defined range of accuracy or the model is invalid for the experimental conditions. Type I and Type II errors are used to determine the validity. Sargent also alludes the validity measure lambda defined in the validity range $0 \leq \lambda \leq \lambda\star$. Additionally he mentions three operating characteristics where the accuracy is coupled to the size of the sample. In this case, we will retrieve a small sample size, that has a high probability, that the model will be accepted. The basis for this test will be spreadsheet outputs from the simulation experiment tool. Because of the high level of abstraction and reduced comparability, the subjective approach, observing deviations as well as the output behavior will be applied. If comparable data is available, a quantitative approach will be used.

Finally, Sargent points out the documentation culture, where a detailed as well as a summary documentation is desirable. The detailed form contains test, evaluation and result specifications.

The summary documentation should include an evaluation table for all framework elements and the overall summary. This table includes category, used technique(s), justification, references to support the report, result and the confidence in the result.

3.3 Model description

Now I want to give the reader an overview about the actual model including calculation. Basically I will divide between environment parameters, that reflect the employers and the agent variables, that represent the Austrian inhabitants containing individual as well as common attributes and the social network. At first, I want to clarify some general wordings: Agents are individuals and employers reflect an underlying provided workplace.

Environmental Definitions and Limitations

Imagine a two dimensional space, where the agents are situated in and are separated in cohorts, with a distance of n. This space will be expressed as matrix, with the formula, containing the agent A, Size of cohort s, count of sectors b, agents per cohort a and agents per sector p:

$$SpaceS = \sum_{i=50}^{100} \sum_{j=1}^{a} A(i,j) \tag{3.1}$$

$$a = b * p \tag{3.2}$$

A legally set stipulated retirement age R_S is needed. Sector B with specific properties want to shift employees earlier or later than others and facilitate a pre or post-stipulated retirement at R_A. It is important to mention, that genders are not used to reduce side effects caused by unequal treatment regarding income as well as employment. Although there are at least 21 different branches according to ÖNACE[1] [38, p. 56f]) in the Austrian economy, the number of sectors in this model is reduced and determined by the permutation of important sector attributes relevant for this research, receiving following settings:

- Private **OR** Public sector
- Adverse **OR** Accommodative release strategy

It has already been discussed in the introduction chapter in the corresponding section of the pension system, that there are historical grown and lead to deviations. Holzmann stated, that *Eine ungleiche Behandlung ergibt sich diesbezüglich aber auch zwischen (männlichen) privaten und öffentlichen Bediensteten. Männliche Beamte erreichen das gesetzliche Pensionsalter, und damit einen Anspruch auf eine reguläre Alterspension, bereits mit 60 Jahren (ab 2003 mit 61,5 Jahren), privat Beschäftigte allerdings erst mit 65 Jahren.* [20, p. 12]. He states a major difference between the average retirement age of private and public employed people. From this statement, no clear boundaries can be derived, but the major deviation will be projected in different retirement eligibility ranges. This sector release culture is represented through a specific

[1] Austrian Classification of Economic Activity

low $T_H(n)$ and high $T_L(n)$ threshold that are illustrated below. Three different policies are introduced, representing liberal, adverse and balanced retirement eligibility ranges, the employers in the different sectors will apply.

Policy	Release	**Public**	**Private**
P1	**Accommodative**	$T_L(1) = R_S - 5$ $T_H(1) = R_S$	$T_L(3) = R_S - 2$ $T_H(3) = R_S$
	Adverse	$T_L(2) = R_S$ $T_H(2) = R_S$	$T_L(4) = R_S$ $T_H(4) = R_S + 5$
P2	**Accommodative**	$T_L(1) = R_S - 10$ $T_H(1) = R_S$	$T_L(3) = R_S - 5$ $T_H(3) = R_S$
	Adverse	$T_L(2) = R_S - 5$ $T_H(1) = R_S$	$T_L(4) = R_S$ $T_H(4) = R_S + 5$
P3	**Accommodative**	$T_L(1) = R_S - 10$ $T_H(1) = R_S$	$T_L(3) = R_S - 7$ $T_H(3) = R_S$
	Adverse	$T_L(2) = R_S - 5$ $T_H(2) = R_S$	$T_L(4) = R_S$ $T_H(4) = R_S + 5$
P4	**Accommodative**	$T_L(1) = R_S - 10$ $T_H(1) = R_S$	$T_L(3) = R_S - 8$ $T_H(3) = R_S$
	Adverse	$T_L(2) = R_S - 7$ $T_H(2) = R_S$	$T_L(4) = R_S - 5$ $T_H(4) = R_S + 5$

Table 3.1: Definition of relative sector policy levels

The validation of these values as well as further definitions or corrections are stated in the section regarding the validation of the simulation model.

Agent Attributes

Following attributes are defined as turtle-own (local variables) of the Agent A:

- Current age A_A: Will be incremented every period, called tick. One period will represent a year.
- Income A_I: Is set with obtained data from the Statistik Austria Income Report 2012 and respects values from the lower to the upper quantile. [2, p. 14f.]

$$9166 \leq A_I \leq 27188 \tag{3.3}$$

- Calculated pension A_P: Is fixed with 80 percent of the individual income value. Because of the complexity of current pension calculation models, this simple approach is selected.

$$A_P = 0.8 * A_I \tag{3.4}$$

- Social network A_S stores n random agents of the whole population and persists over the agents lifetime. Preset for $n = 15$ but the final value has not been evaluated yet.

$$A_S(n) = random[n_M](A_o) \tag{3.5}$$

- Calculated retirement age A_L: Is calculated in order to the income of the agent A_I. The higher the income, the lower is the calculated retirement age, because the agent has reached the value of well-being for the whole pension phase earlier, than an agent with a lower income. Only rational agents will refer to this value to gain an optimal retirement time-point.

$$A_L = \frac{27 - A_I}{1000} + 55 \tag{3.6}$$

- Reservation retirement age A_R: The initial value is set with A_L. Rational agents will not use this attribute. Imitator agents will update this value in order to the imitation process, that is explained in the corresponding sector of this chapter.

- Actual retirement age A_C: Is immediately set if the agent retires

- Agent type A_T: The agent belongs to one of four different agent types

  - **Rational**: Calculates the retirement age in correspondence to the income. The agent does not perform imitation.
  - **Imitator**: Sets the reservation level in order to the calculated pension but changes the reservation retirement age because of imitation of other agents in the social network. The fraction of imitator agents is provided by the variable R_I.
  - **Random imitator**: Shows similar behavior as the imitator agent but changes the reservation level not because of communication with the social network. The reservation level updates are of endogenous nature.
  - **Full random**: Does not use the social network and retires actually to a random point of time. This agent represents all individuals of the population which are e.g. disabled and have to retire much earlier or made special accommodations with the employer to work much longer as possible. One percent of all agents are of that type.

- Collar A_C: The agent is assigned to the white collar or blue collar type. The blue collar type of agent is only available in the private sector with a ratio of 38 percent.

- Status: A_S: Is initiated with the value 0 for *working*, changing to 1 if agent is *retired* and finally is set to 2 if the agent is dead.

- Imitation: A_F: Is set to the age, when the agent performed successful imitation.

The agents are randomly distributed in space S, over the different sectors in the cohort 50, regarding the allocation of the blue collar workers to the corresponding sectors as well as the distribution of the income.

Input variables / parameters

Following variables will be defined as input parameters for the model

- An integer value is a preset for the value n_M, defining, how many edges at maximum are created from one agent.
- The value b stand for the amount of sectors as well as p the size of agents per sectors are integer values.
- The mortality rate will be provided as continuous variable read from a file, showing the mortality rates of Vienna, unisex from the year 2000[2].
- The ratio of imitator agents R_I defines the fraction of imitating agents of the whole population. It directly influences the creation process of the agents.
- The national defined stipulated age R_S is implemented in the calculation of the rational as well as the initial retirement reservation age.
- Because it will make a qualitative difference, how old the agents are, every agents is asking within their social network, three different modes will be introduced and specified afterwards.

Reservation Level and Imitation Mode

As described in Axtell and Epsteins Paper on coordination in transient networks [3], it makes a quantitative difference, if all agents in the social network are considered or only those around the agent, that updates the retirement level. Therefore I want to introduce a trivalent selection process. In Mode *Retired*, all agents, that are already retired but have retired earlier than the respective agent, are selected. Mode *Working* asks all agents, that are still working, not more than 10 years younger and have an lower reservation level than the respective agent. Mode *Dual* combines Mode Working and Retired and uses a variable box $x - 5 \leq x \leq x + 5$ from the age of the agent that performs imitation.

Output variables and accuracy

The main focus is on the ratio of successful imitation and earlier retired agents $Aset_P$. $Aset_I$ describes all agents, that have performed a successful imitation and A describes the aggregate of all agents in the world.

$$Aset_P \subset Aset_I \subset A \tag{3.7}$$

Definition 3.8 describes the fraction of agents, that performed successful imitation and have a reservation age beyond the stipulated level to all agents, that are retired.

$$Aset_P = \frac{\sum A(A_C \leq A_L \wedge A_F \geq 0)}{\sum A(A_S = 1)} \tag{3.8}$$

[2] http://www.statistik.at

The second important output variable is the purchasing power O_P, that is calculated for all agents, that are retired.

$$O_P = \sum(A_P(A_S = 1)) - \sum(A_P(A_S = 2)) \tag{3.9}$$

If an agent dies, the purchasing power is reduced with the value A_P of the death agent.

Simplifications and Assumptions

As already mentioned, there is no gender used in this model, because it would lead to more complexities in the income distribution and retiring process. It will also be assumed, that there are no unemployed or ill individuals. Agents will always stay in the same affiliation with constant income. The pension of the agent A_P is calculated with a static fraction, although current calculation models are much more complex and take all economically active years into consideration. I will assume, to have no labor market including unemployed people, adding too much complexity to the system, causing subsequent simplifications. Furthermore, no qualification level will be used directly, but I will use the income level as a proxy for qualification, what will indirectly be a decision parameter for the retirement time point.

3.4 Simulation model

In this section, I briefly want to transform the model, defined in the section before, to a simulation model, suitable for the implementation through a simulation software. All important variables and calculations have been provided and will be extended in their characteristics. All here described limitations are initial values, that may be modified in the validation step in chapter 6. The range for the maximum size of the social network will be set to 30. The ratio of blue collar workers can be defined in a range between 0 and 1. The ratio of imitator agents R_I will be adjustable between 0 and 100 percent in order to perform multiple experiments. The stipulated retirement age R_S is defined as 65 years and the trivalent imitation mode selector will be used.

CHAPTER 4

Simulation Environment

4.1 NetLogo

Overview

NetLogo[1] is a programing language to realize multi-agent based simulations in context of social, natural but also economic complex phenomena. It has been developed by Uri Wilensky and Seth Tisue as a tool for eduction as well as research purpose and is under continuous development at the center of Connected Learning and Computer-Based Modeling. The tool is used especially for the modeling of complex systems that evolve over time exploring macro-level effects based on micro-level behavior of individuals. As Tisue and Wilenski state, *NetLogo as a powerful research tool and as a tool for learners at the undergraduate level and higher* [36, p. 2], what expresses the wide range of usability. It is based on the language Logo, which has originally been developed by Seymour, Papert and Feurzeig and is a programmer friendly version of lisp. It does not include a symbol data type, functions, known from other languages, only procedures can be used for segmentation. Another advantage is the unbounded graphical representation introducing wordings that are based on the usage of children, like *turtle graphics*, where a virtual turtle moves around on the screen leaving a trail behind. That is why agents are named as turtles and points on the grid are named patches, where turtles move over. It is written in Java, using the just in time compiler (JITC), with high performance, including bigger and powerful libraries. The virtual machines (JVM) are of higher quality, using the GUI toolkits (Java Swing Framework) with a good look & feel, embedding apple support with MAC OS X showing cross platform compatibility.

Netlogo User Interface

Figure 4.1 shows the user interface of NetLogo with an example from the provided model library explaining the major elements of the GUI.

[1] `http://ccl.northwestern.edu/netlogo/`

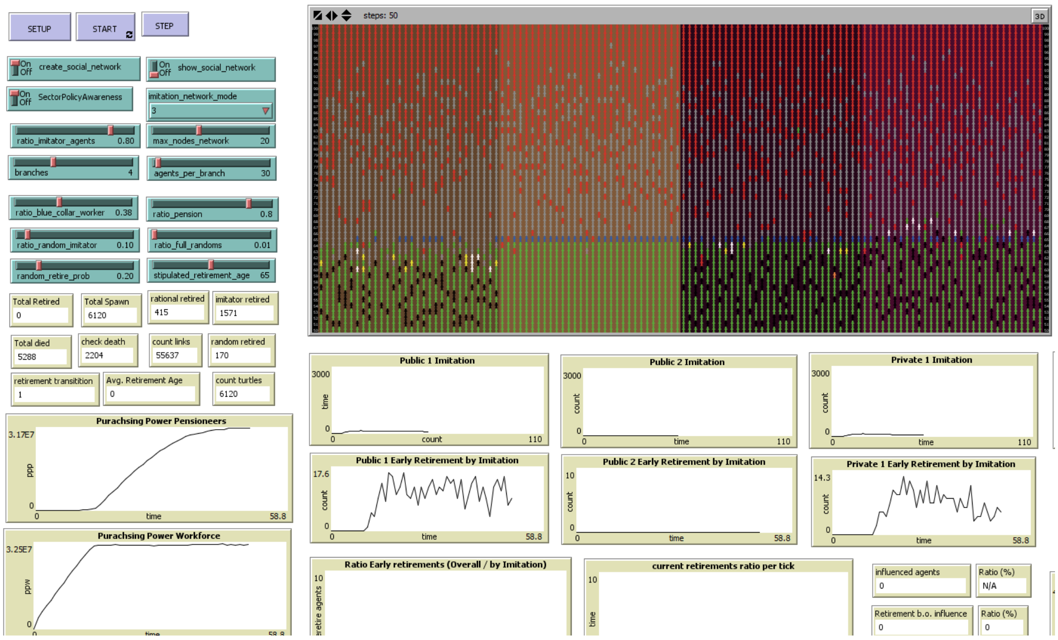


Figure 4.1: Screen-shot of NetLogo UI of simulation model

The User Interface consists out of three tabs, with the interface, information and code tab.

- The **Interface** contains the *world*, that is the visualization of the model, where the turtles represent individuals, moving from one age cohort to the next one. On the left side, sliders, buttons as well as monitors and plots are positioned. Buttons are used to control the model with the *Go* or the *Setup* procedure, that is triggered with the button. Sliders are a common element for input variables, supporting a range function with min, max and step setup. Monitors are used to output real-time variables or global values. Plots display those variables as time series. At the bottom, the command center is visible, where defined commands can be issued, even while the model is running and provides a perfect tool for debugging and testing.
- **Information** stores the documentation of the simulation model containing an explanation of the model as well as rules and gives the reader a guideline how to use the system and read outputs.
- The **Code** tab contains the programming procedures with the crucial setup and go part branching into sub-procedures using local or global variables and additional packages

Performance and Concurrency

Tisue and Wilenski point out higher speed for models that have few agents but complex code. With simple code, more turtles and patches, the overall speed could be accelerated having no side effects like too complex code or huge sets of agents. NetLogo is a hybrid compiler that interprets the user code directly with higher efficiency [36, p. 13]. As an informatics student, I like the idea of using Javas virtual machine stack to immediately store the results in tree-structure, than in an own created stack [36, p. 14], where I would suggest performance issues. Tisue and Wilenski state, that NetLogo also features concurrent processes based on two sources, where the first affects the elements of the user interface like buttons, monitors or the command center and on the operation system level, it is recognized as one process, although the execution part is bundled in one job, where the model is executed differing to intermediate inputs from the user, giving inputs to the command line as a thread [36, p. 14]. If more than one job is active, the engine selects automatically the job, that has a higher priority. The second concurrency appears in the execution of turtle actions, e.g. if they are asked equally-balanced to perform their processes. Wilensky comes up with an example on [36, p. 14], how multiple agents perform moves, step-by-step. NetLogo includes breeds, where turtles can be spawn of and are permanently assigned to them. They offer the advantage, that not every single turtle has to be accessed serially. This structure is highly recommended for the development process.

4.2 Turtles represent Employees

As already mentioned, turtles represent the inhabitants of Austria. There will be no procreation, agents will be generated at the age of 50 and will be removed from the grid if they are 100 years old. The time point of death is determined by the mortality probability in the concurrent age cohort. Agents inherit following attributes:

- `Who` refers to an unique assigned id for each agent.
- `Color` is one of the 140 predefined colors, which can be assigned with a String name or an integer value.
- `Heading` is initially assigned as *north* that is the integer value representing the angle 0.
- `XCor` and `YCor` represent the vertical and horizontal coordinate on the grid.
- `Shape` is assigned with the person shape of the default vector shapes.
- `Label` is a small string text over the turtle an can be used to display e.g. the retirement age
- `Breed` can be any textual naming.
- `Size` is a built-in turtle variable holding the number of the turtles apparent size. Size one corresponds to the size of exactly one path.
- `Pen-Size` and Pen-Mode Can be used to track the movement of a turtle.
- `person_age` is initialized with 50 and incremented with every tick.

- person_retirement_reservation_age is calculated in respect to all agents in the same sector shifting the own reservation level up or down.
- person_calculated_retirement_age is initially set to the preset value, representing national pension reforms and is modified in dependency of the sector the agent is situated in.
- person_actual_retirement_age is immediately set, if the agent retires.
- person_type ,specifies one of four different agent types, represented through integer values.
  - Type *rational* 0
  - Type *imitator* 1
  - Type *random imitator* 2
  - Type *full random* 3
- person status represents an integer value, differing between
  - Type *Working* 0
  - Type *Retired* 1
  - Type *Dead* 2
- person_influenced is initially set to 0, but replaced with the current age, when the agent was influenced.
- person_collar the agent is assigned to one of two affiliation types
  - white refers to the typical clerk in offices
  - blue refers to classic worker this type of agent is only available in the private sector with a ratio of 38 percent.

4.3 Patches represent Employers

Besides the employee, that is represented through turtles, the employer needs further definition. The grid defines a two dimensional net, where the agents move onto. On every part of the grid, a patch is defined as an employer, representing a branch/sector with inherited parameters. They can be illustrated as two nets, where employer-turtles are placed on an employee-slot, representing a place of employment. The employer (or patch) contains following attributes derived from the characteristic of the labor market property permutation

- Employer_Type specifies, if the employer wants to keep employees as long as possible or releases them earlier
- Employer_Kind represents, if it will be a private or public sector

Because, the employer settings are static for one sector, they are assigned once, not cyclically.

4.4 Links represent the social connectedness

Figure 4.2 illustrates the creation of the social network, where numerous random drawn links are visible. Connections, coming from above the frame are drawn from agents on the bottom line. Due to performance issues, the visibility of these links is turned off during runtime.

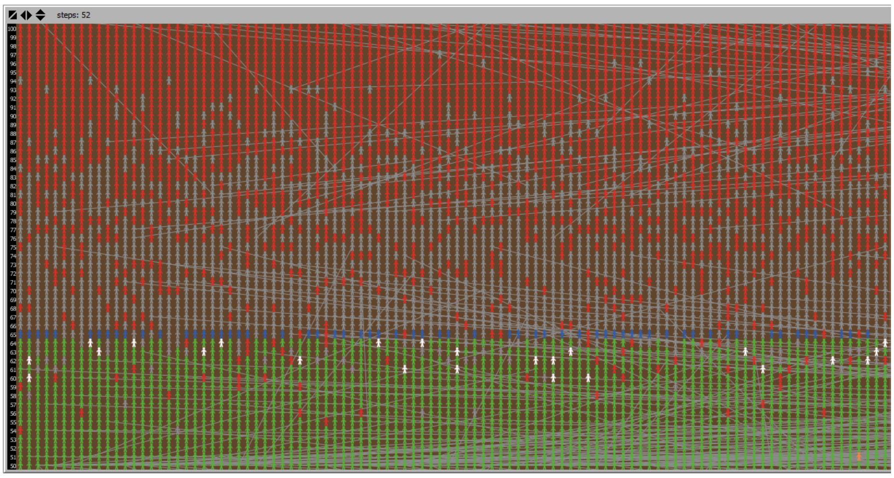


Figure 4.2: Image of layered networks

4.5 Inputs

As already mentioned, the model needs different input parameters, that are represented through sliders in the user interface. I will declare the subsequent ranges for all input parameters:

1. `create_social_network` (boolean), defines, if agents creates a social network in compliance to the connection policy. If no network is created, no social effects will occur.
2. `sector_policy_awareness` (boolean), defines, if agents will imitate with an optimization algorith or without.
3. `imitation_network_mode` (trivalent) ($1 \leq mode \leq 3$), specifications have already been provided.
4. `max_nodes_network` (integer) ($0 \leq n_M \leq 50$): An integer value is a preset for the value n_M, defining, how many edges at maximum are created from one specific agent.
5. `agents_per_sector` (integer) ($0 \leq p \leq 500$) representing the size of agents per sector
6. `ratio_imitator_agents` (double) ($0 \leq R_I \leq 1$) fixes the fraction of imitator agents over all sectors and age cohorts.

7. ratio_blue_collar_worker (double) ($0 \leq c \leq 1$) defines the fraction of blue collar workers, that are only distributed in the private sector area, but refers to the whole population.

8. ratio_pension (double) ($0 \leq r \leq 1$) sets the fraction of the income, that defines the pension value.

9. ratio_random_imitator (double) ($0 \leq i \leq 1$) specifies the proportion of random imitator agents.

10. ratio_full_random (double) ($0 \leq f \leq 1$) specifies the proportion of full random agents.

11. random_retire_prob (double) ($0 \leq o \leq 1$) defines the fraction of full random agents, that will retire with each tick.

12. stipulated_retirement_age (integer) ($60 \leq R_S \leq 70$) is implemented in the calculation of the rational as well as the initial retirement reservation age.

13. sp1_l (integer) ($55 \leq sp1_L \leq 65$) sets the low threshold value for the public sector 1

14. sp2_l (integer) ($55 \leq sp2_L \leq 65$) sets the low threshold value for the public sector 2

15. sp3_l (integer) ($55 \leq sp3_L \leq 65$) sets the low threshold value for the private sector 3

16. sp4_l (integer) ($60 \leq sp4_L \leq 65$) sets the low threshold value for the private sector 4

17. sp1_h (integer) ($60 \leq sp1_H \leq 65$) sets the high threshold value for the public sector 1

18. sp2_h (integer) ($60 \leq sp2_H \leq 65$) sets the high threshold value for the public sector 2

19. sp3_h (integer) ($60 \leq sp3_H \leq 65$) sets the high threshold value for the private sector 3

20. sp4_h (integer) ($60 \leq sp4_H \leq 70$) sets the high threshold value for the private sector 4

In Figure 4.3, all mentioned parameter realizations, with default values, are represented.

4.6 Outputs

In this section, the output parameters through the simulation software will be annotated. The important variables have already been mentioned in the methodology chapter. The listing contains the parameter and variable name.

- Overall retired, working and died agents
- Purchasing Power as time series
- First Sector successful imitations as time series

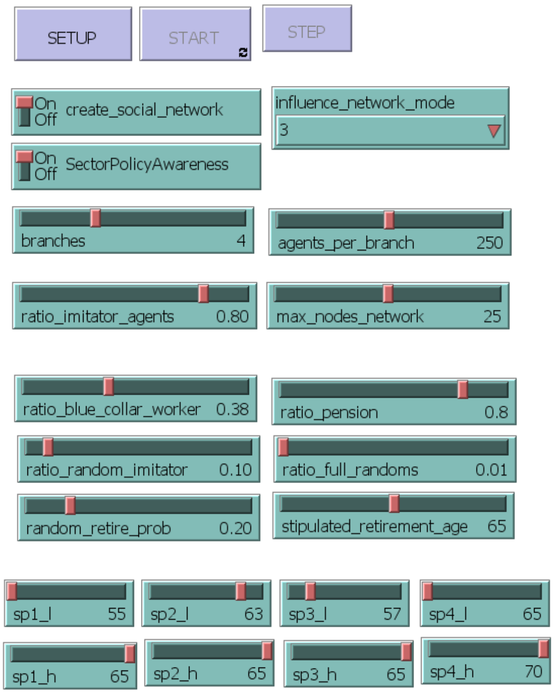


Figure 4.3: Image of sliders used as input parameters

- Second Sector successful imitations as time series
- Third Sector successful imitations as time series
- Fourth Sector successful imitations as time series
- First Sector earlier retired agents caused by successful imitation as time series
- Second Sector earlier retired agents caused by successful imitation as time series
- Third Sector earlier retired agents caused by successful imitation as time series
- Fourth Sector earlier retired agents caused by successful imitation as time series
- Overall earlier retired agents caused by successful imitation as time series
- Ratio of earlier retired agents caused by successful imitation to all retiring agents as time series
- Aggregated ratio of earlier retired agents caused by successful imitation to all retiring agents as time series
- Aggregated sum of types of agents
- Additional variables and parameters as check values

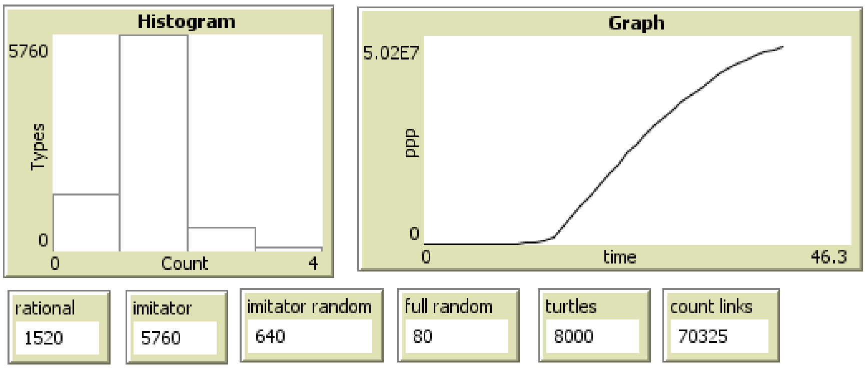


Figure 4.4: Image of Netlogo output Plots and Monitors

The output of the world as main visualization will only be used to perform a subjective estimation of structures, correct behavior applying the watch, follow and inspect function. During the experiments, it is recommended, to disable visualizations to prevent performance loss.

4.7 Simplifications and Limitations

There will be 81.600 Agents involved in the simulation, that are covering the population. Because of computational limitations, it is not possible to extent that number. Agents to do not move around on the grid like in an real world, where they could get in contact with different people. The simplified approach creates a network without individual interaction. Agents do not change their affiliation during their life time, applying the simplification in terms of the labor market to the simulation model.

4.8 Profiler

The Profiler extension will be used to measure the total execution time and rate the performance of all used procedures. I will give some general information and suggest the reader with deeper interests to obtain knowledge from the NetLogo website[2]. The profiler has to be setup correctly and is performed during the runtime as long as the user declares it. The output file includes exclusive as well inclusive times of the analyzed procedures.

The code needs to have the extension implemented.

```
extensions [profiler]
```

The setup part includes the initialization and the start of the profiler.

```
profiler:reset
profiler:start
```

[2]http://ccl.northwestern.edu/netlogo/docs/profiler.html

Then the go part implements the stop and the output of the profiler result.

```
profiler:stop          ;; stop profiling
print profiler:report  ;; view the results
profiler:reset         ;; clear the data
```

The results can be exported from the command center to an external file for further analysis.

4.9 BehaviorSpace

It is a software tool, that is integrated in NetLogo and allows different experiment setup and runs multiple times systematically varying the settings and recording the defined output parameters. If the computer supports multiple processor cores, every run will use one core in parallel. It is used to produce the relevant experiments optimally and effective. More information can be obtained at the corresponding NetLogo website[3]. The total amount of experiments is a permutation of all parameters. An exemplary setup can be observed in figure 4.5.

[3] http://ccl.northwestern.edu/netlogo/docs/behaviorspace.html

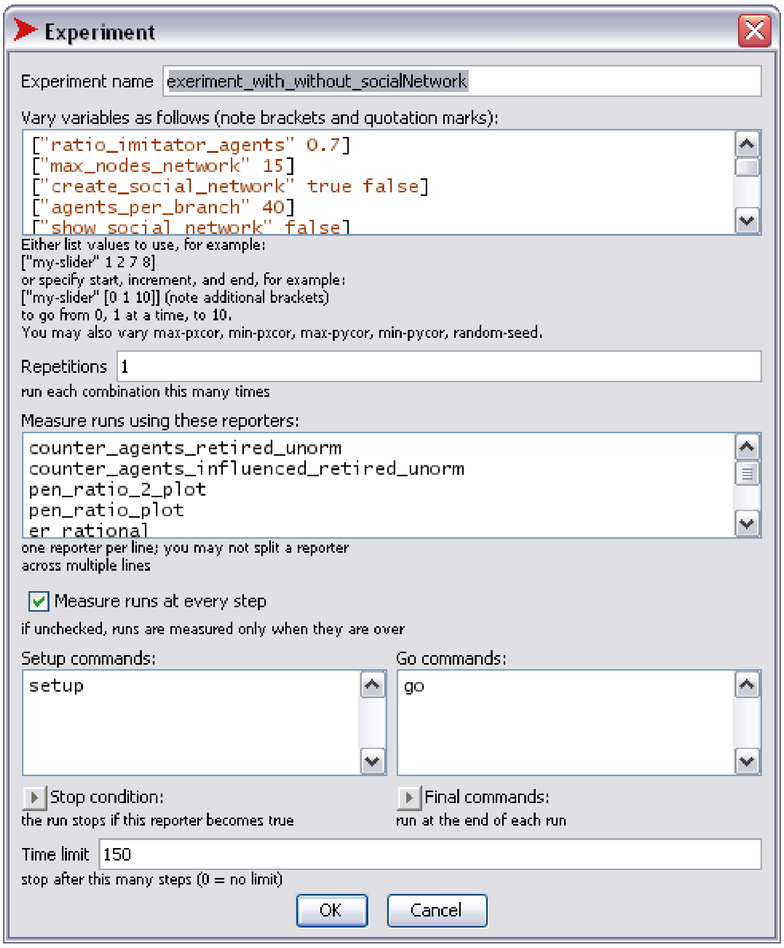


Figure 4.5: BehaviorSpace with example Setup

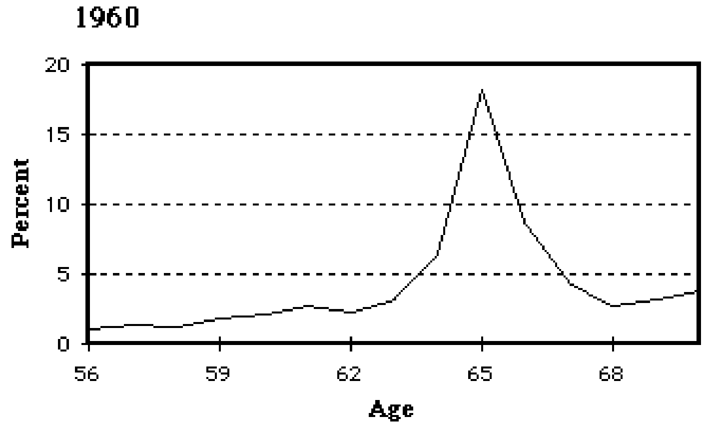
CHAPTER 5

State of the art

In this section, I want to discuss some previous work. One major contribution and base for this work is the paper of Robert L. Axtell and Joshua Epstein, 1999 about Coordination in Transient Social Networks. They suggest, that individuals, compute the age when to retire in an optimal manner, where the majority of the population follows an imitative behavior. They analyze their model with techniques of computational type. Their work was motivated by a policy question, analyzing the connection between individual rationality and aggregate efficiency with optimization of individuals as well as the role of social interactions, social networks and individual decision making including outcomes and dynamics [3, p. 1]. The research is based on a reform, established by the Congress of the United States of America, lowering the minimum retirement age from 65 to 62 years, with the possibility to claim the benefit of the social security earlier, expressing a policy shift. It was interesting, that it took over three decades to reduce the actual retirement level to 62. The process is illustrated in figure 5.1 and 5.2. A retirement decision making process is defined in following terms [3, p. 2]:

- At an optimal age, some action Y is performed
- A policy $Y* \neq Y$ is instituted exogenously
- But the individual does not instantly shift from Y to $Y\star$, what would be a fully rational behavior.
- Social interactions follow, that trigger the change.

They develop a model including imitation in social networks trying to generate what they call it a *patchy and sluggish dynamics* [3, p. 4]. They use simplified data without losing capacity to solve problems of dynamic programming and admit, that the model fails to provide a realistic microeconomic account of the phenomenon [3, p. 3]. A heterogeneous population is created, where some will behave as they were informed rationals, while the others will not. They emphasized, the explicit central role of social interactions and the used network. Axtell and Epstein introduce three different agent types:



Source: Axtell, Epstein, 1999, Coordination in Transient Social Networks, p.2, Fig. 6-1

Figure 5.1: Shift of minimum retirement age from 65 to 62 at 1960

- Optimal behaving agents, that are a rational minority and will retire as early as possible in accordance with governmental policies.
- Randomly behaving agents, which are a minority too and retire with a fixed probability P each period, if they reach an eligible retirement age.
- Imitators, that mimic other agents in their social milieu and are the majority. They are the most interesting to focus on, not only because of their heterogeneous nature. Every agent has an imitation threshold that is compared to the fraction of known other agents, that have already retired. If the fraction is over the threshold value, the agent will retire too. So basically, they are playing a coordination game, defined by Young, 1998 [37, p. 3]. The agents derive a utility from communication with the social network, where they are either working or retired. Through the interaction, a payoff function is applied in a 2x2 social network game. Further information on the calculations can be obtained from Axtell, Epstein(1999 [3, p. 5f]. This is slightly different from my approach, where no coordination game is executed, but all reservation levels are compared and the rounded minimum average is selected by the interacting agent. Additionally, this coordination game would not decide in the end, if the agent is actually retiring, because the employer and national stipulations have to be obeyed strictly.

In their simulation model, they use a similar cohort structure, where a total of $81C \equiv A$ agents are assigned with a random death age $U[60, 100]$. In contrast to my model where a point probability for every agent in the age cohort is applied, they use uniform rectangular distribution on the interval. They apply fractions of 75% imitator, 5% random and 15% rationals agents [3, p. 7]. The random retire probability is set to 0.5 each period [3, p. 7]. Every agent uses hetero-

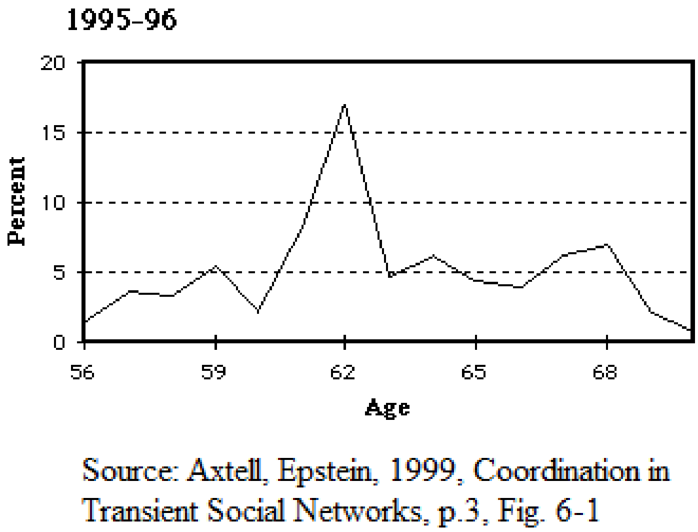


Figure 5.2: Shift of minimum retirement age from 65 to 62 at 1995

geneous social network, that is created upon five age cohorts above and below the own age, represented through a list of other agents, what corresponds to my model. There is no need to use a matrix, what is data and performance consuming. The members of each list are randomly selected and vary in size over the life time of the agent. The connection is drawn to older or younger agents having networks overlapped producing a high amount of single random graphs where known individuals are represented as nodes and directed edges as social awareness. In the two-dimensional representation of the simulation model of Epstein and Axtell, each agent is visualized through a rectangle, that is positioned in specific cohorts and age progressively. The researchers are interested in the diffusion of the interests of individuals through coupled heterogeneous networks and how the dynamics vary with important parameters like the fraction of the different agent types. The answer should be found with a quantitative approach of an agent-based model where *macroscopic regularities grow from the bottom-up.* [3, p. 6]. Agents do not possess global information and involve computational capacities. Axtell and Epstein describe the advantages of this new methodology, including modeling of individual heterogeneity, bounded rational behavior, non-equilibrium dynamics and spatial processes. They implement their simulation model with an object-oriented programming style using the advantages of local and global methods and are able to apply functions. This paper is rated as optimal base for this project, identifying many conformances. They are focusing on the effects of individual heterogeneity caused by dynamic networks, while I am about to use to observe far reaching processes.

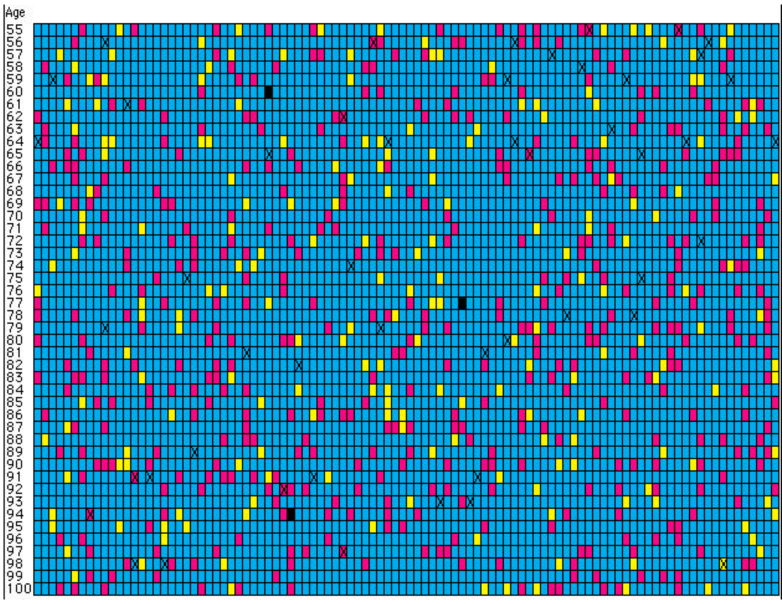


Figure 5.3: Axtell and Epsteins Visualization of the world

CHAPTER 6

Model Validation and Verification

6.1 Conceptual Model Validation

As Sargent defines in the paper on Simulation Model Validation and Verification, the conceptual model has to include theories and assumptions that are correct and reasonable for the intended purpose of the model [32, p. 2]. First, I want to validate the agent-based modeling approach. A correspondence to real world actors including important attributes like age, reservation levels, character type and a heterogeneous social network is noticeable. The circle of acquaintance changes over time, adding several members without losing already coupled once. Human networks also do not change permanently over time in a big scope. An average of 4 to 20 static network nodes, with an average degree of 12 can be recognized with social network analysis tools and correspondence to the result of Pressman (2005), that also stated social relations between four and 20 members [28, p. 18]. Burtless (2006) verified, that individuals do not make their retirement decision multiple times, but once [12, p. 2], which is true for the conceptual thesis model. It also differs between employers and employees, supporting the validation of ontological correspondence. The individuals are aging one year per tick, what is an acceptable and accurate time step for a macro-level analysis and correspondence to the model of Axtell and Epstein (2006). The calculation of the individual income is defined with a discrete distribution of the total population assigning the values randomly between all agents at the initial creation time point. The income range is defined between $9166 \leq A_I \leq 27188$, what corresponds to the statistical data from 2012 [1]. The calculated retirement age was initially calculated with the formula 6.1

$$A_L = \frac{27 - A_I}{1000} + 55 \tag{6.1}$$

resulting in old agents, that have a small income, not applying the branch specifications correctly. The reformulated calculation uses this formula 6.2:

$$A_L = \frac{R_S - 17 + A_I}{1000} \tag{6.2}$$

The result is then rounded. The value R_S is adjusted +2 for blue collar worker, because it is verified, that they would prefer to retire earlier, but statistical data reveal a later regular workforce exit. The next validation is concerned with the pension calculation: $A_P = 0.8 * A_I$, that are 80 percent of the income of the individual. This no full correspondence to the real world, but includes the deprecated calculation model, because the implementation of the current model, including different employers, unstable income as well as unemployment, would be to extensive. Agents are randomly assigned to one of four different agent types in order to the already defined fractions, the user provides. A detailed descriptions of the types can be obtained in the chapter on *Methodology* and *Simulation Environment*.

- Imitator: The fraction value is provided by the input parameter R_I, that is set initially with the value of 80 percent and differs only 5 years from the configuration setup of Axtell and Epstein [3, p. 9].

- Random imitator: 10 percent of the imitator agents R_I are random imitator. This value corresponds to the 5 percent Axtell and Epstein were applying in their default setup [3, p. 8]

- Full random: one percent of remaining not assigned agents. Face Validity was performed with members of the ECON institute that verified the value as low enough to include certain side effects but to neglect bigger impacts on the outcome.

- Rational: the complement of all agents not assigned to those, who are already part of a subset. In comparison to Axtell and Epstein [3, p. 8] the value is acceptable.

Those fractions are important to verify the simulation model and assure computational model reliability. As described in Axtell and Epsteins Paper on coordination in transient networks, it makes a quantitative difference, if all agents in the social network are considered or only those who are eligible to retire. This assertion validates the ranges, that have been defined in chapter three. Agents will update the reservation level according to the policy with the notice, that agents are only receiving values from agent of the same employer kind (public or private):

1. Mode 1 - Retired: That economical active agents ask only retired agents may be unrealistic, but could yield acceptable results. Therefore, the mode is valid for usage with the limitation of a +10 year box for the requesting procedure.

2. Mode 2 - Working: This mode is valid under the condition, that only agents, that are not younger than 10 years as the requesting turtle are in the sub-set, that is used for calculation.

3. Mode 3 - Dual: The third mode was used by Axtell and Epstein and could also be confirmed in the Face Validation phase, performed by members of the ECON institute of the University of Technology in Vienna.

The update of reservation level in correspondence to the modes will be illustrated with the pseudo code listed below.

```
Begin
  For i = 1 to max(connected_agent)
  Begin
    if (Mode = 1)
    Begin
      if (actual_retirement(i) < reservation &
        age(i) <= actual_retirement(i) + 10)
      Begin
        update_reservation_level = mean(actual_retirement(i))
      End
    End
    if (Mode = 2)
    Begin
      if (reservation(i) < reservation &
        age-10 <= age(i))
      Begin
        update_reservation_level = mean(reservation(i))
      End
    End
    if (Mode = 3)
    Begin
      if (reservation(i) < reservation ||
         actual_retirement(i) < reservation &
         age-5 <= age(i) <= age+5)
      Begin
        update_reservation_level = mean(reservation(i))
      End
    End
  End

  reservation = update_reservation_level
End
```

Sector Policy Awareness (SPA)

If imitating agents adapt their reservation level, they do not add any information about the sector policy to that formula and are therefore not aware of boundaries of eligibility. To overcome this issue, SPA is introduced. The subsequent pseudo code will explain the differences to the algorithm, that has formerly been defined. If the requested levels do not fulfill the sector policy boundaries, the value is skipped and not considered in the calculation. This effect can be explained through the bounded rationality of the heterogeneous individuals. The following code snippet shows the implementation of the sector policy awareness functionality. The user can decide, if the SPA should be applied or not.

```
Begin
  For i = 1 to max(connected_agent)
  Begin
    if (Mode = 1)
    Begin
      if (actual_retirement(i) < reservation &
        age(i) <= actual_retirement(i) + 10 &
        reservation >= sector_policy_threshold_low &
        reservation <= sector_policy_threshold_high)
      Begin
        update_reservation_level = mean(actual_retirement(i))
      End
    End
    if (Mode = 2)
    Begin
      if (reservation(i) < reservation &
        age-10 <= age(i) &
        reservation >= sector_policy_threshold_low &
        reservation <= sector_policy_threshold_high)
      Begin
        update_reservation_level = mean(reservation(i))
      End
    End
    if (Mode = 3)
    Begin
      if (reservation(i) < reservation ||
         actual_retirement(i) < reservation &
         age-5 <= age(i) <= age+5 &
         reservation >= sector_policy_threshold_low &
         reservation <= sector_policy_threshold_high)
      Begin
        update_reservation_level = mean(reservation(i))
      End
    End
  End

  reservation = update_reservation_level
End
```

Axtell and Epstein use a coordination game to pinpoint the retirement reservation age, but this is in my opinion a simple approach, that would include knowledge of others information, that is often not available for the individual. Therefore, an advanced approach is applied. The next validation step analyzes the retirement process. Depending on the sector, the agent is situated in, the actual retirement age depends on two factors. The governmental stipulated minimum retirement age, the employer and the respective sector policy for non-formal exceptions. The process of early retirement is defined in the context of company retirement programs and does not fully apply to the official term of an *early retirement*, because they are handled only by the national administration. This scenario is about to be fully prohibited by new reforms. In the methodology section, the relative ranges have been stated. In table 6.1, the sector policy ranges for the stipulated minimum retirement age of 65. These values can not be directly derived

Policy	Release	**Public**	**Private**
P1	**Accommodative**	$T_L(1) = 60$ $T_H(1) = 65$	$T_L(3) = 63$ $T_H(3) = 65$
	Adverse	$T_L(2) = 65$ $T_H(2) = 65$	$T_L(4) = 65$ $T_H(4) = 70$
P2	**Accommodative**	$T_L(1) = 55$ $T_H(1) = 65$	$T_L(3) = 60$ $T_H(3) = 65$
	Adverse	$T_L(2) = 60$ $T_H(2) = 65$	$T_L(4) = 65$ $T_H(4) = 70$
P3	**Accommodative**	$T_L(1) = 55$ $T_H(1) = 65$	$T_L(3) = 58$ $T_H(3) = 65$
	Adverse	$T_L(2) = 60$ $T_H(2) = 65$	$T_L(4) = 65$ $T_H(4) = 70$
P4	**Accommodative**	$T_L(1) = 55$ $T_H(1) = 65$	$T_L(3) = 57$ $T_H(3) = 65$
	Adverse	$T_L(2) = 58$ $T_H(2) = 65$	$T_L(4) = 60$ $T_H(4) = 70$

Table 6.1: Definition of absolute sector policy levels

from previous studies or statistics, but they reflect assumptions based on acknowledgments of Holzmann (2001), that stated, that employees in the public sector retire earlier, than private affiliated employees [20, p. 13]. Therefore, a lower threshold value in the public sector will be assumed. The levels are subject of the experiments and the final operational validity, to prove, which policies fit best. Agents will retire within this framework according to their type.

- Rationals: Retire, if the calculated retirement age is achieved and the framework conditions are true.

- Random Imitator: Set their retirement age randomly and pretend imitation. They will try to retire at the random formed age, but at last at the stipulated age.

- Full Randoms retire at the random defined age not caring about any conditions, e.g. retirement with 52 or 90 is possible.

- Imitator: Calculate their retirement age initially, may perform successful imitation and retire within the framework conditions.

Observing different literature on retirement timing, retiring at old age, social stratification policies and claiming of social security statements, this defined pattern is valid, because it covers all possible conditions and effects.

Network Model

This subsection defines the network, where individuals are interconnected. The network is a large-scale type, that is mainly used in behavioral, social, computer and economic sciences. Pressman, Cohan, Miller and Barkin (2005) did an evaluation, that matches many other studies, concluding social network sizes with 4 - 20 members. With the input variable n_M defines the maximum number of edges from the agent, although the correct size of the connections is determined with:

$$A_S(n) = random[n_M](A_o) \tag{6.3}$$

Edges are only drawn to agents, that do not already have a connection with each other, because this model uses bidirectional awareness. The subset contains all agents, that are not dead, not the requesting agent self and do not have already a connection to the agent. Because a random variable is included, an agent can have a social network of size zero. It must be tested carefully, if the average network size does not exceed the value of 20 members, independent of the preselected value n_M.

6.2 Computational Model verification

Sargent states in his paper on Simulation Model Validation and Verification, the computerized model verification is defined as ensuring that the computer programming and implementation of the conceptual model is correct [32, p. 2,3]. This section includes two subsections. The first deals with the structure, programming design and techniques of software engineering like top-down approaches and program modularity. The second section uses either static or dynamic testing to verify if all levels return correct values and work in accordance to the conceptual model. Because there is no development team, where the code is explained statement-by-statement to convince all members, the dynamic approach is selected, where a bottom-up testing is performed. The results and the verification is listed below.

Stage 1 - Code analysis

Sargent points out the primary technique of structured walk through and traces to check programming style and structure. The walk-through of the code is done by academic members of the econ institute of the University of Technology of Vienna. The code structure and evaluation results of the assigned person are listed below. The code is structured in two top and 17 sub procedures.

1. `setup_world` (Clears the visualization and removes all stored values from the cache)
2. `setup_sectors_as_patches` (Sets up the Sectors with boundaries and allocates stipulation levels and colors)

3. `setup_create_agents` (Agents are spawn at the point of origin [0,0] and are distributed in the cohort 50. This procedure includes several sub-procedures that assign static and dynamic parameters, create social networks and do several calculations)

4. `agents_aging_process` (increments all age values with one year and moves it one position north to the next age cohort)

5. `agents_update_reservation_level_through_imitation` (In respect to the mode, the levels from all agents are aggregated to one average new value, that will replace the old reservation)

6. `agents_check_retirement_eligibility` (Inherits the role of the national social security institution allowing to retire at the stipulated age or earlier in the agreement with the employer)

7. `agent_retire` (Procedure, that handles the retirement transition)

8. `agents_check_mortality` (Reads the mortality file and applies the cohort probability to each agent)

9. `ui_refresh_visualization` (Enables or disables different colorings or the network structure)

Evaluation Results

All code segments fulfill the programming design guidelines and produce no runtime errors. The techniques of *Fixed Values* and *Traces* were mainly used to assure procedure functionality. One elemental error occurred in the call of agents for further processing are *ask agents with [condition]* constructs. The problem results in a high runtime in the setup create agents procedure, because all agents are included at the beginning to then exclude 90 percent of all elements in the subset. This weakness can be solved by the usage of *breeds*, where agents of the sectors are assigned to its breed that have been mentioned in the section four discussing performance issues. When accessing these breeds, only 25% of all agents are selected and runtime could be reduced down to 60 percent of the maximum value. Another experiment setup where Agent-Sets are used to do further reductions did not yield better results. Following breeds will be assigned to the sectors.

- Sector 1: `PublicSector1AgentBreed`
- Sector 2: `PublicSector2AgentBreed`
- Sector 3: `PrivateSector1AgentBreed`
- Sector 4: `PrivateSector2AgentBreed`

Stage 2 - Testing Simulation Software

As already mentioned in the methodology section, there are two approaches for the verification of simulation models. Finally, the dynamic approach, where the *Parameter Variability-Sensitivity Analysis* and the *Fixed Value* method is selected to assure correct and stable procedure execution. Following flaws could be detected, all other routines are executed stable and reliable.

1. In the procedure that creates a social network, an error was detected, where agents did not create outgoing links if they have at least one incoming link from other agents.
2. In the `agents_check_retirement_eligibility` procedure, an error was observed regarding testing ranges that led to unstable results like agents with ages over the max sector policy level of 70, that are still economically active.
3. The blue collar ratio was not implemented correctly that led to an fraction of 88 percent instead of 38.
4. The `agents_update_reservation_level_through_imitation` routine produces unstable results, because agents do not update their level at any time, but at specific levels. That is no error, but will result in a lower imitations, because the imtiation is happening at a very late point of time, where no real early retirement is possible any more.

Stage 2 - Agent type distribution

Figure 6.1 displays the distribution of agent types with the setting of an imitator ratio of 0.8 and a random fraction of 0.01. The first bar represents the rationals followed by the imitators, that are the majority in the simulation environment. The third bar shows the fraction of the random imitators, that are defined as ten percent of the imitator fraction and on the left the random agents with a proportion of 1%.

Sensitivity Analysis

To assure the stability of the results, several experiments with different imitator ratios with 30 repetitions each were conducted. Then, mean values of the key parameter *Early Retirement Fraction caused by Imitation* $Aset_P$ as well as errors are calculated and are displayed in figure 6.2 for P1 with Sector Policy Awareness. Increased deviations at the first 10 periods of the measurement can be evaluated as swings from the last initialization ticks and do not exceed 14 percent, followed by several divergences between 1 and 5 percent. The majority of the measurements holds at and average minimum and maximum discrepancy of 1.4% and can be defined especially at the last 30 periods as stable process. If the reader would disagree in this classification, an improvement of 20 more initialization ticks is suggested. The stability conditions holds for all global key parameters.

Overall results of Simulation Model Verification

Table 6.2 shows the condensed overall results of the evaluation process of the simulation model in order to the documentation guidelines of Sargent [32, p. 178].

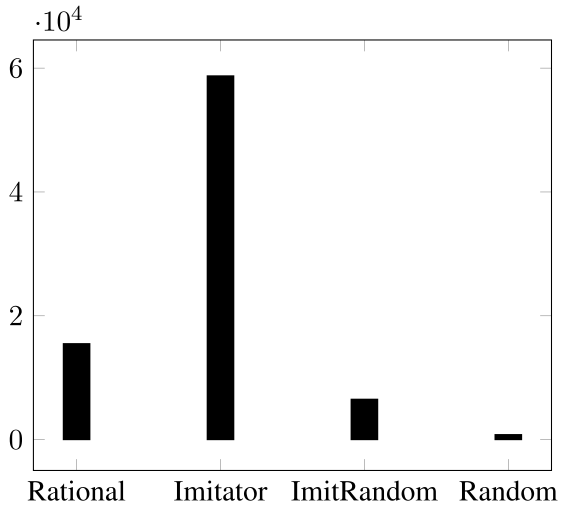


Figure 6.1: Agent types distribution - 80% imitators

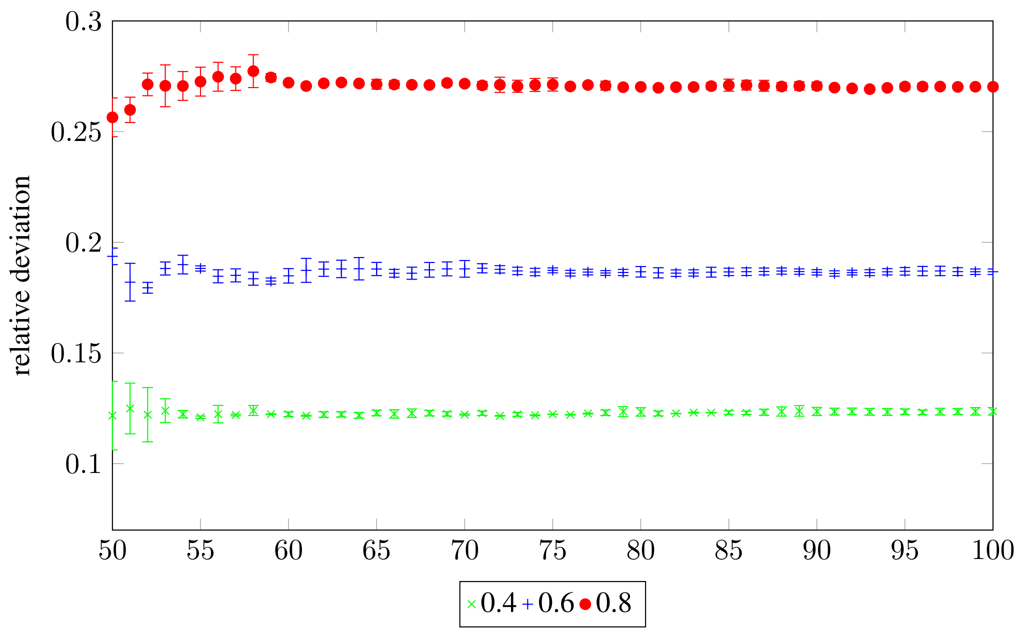


Figure 6.2: Stability Analysis with retirement fractions - Policy 1, Dual Mode

6.3 Data validation

The data is obtained from the Statistik Austria as well as from the Main Association of Austrian Social Insurance Institutions and is evaluated as trustful and are not further validated.

[5]Parameter Variability Sensitivity Analysis

Table 6.2: Overall Evaluation Results

Item	Technique used	Result / Conclusion	Confidence
1	Face Validity	Stable and confident results	100%
2	Fixed Values, Tracing	Stable and confident results	100%
3	Fixed Values, PVSA[1]	Partly stable results	95%
4	Traces	Stable and confident results	100%
5	Fixed Values, Traces	After code correction Stable and confident results	100%
7	Face Validity	Stable and confident results	100%
8	Fixed Values	Stable and confident results	100%
9	Face Validity	Stable and confident results	100%
Setup	Miscellaneous	Stable and confident results	99.4%
Go	Miscellaneous	Stable and confident results	99.4%

CHAPTER 7

Simulation Setup

7.1 Experimental Conditions

The experiments are performed with BehaviorSpace, implementing Key Factor Screening, that supports the developer in reducing the endogenous variables to its optimum to perform a minimum number of necessary experiments. Following attributes with predefined ranges are given in an chronological description. If results or the behavior is questionable, modifications as well as new parameter settings will be presented.

Following reporters are measured each run of the experiment.

Table 7.1: Configuration Parameter Variability

Parameter	Fixed/Variable	Value(s)
Create Social Network	Fixed	False, True
Count Sector	Fixed	4
Agent in Sector	Fixed	400
Ratio Blue Collar Worker	Fixed	0.38
Ratio Pension	Fixed	0.8
Ratio Random Imitator Agents	Fixed	0.1
Ratio Full Random Agents	Fixed	0.01
Random Retire probability	Fixed	0.2
Stipulated Retirement Age	Fixed	65
Imitation Mode	Variable	1, 2, 3
Maximum Network Size	Variable	20, 30
Imitator Ratio	Variable	0.4, 0.6, 0.8
Sector Policies	Variable	P1, P2, P3, P4

Table 7.2: Reporter Measurement Definition and valid ranges

Reporter	Precision	Range
current turtle count	Integer	0 - 81.600
Total retired	Integer	0 - 100k
Total created	Integer	0 - 100k
Pre-Retirements (Overall)	Integer	0 - 50k
Pre-Retirements (Imitation)	Integer	0 - 50k
Successful Imitations	Integer	0 - 10.000
Fraction Successful Imitations / Total retired	Double(3)	0 - 1.00
Fraction Pre-Retirements (Overall) / Total retired	Double(3)	0 - 1.00
Fraction Pre-Retirements (Imitation) / Total retired	Double(3)	0 - 1.00
Purachsing Power	Integer	0 - 500M
Average retrement Age	Double(2)	55.00 - 70.00

7.2 Procedure

Here, a short guideline through the simulation process is provided. After the execution of the setup procedure, to perform initialization of the world and all variables, the mortality probability file is read. Then, the Go Procedure is executed iteratively until the Go Loop is stopped manually or if the final count tick is reached. 49 initialization periods and at least 50 simulation measure ticks are recommended.

CHAPTER 8

Simulation Results

In the last chapter, all preconditions for the simulation conduction have been described. This chapter contains the result of the different configurations to observe the model behavior and continue with the interpretation and evaluation of the results.

8.1 Simulation Experiment Output

In the following tables, the results of the simulation execution are presented, varying the key parameters under different configuration sets. Additionally, some screen-shots of the 2D-View from the software show the initialization phase as well as transition coloring of agents. The experiments are performed with different sector polices, that are defined in the table 6.1.

8.2 Annotation information

Each simulation experiment includes two tables with the configuration setup and the results followed by descriptive information. I want to give some information on the annotation of the tables. `Imit.Ratio` stands for the ratio of imitator in the world. `Imit.Mode` describes the mode, the imitation is performed with. `SuccImit.` reflects the fraction of imitator agents, that performed a successful imitation in relation to all agents. `PreRet(All)` stands for all premature retirements, independent of the agent type. `PreRet(Im.)` is the fraction of imitator agents, that performed successful imitation and retired prematurely. `PP` sets the different absolute values of the workforce purchasing power in relation and has to be read vertically, delimited through horizontal lines. And finally expresses ARA the average retirement age.

Observing the simulation results from table 8.2, increased imitation ratio leads to more successful imitations. A growth of 20 percent of imitator agents is recognized, that have more elements in their social network to connect to. An increasing fraction of early retiring agents from 5.3 to 9 percent is noticed. The average retirement age is reduced about a year with strong increasing imitation ratio. This affirms the data from the conceptual model validation that states

Table 8.1: Simulation Configuration 1

Parameter	Value(s)
Create Social Network	True
Count Sector	4
Agent in Sector	400
Ratio Blue Collar Worker	0.38
Ratio Pension	0.8
Ratio Random Imitator Agents	0.1
Ratio Full Random Agents	0.01
Random Retire probability	0.2
Stipulated Retirement Age	65
Imitation Mode	Retired, Working, Dual
Maximum Network Size	20
Imitator Ratio	0.4, 0.6, 0.8
Repetitions	30
Sector Policy applied	P1

Table 8.2: Simulation Results 1

Imit.Ratio	Imit.Mode	SuccImit.	PreRet(All)	PreRet(Im.)	PP	ARA
0.4	Retired	0.088	0.119	0.009	1	64.9
	Working	0.285	0.141	0.056	0.988	64.8
	Dual	0.292	0.138	0.053	0.989	64.8
0.6	Retired	0.133	0.120	0.014	1	64.9
	Working	0.448	0.146	0.076	0.983	64.7
	Dual	0.459	0.148	0.079	0.982	64.7
0.8	Retired	0.176	0.124	0.019	1	64.9
	Working	0.636	0.143	0.143	0.981	64.6
	Dual	0.647	0.141	0.090	0.981	64.7

an imitation ratio of 80 percent. It would be unrealistic, if agents would only ask known people, that have not retired as well as if they would ask just retired friends and family members. The differences between the imitation modes, especially with different imitation ratios are also noticeable. At a low imitator ratio, 21 percent more successful imitation with 4 percent more premature retirements occur. With increasing imitator ratios, this gap is rising up to 47 percent more imitations and 8 percent more premature retirements. 9 out of 65 percent of those agents, that perform an successful imitation are eligible to retire. This happens, because they do not optimize! Successful imitation leads to an reduction of the reservation level, partly over the limits of eligibility, where sector policies do not allow retirements. Imitating agents can then only retire at the calculated level, that is often set after 65. Therefore, the next simulations will be performed with enabled Sector Policy Awareness, that helps imitating agents to reduce the reservation level with optimality. The results of simulations with this rule are presented in

Table 8.3: Simulation Configuration 2

Parameter	Value(s)
Create Social Network	True
Count Sector	4
Agent in Sector	400
Ratio Blue Collar Worker	0.38
Ratio Pension	0.8
Ratio Random Imitator Agents	0.1
Ratio Full Random Agents	0.01
Random Retire probability	0.2
Stipulated Retirement Age	65
Imitation Mode	Retired, Working, Dual
Maximum Network Size	20
Imitator Ratio	0.4, 0.6, 0.8
Repetitions	30
Sector Policy Awareness	True
Sector Policy applied	P1

Table 8.4: Simulation Results 2

Imit.Ratio	Imit.Mode	SuccImit.	PreRet(All)	PreRet(Im.)	PP	ARA
0.4	Retired	0.119	0.261	0.070	1	64.0
	Working	0.161	0.319	0.127	0.990	63.9
	Dual	0.176	0.303	0.122	0.987	63.8
0.6	Retired	0.207	0.301	0.115	0.978	63.8
	Working	0.238	0.339	0.175	0.968	63.7
	Dual	0.265	0.348	0.186	0.950	63.4
0.8	Retired	0.256	0.311	0.148	0.950	63.5
	Working	0.321	0.372	0.232	0.941	63.3
	Dual	0.363	0.386	0.256	0.923	63.0

configuration two.

We can now observe, that the Policy Awareness (SPA) and optimization is working and yields divergent results. The successful imitation rate has decreased by increasing total early retirements as well as premature workforce exits caused by imitation. With an imitator ratio of 0.4, the rate of successful imitations has decreased from 29 to 18 percent although the fraction of early retirements caused by imitation increased from 5 to 12 percent, that confirms the force of the SPA. With an increasing imitation ratio, the early retirements caused by imitation increase disproportionately to the configuration 1, comparing the successful imitations. Average retirement age as well as purchasing power decreased stronger than without the optimization algorithm. Another interesting effect can be observed in the comparison of the results in order to the imitation modes of the configuration 2. While in configuration 1 the successful imita-

Table 8.5: Simulation Configuration 3

Parameter	Value(s)
Create Social Network	True
Count Sector	4
Agent in Sector	400
Ratio Blue Collar Worker	0.38
Ratio Pension	0.8
Ratio Random Imitator Agents	0.1
Ratio Full Random Agents	0.01
Random Retire probability	0.2
Stipulated Retirement Age	65
Imitation Mode	Retired, Working, Dual
Maximum Network Size	30
Imitator Ratio	0.4, 0.6, 0.8
Repetitions	30
Sector Policy Awareness	True
Sector Policy applied	P1

tions between dual and working mode are quite contiguous (0.285, 0.292 or 0.636, 0.647), in the second run, they differ up to four percent. And where the difference of the early retirement fractions in configuration 1 varies between 12 and 16 percent, in configuration 2 they gap has increased (26 to 39 percent). The overall results could be slightly improved yielding a lower average retirement age and a higher purchasing power reduction.

8.3 Modified network size

Up to now, it could be observed, that different imitation modes as well as the individual awareness of rules play an important role. The network size has been fixed under the validated size of 20. But how do the results change, if the network size is increasing, like simulating other cultures with bigger social networks.

In the simulation result (table 8.6) can be observed, how the results differ from those with a network size of 20 (configuration 2). With an imitation ratio of 0.4, values are slightly under those of configuration 2. With increasing proportion of imitating agents (0.4 and 0.6), the overall value as well as the imitation success rises. A peak value of 29 percent of agents can be achieved, that retire earlier because of imitation and lead to an average retirement age below 63. And all with the same sector policy rules. A saturation of the key fractions with increasing network size can be assumed, where propagation meets its boundaries.

Table 8.6: Simulation Results 3

Imit.Ratio	Imit.Mode	SuccImit.	PreRet(All)	PreRet(Im.)	PP	ARA
0.4	Retired	0.145	0.275	0.009	1	63.9
	Working	0.175	0.302	0.127	0.994	63.8
	Dual	0.188	0.307	0.133	0.984	63.7
0.6	Retired	0.219	0.301	0.130	0.973	63.6
	Working	0.278	0.349	0.198	0.973	63.5
	Dual	0.294	0.358	0.211	0.955	63.3
0.8	Retired	0.314	0.336	0.191	0.948	63.2
	Working	0.368	0.397	0.269	0.937	63.1
	Dual	0.393	0.401	0.285	0.922	62.9

Table 8.7: Simulation Configuration 4

Parameter	Value(s)
Create Social Network	False
Count Sector	4
Agent in Sector	400
Ratio Blue Collar Worker	0.38
Ratio Pension	0.8
Ratio Random Imitator Agents	0.1
Ratio Full Random Agents	0.01
Random Retire probability	0.2
Stipulated Retirement Age	65
Imitation Mode	Dual
Maximum Network Size	20
Imitator Ratio	0.8
Repetitions	30
Sector Policy Awareness	True
Sector Policy applied	P1

8.4 Without Imitation

To complete the experiments, one further simulation is conducted, although the simulation results will not include imitation success and retirements through imitation rates.

The results of this experiment are stated in table 8.11. Between the results with different imitation ratios, no significant differences can be observed. There is no relevant decrease of the purchasing power or the average retirement age visible, what was expected.

Table 8.8: Simulation Results 4

Imit.Ratio	Imit.Mode	PreRet(All)	PP	ARA
0.4	Retired	0.109	1	65.0
	Working	0.112	0.999	65.0
	Dual	0.110	0.998	65.0
0.6	Retired	0.110	1	65.0
	Working	0.111	0.999	65.0
	Dual	0.110	0.999	65.0
0.8	Retired	0.111	1	65.0
	Working	0.112	0.999	65.0
	Dual	0.113	0.999	65.0

Table 8.9: Simulation Configuration 5

Parameter	Value(s)
Create Social Network	True
Count Sector	4
Agent in Sector	400
Ratio Blue Collar Worker	0.38
Ratio Pension	0.8
Ratio Random Imitator Agents	0.1
Ratio Full Random Agents	0.01
Random Retire probability	0.2
Stipulated Retirement Age	65
Imitation Mode	Dual
Maximum Network Size	20
Imitator Ratio	0.8
Repetitions	30
Sector Policy Awareness	True
Sector Policy applied	P2

8.5 Sector Policy variation

In the last section, different results with varying key parameters have been illustrated. The experiments are performed in the dual imitation mode with enabled Sector Policy Awareness. After the focus on imitation, I want to analyze the second relevant influence, that has been defined as the decisions on the retirement eligibility of employees made by the employers on the corporate sector. In the table 3.1, these policy ranges with low and high threshold values have been stated and discussed in the validation chapter. Now they are applied and the results are listed below, using P2, P3 and P4 with extended ranges.

The first liberal applied sectoral policy P2 yields results with 34% successful imitations of all imitator agents, leading to a fraction of 26% earlier retirements. Comparing these results to

Table 8.10: Simulation Results 5

Imit.Ratio	SuccImit.	PreRet(All)	PreRet(Im.)	PP	ARA
0.4	0.165	0.332	0.126	1	63.6
0.6	0.251	0.373	0.193	0.973	63.2
0.8	0.338	0.419	0.261	0.948	62.9

Table 8.11: Simulation Configuration 6

Parameter	Value(s)
Create Social Network	True
Count Sector	4
Agent in Sector	400
Ratio Blue Collar Worker	0.38
Ratio Pension	0.8
Ratio Random Imitator Agents	0.1
Ratio Full Random Agents	0.01
Random Retire probability	0.2
Stipulated Retirement Age	65
Imitation Mode	Dual
Maximum Network Size	20
Imitator Ratio	0.8
Repetitions	30
Sector Policy Awareness	True
Sector Policy applied	P3

Table 8.12: Simulation Results 6

Imit.Ratio	SuccImit.	PreRet(All)	PreRet(Im.)	PP	ARA
0.4	0.204	0.423	0.164	1	63.3
0.6	0.315	0.484	0.243	0.963	62.9
0.8	0.436	0.548	0.351	0.935	62.5

configuration two, the extended sector policy ranges yields similar results, but a lower average retirement levels caused by a increased proportion of early retirements. Obviously, more agents with a lower income and a average higher retirement reservations have used the possibility to retire earlier. We can also recognize the increasing difference between successful imitation and the use for the retirement, that is mainly caused by the sector four, where imitation does not lead to earlier retirement.

Applying policy three, all fractions are, as expected, increased and lead to further reductions in the workforce purchasing power and of the average retirement age. The gap between successful imitation and actual retirement increased with 1 to 2 percent.

Applying the most liberal and accommodative policy P4, highest fractions of successful imitations, more early retirements caused by imitation as well as total premature retirements of

Table 8.13: Simulation Configuration 7

Parameter	Value(s)
Create Social Network	True
Count Sector	4
Agent in Sector	400
Ratio Blue Collar Worker	0.38
Ratio Pension	0.8
Ratio Random Imitator Agents	0.1
Ratio Full Random Agents	0.01
Random Retire probability	0.2
Stipulated Retirement Age	65
Imitation Mode	Dual
Maximum Network Size	20
Imitator Ratio	0.8
Repetitions	30
Sector Policy Awareness	True
Sector Policy applied	P4

Table 8.14: Simulation Results 7

Imit.Ratio	SuccImit.	PreRet(All)	PreRet(Im.)	PP	ARA
0.4	0.252	0.608	0.231	1	62.3
0.6	0.398	0.696	0.369	0.987	61.6
0.8	0.553	0.786	0.516	0.881	60.3

over 75% before the stipulation occur. The loss of purchasing power has reached over 20% in relation to a low imitation case and deviates strongly to the results, yielded in configuration 2 and fulfills the missing answers to the initial expectations.

Further Policy adaption

To finalize the range of different simulations, I want to present a last experiment with slightly changed policy ranges to show the sensitivity of the model. For the sake of simplicity, all low and hight threshold values have been decremented with one. The experiments are performed in the Dual mode with an imitation ratio of 80 percent. The Setup and the results are defined as configuration 8. Comparing the results with the experiments 5-7 in the dual mode and with an imitation ratio of 80 percent, several differences can be observed. Some experiments are nearly identical with an deviation of 3% and some are quite different with an aberration of 10%. Although, some fractions of imitation and premature retirement are nearly the same, purchasing power and average retirement age are not. Basically, all results and the behavior fulfill the expectation. The explanation is given in the chapter containing the interpretation.

After the tabular representation of the simulation model results, the next chapter will continue with visualizations, evaluations and the appliance of the operational validity techniques,

Table 8.15: Simulation Configuration 8

Parameter	Value(s)
Stipulated Retirement Age	65
Imitation Mode	Dual
Maximum Network Size	20
Imitator Ratio	0.8
Repetitions	30
Sector Policy Awareness	True
Sector Policy applied	P2M, P3M, P4M

Table 8.16: Simulation Results 8

Policy	SuccImit.	PreRet(All)	PreRet(Im.)	PP	ARA
P2M	0.404	0.441	0.309	0.914	62.6
P3M	0.614	0.776	0.572	0.813	60.8
P4M	0.647	0.827	0.616	0.729	60.1

recommended by the evaluation framework of Sargent.

CHAPTER 9

Evaluation and Interpretation

9.1 Simulation output behavior

In this section, some graphical results for comprehensive evaluation are presented. All data, used for the visualization rely on the experiment with configuration 2, if it is not explicitly declared differently. The horizontal axes represents the 100 periods runtime including the initialization phase. Figure 9.1 displays the imitation success from all sectors except Public Sector 2, where no imitation occurred, noticing the imitation process in the first sector, where agents are eligible to retire up to five years earlier and make use of this opportunity. These reporters start from the beginning (tick 1) and also cover the initialization phase of 50 periods. But it supports the comprehension of start up effects including social as well as policy impacts. In Sector 4, imitations are performed, although they do not lead to any earlier retirements in this sector. The imitation process in public sector one shows a peak at period 15, followed by a 50 periods lasting down-ward trend bypassing into a swinging behavior with low amplitude. The time series of the private sector 1 and 2 are similar, whereas sector 2 shows a stagnating character, different to public sector 1, where an down-warding swinging trend is observable. In figure 9.2, the corresponding time series of the early retirements are displayed. The same effects can be observed in the second private sector, where imitation is performed, trying to lower the reservation levels, although it can not lead to early retirements at all, because retirement before the stipulated level of 65 is prohibited. The curves in figure 9.2 show a swinging effect with down warding trend similar to the curves in figure 9.1. This kind of chaotic behavior can be triggered by all other groups of agents, that make up to 28% of the total population. In figure 9.5, the development of the purchasing power is illustrated, showing a slightly positive trend, that is hardly observable in the figure. The initialization phase of the purchasing power of the workforce shows a different characteristic as the curve of the retirees, where the gradient from period 30 strongly decrements near zero. Plot 9.6 shows no questionable effects in the fractions of early as well as normal retiring agents. Small fluctuations are related to agents with an agent type $\neq$ *imitator*, that have met the sector policy unintended.

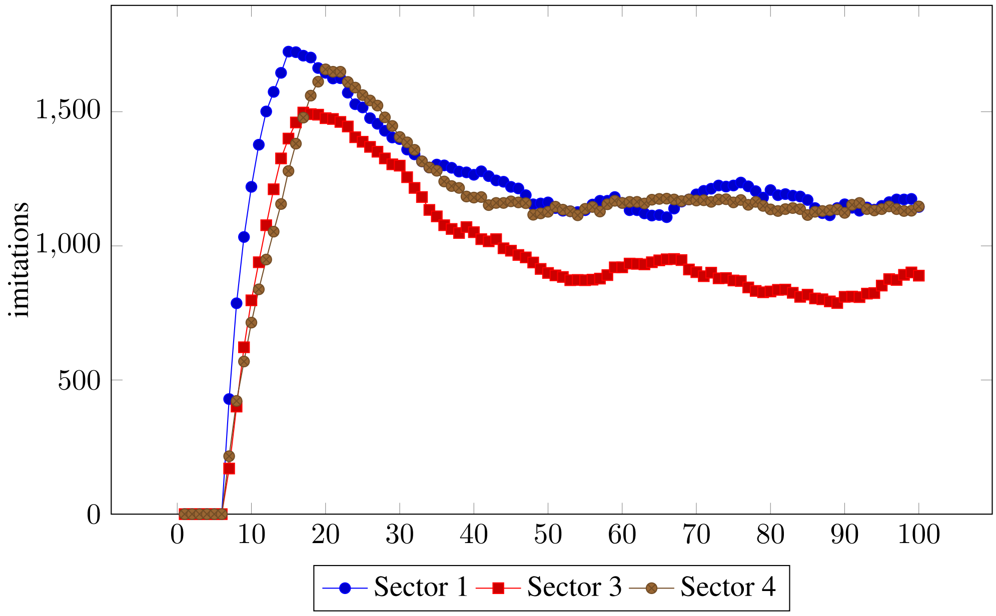


Figure 9.1: Comparison of successful imitations with Sector Policy Awareness

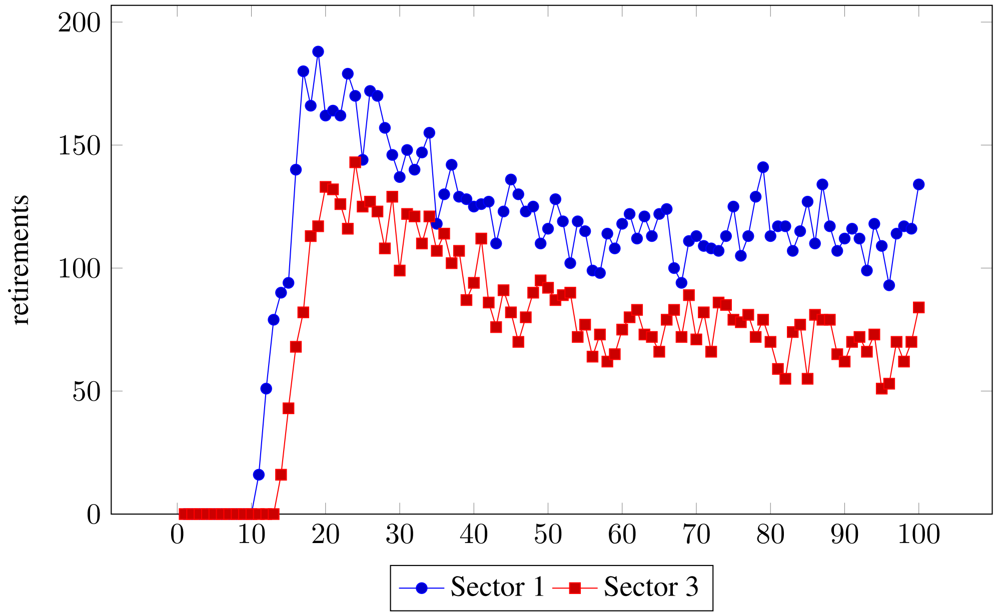


Figure 9.2: Comparison of early retirements with Sector Policy Awareness

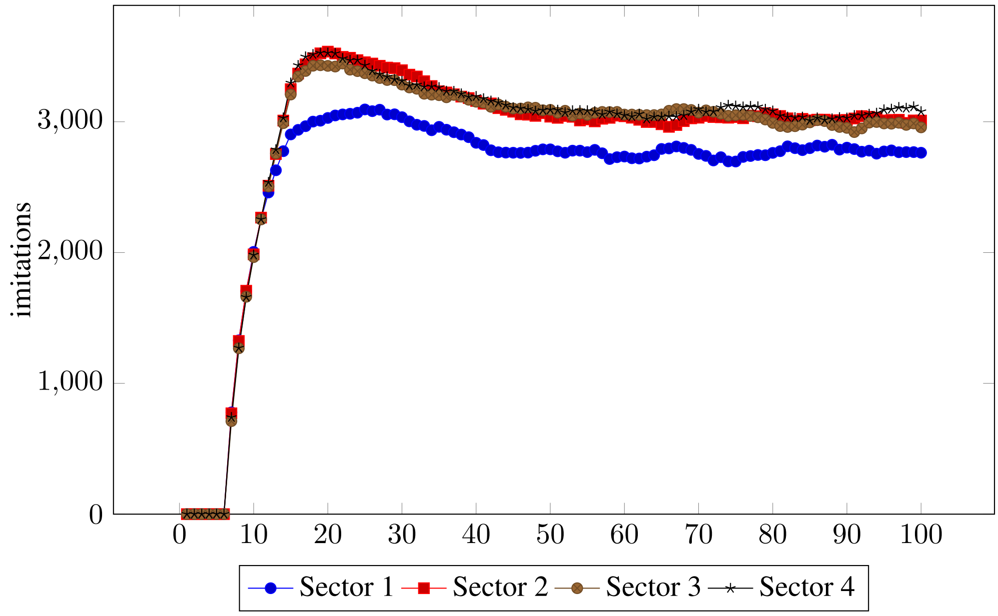


Figure 9.3: Comparison of successful imitations without Sector Policy Awareness

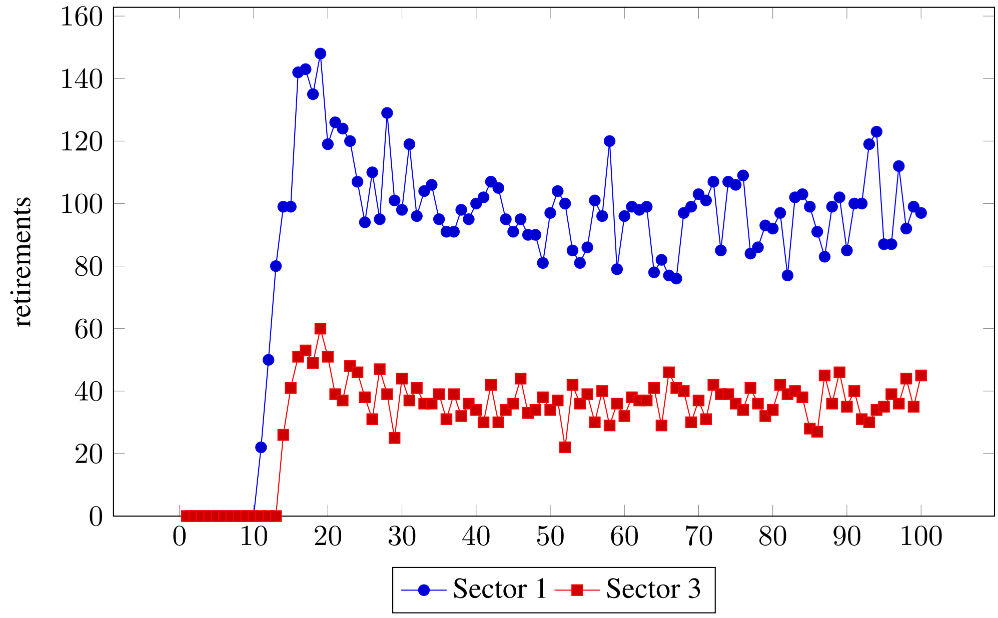


Figure 9.4: Comparison of early retirements without Sector Policy Awareness

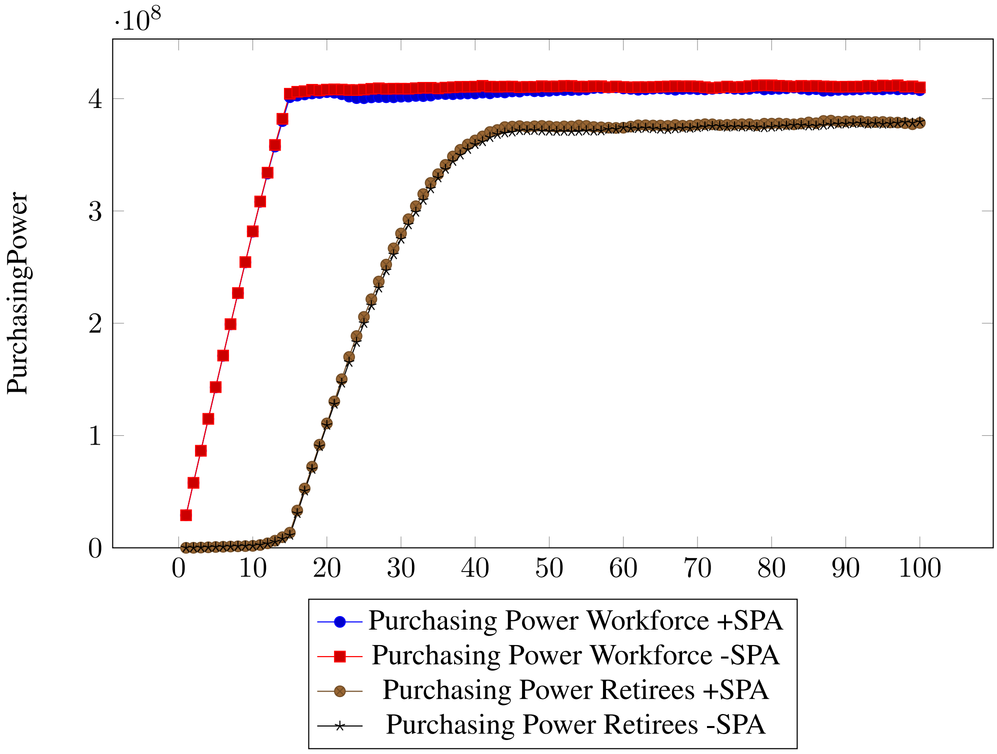


Figure 9.5: Comparison of purchasing power

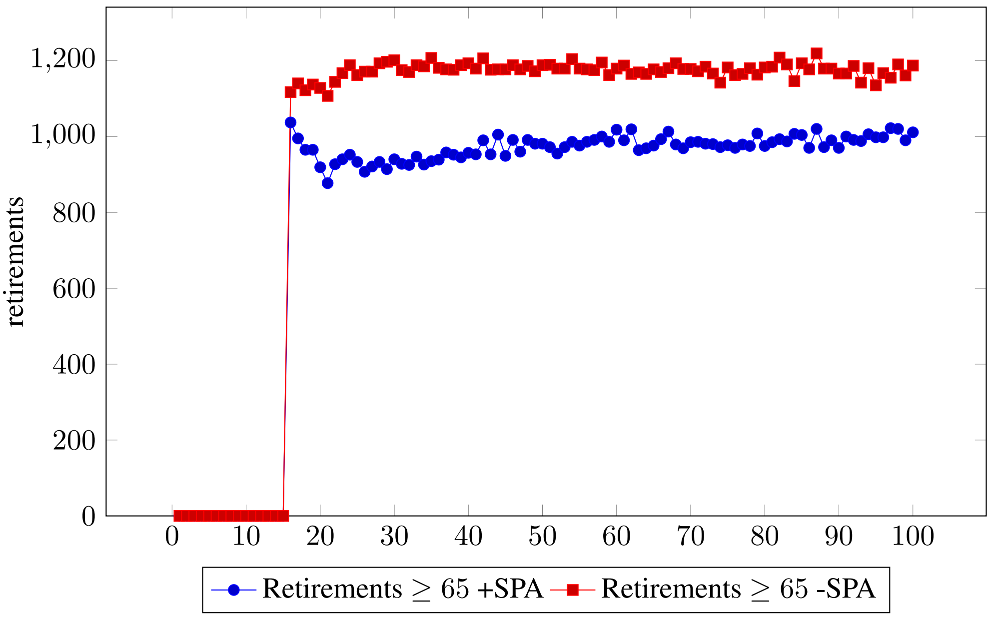


Figure 9.6: Comparison of retirements with and after the stipulated level

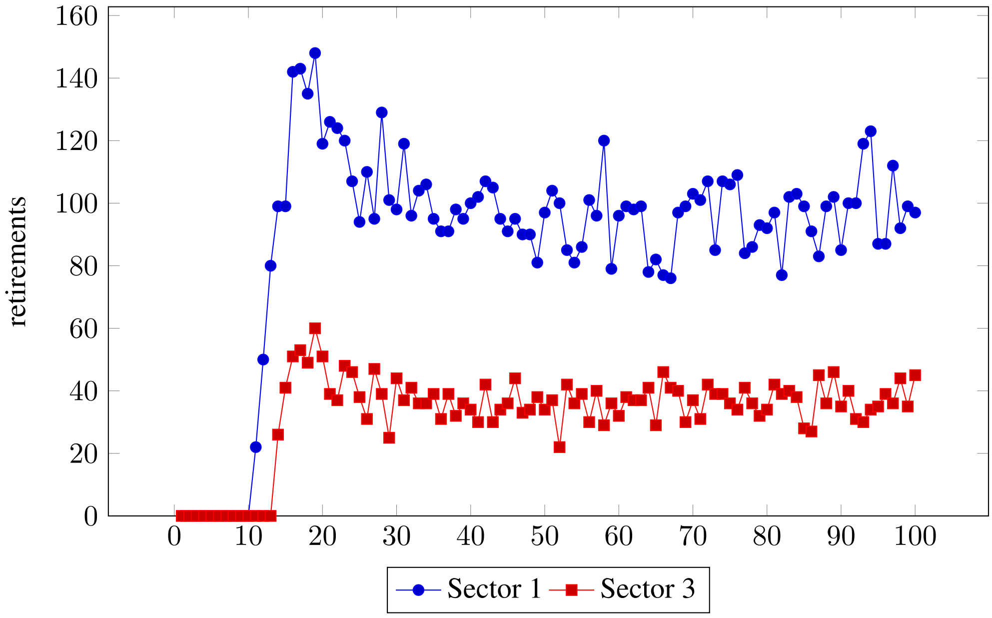


Figure 9.7: Comparison of early retirements without Sector Policy Awareness

9.2 Netlogo World Output

Additionally, I want to show screen-shots of the results on different configuration setups, where the reader might get a focused impression of the active processes after reading over the tabular data. Afore I want to point out the different background coloring of the sectors. All figures cover one sector to highlight certain effects. Green agents are economically active, black colored agents performed a successful imitation, yellow coloring indicate a retirement before the stipulated level caused by imitation and white agents also retire before the maximum age, but not because of imitation. An agent is colored blue if the retirement occurs at the stipulated age and turns to gray, when the agent performed the transition to retirement. Random agent retirements are colored as orange. If an turtle dies, it is indicated red. Figure 9.8 and 9.9 illustrate the impact of the Sector Policy Awareness, where less imitation occurs, leading to an increased number of early retirements (yellow agents) and less retirements at the stipulated level (blue agents) of 65. In figure 9.9, a modified sector policy is applied, that imply an increased amount of early retirements visible through a strong decreased portion of blue color turtles. Figure 9.10 and 9.11 illustrate the results of the same configuration with different imitation modes <Working> as well as <Retired>, where especially the <Retired> mode shows less imitations than with any other mode. In figure 9.13, the second sector is displayed, where no imitation or early retirements occur, if the default sector policy is applied, while Figure 9.14 shows the third sector, that it similar to sector 1 with the limitation of smaller eligibility ranges. Therefore, the main retirements occur at the stipulated age. The different background coloring belongs to the sector marking and is no optical error. The agent behavior of sector four is observable in figure 9.15, where a high ratio of white agents shows earlier retirements indicating imitation success

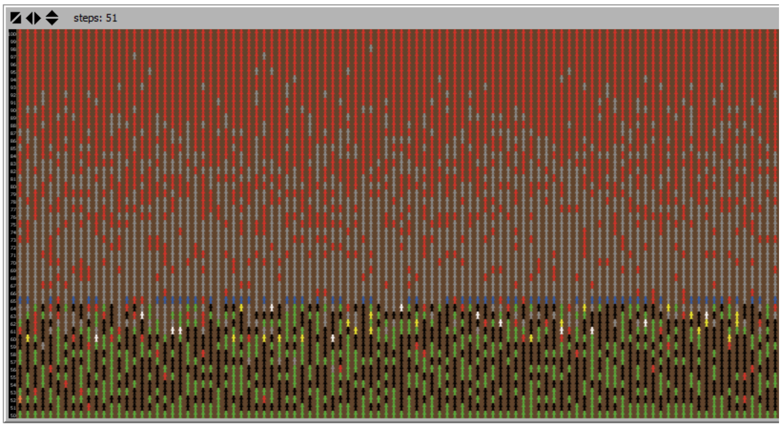


Figure 9.8: Screenshot Configuration 1 (Mode Dual, IR=0.8, SPA=OFF) Sector 1

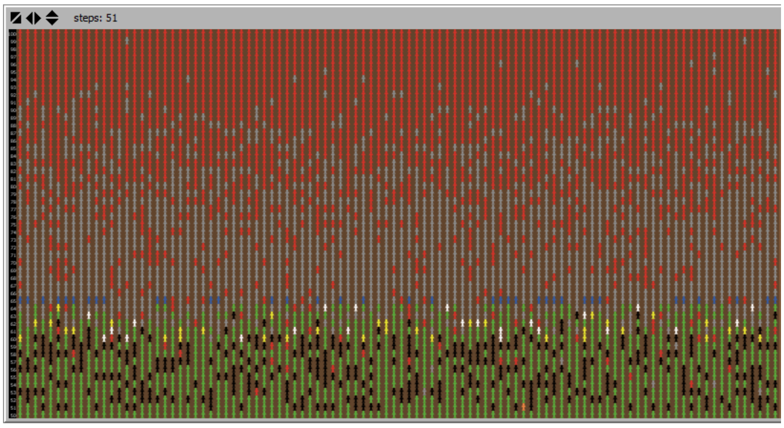


Figure 9.9: Screenshot Configuration 2 (Mode Dual, IR=0.8) Sector 1

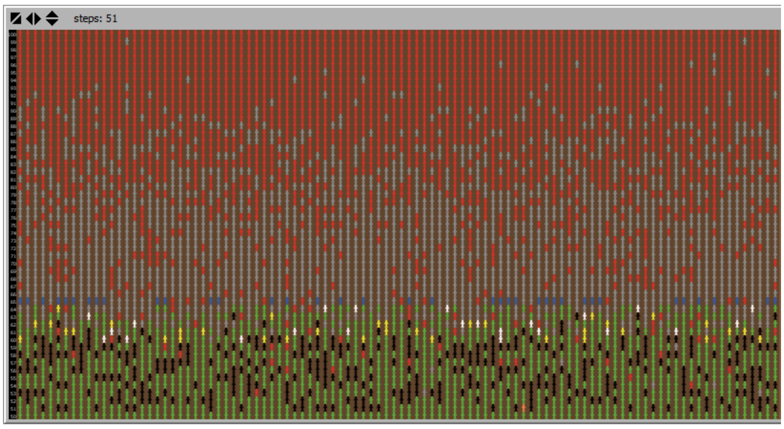


Figure 9.10: Screenshot Configuration 2 (Mode Working, IR=0.8) Sector 1

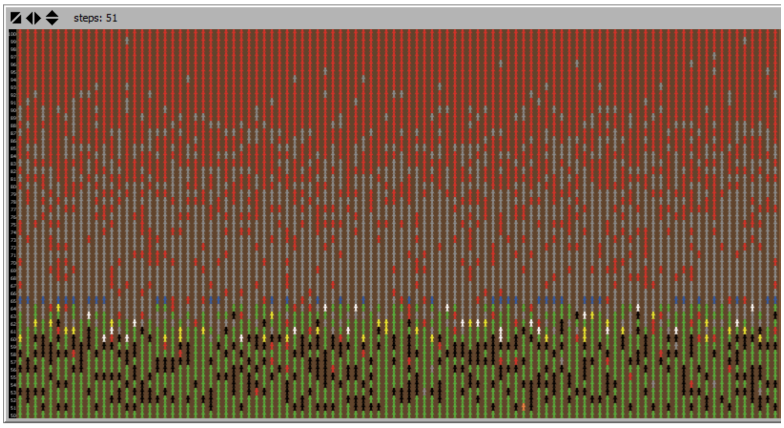


Figure 9.11: Screenshot Configuration 2 (Mode Retired, IR=0.8) Sector 1

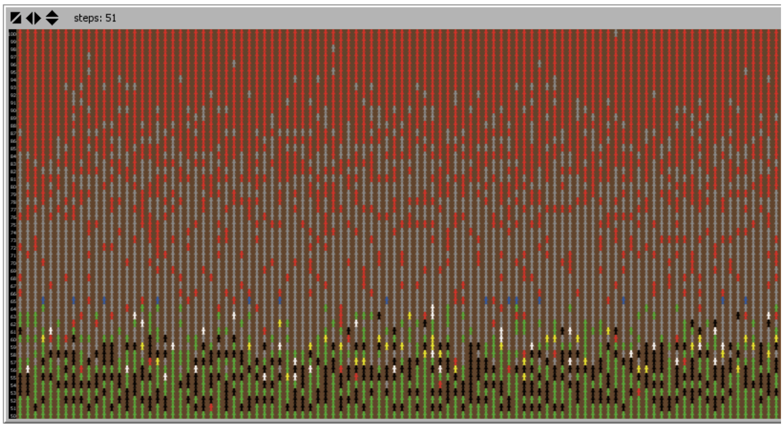


Figure 9.12: Screenshot Configuration 5 (Mode Dual, IR=0.8) Sector 1

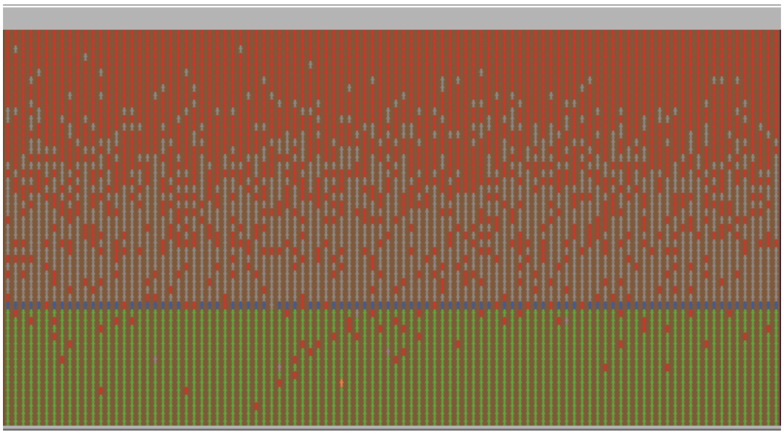


Figure 9.13: Screenshot Configuration 2 (Mode Dual, IR=0.8) Sector 2

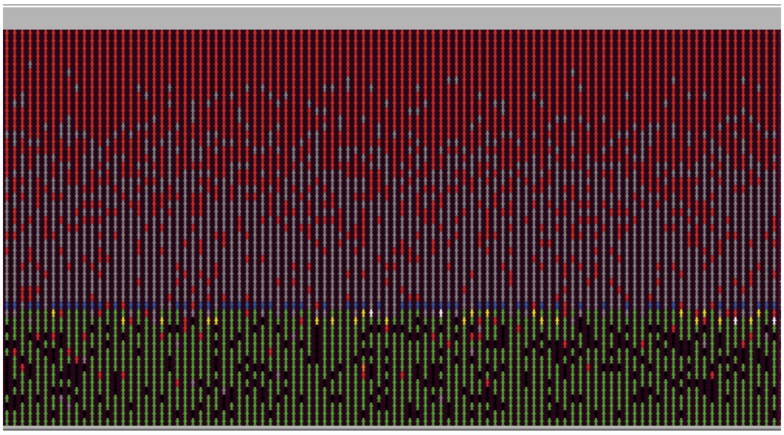


Figure 9.14: Screenshot Configuration 2 (Mode Dual, IR=0.8) Sector 3

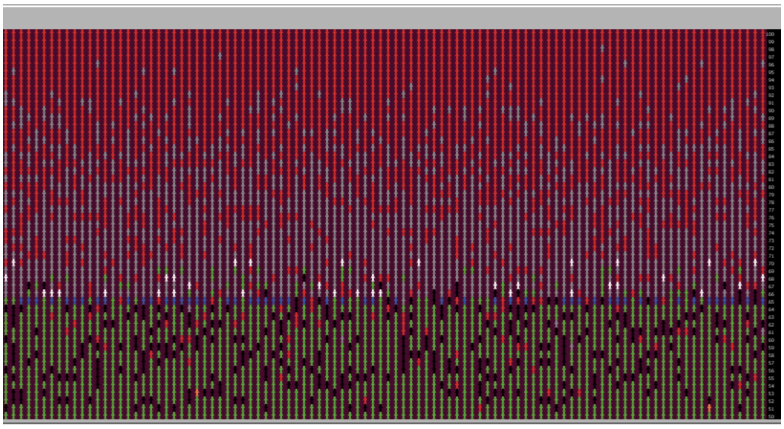


Figure 9.15: Screenshot Configuration 2 (Mode Dual, IR=0.8) Sector 4

and earlier retirement, than originally calculated, but not before the stipulated age! In contrast to those two figures, I want to point out the difference in figure 9.16 and 9.17, that show sector three and four with extended low and high policy thresholds. The figure of sector three (fig. 9.16) is comparable to the configuration 2 with the default policy and in sector four (fig. 9.14), several individuals make use of imitation and retire before the stipulated retirement age.

9.3 Interpretation

In this section, the results of the simulation in the context of the problem statement are discussed. Subsequently, the operational validity in terms of the Simulation Model Validation and Verification Framework of Sargent [32, p.6] is performed. In the expectations, a fraction of under thirty percent early retirements was expected, not having serious effects on the system. Observing the results, two different ways of justification and explanation can be offered. Before I will go

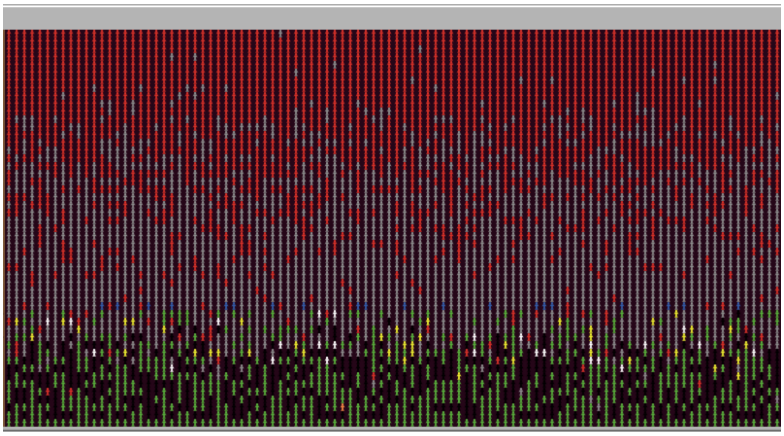


Figure 9.16: Screenshot Configuration 5 (Mode Dual, IR=0.8) Sector 3

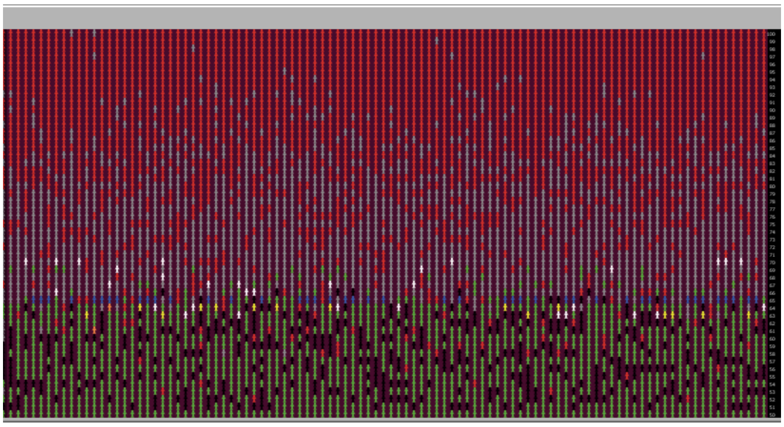


Figure 9.17: Screenshot Configuration 5 (Mode Dual, IR=0.8) Sector 4

into detail, I want to mention, that the additional results regarding the Sector Policy Awareness emerged from algorithm analysis and optimization processes and are not the main consideration of the output analysis. Though I want to consider the results with SPA for the evaluation, presuming, that agents act within bounded rationality and try to optimize in order to the local policies. These facts could be confirmed by Burtless in his paper on *Assessing the Rationality of Workers Choice* [11, p. 18]. Under the condition, that sectors follow strict policies, I can agree to these expectations, as the results in the previous section have shown. With an imitation ratio of 0.8, a social network of 20 and a strict sector policy, a maximum value of 29 percent of earlier retirements caused by imitation was observed, although the overall fraction of agents, that retire before the stipulated level of 65 is about 40 percent. The difference up to 18 percent between those ratios is explained through rationals, randoms and random imitator agents, that make up to 28% of all agents in the default setting (with an imitator ratio of 0.8). And the majority seems to calculate their retirement time point exactly in the sector policy frame, where eligibility applies.

It has to be pointed out, that those types of agents do not apply the Sector Policy Awareness mechanism. The second scenario includes sectors, that are more accommodative and apply to configuration four, where sector policy levels are defined more generous. Because of the optimization and propagation mechanism, up to 10 percent more imitator agents make use of the early retirement, while the overall early retirement value rises over 50 percent and does not meet the previous defined expectations any more. There are three important factors, that have major impact on the results and are evaluated subsequently.

1. Minimum and maximum threshold levels (Sector Policy)
2. Ratio of imitator agents (in cohesion to imitative behavior)
3. Size of Social network (in cohesion to imitative behavior)

The sector policies have the biggest influence on the results, because they are the last instance enabling retirements before the stipulated level of 65. This is probably the weakest point of this thesis, because these levels are variable and not fully justified. But it has been assumed under the condition of a highly abstracted model with empirical justification. The imitation ratio of 0.8 has been derived from Axtel and Epstein and deviant values are used to show the variability of the model and the effects on the results. The lowest influence is caused by the social network size. Figure 9.18 and 9.19 explain the major key variable mean outputs in order to different network sizes with configuration 2 (P1) and 5 (P2) with the dual mode and an imitator ratio of 80 percent. As we can see in the comparison of the results of both configurations, increasing maximum boundaries lead to slightly increasing output results, pointing out, that a network size of 30+ is unrealistic. But this figure also shows the disproportionate growth of the imitation success compared to the other variables.

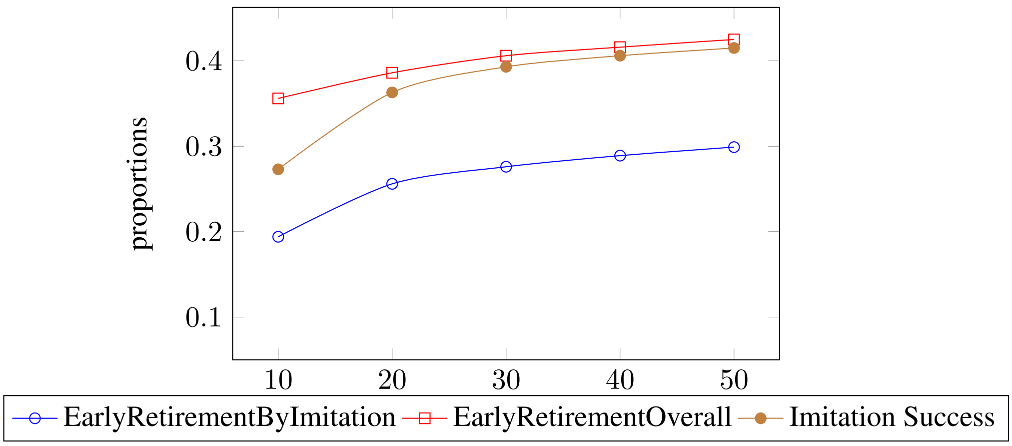


Figure 9.18: Comparison with different maximum network sizes - Configuration 2

If figure 9.18 and 9.19 are compared, similar growth of all curves are noticeable, but different policies in all sectors lead to an increased fraction of overall retirements at small networks and a smaller increase with increased network size. This heap has already been explained and

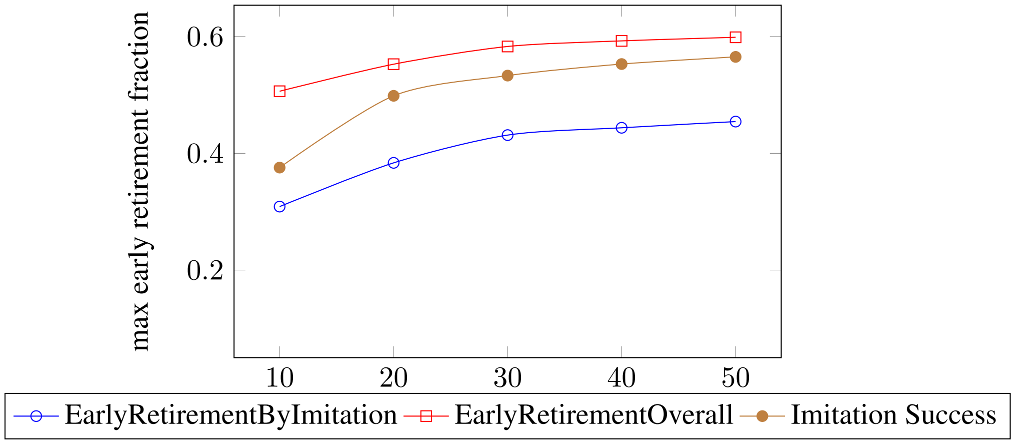


Figure 9.19: Comparison with different maximum network sizes - Configuration 5

emerges through premature retirements of agent types except imitators, that make up to 20% of the population.

9.4 Operational Validity

To validate the simulation output against real world system, Sargents Operational Validation process is applied. But first I want to perform a model classification in order to the used framework. Sargent proposes this two-dimensional specification of the operational validation procedure, where he states the deviation between systems, that are observable or not, proposing either a subjective or objective approach to be applied [32, p. 6]. The system is observable through the 2D visualization, monitors, plots and outputs. The objective approach includes tests with data of a real system. This kind of evaluation is difficult and not feasible with the degree of accuracy that would be needed. There is no equivalent model, similar to this and it is characterized as model with a high level of abstraction. The test would state the hypothesis $H0$, that the model is valid for the acceptable range of accuracy under the set of experimental conditions [32, p. 7] and accept the alternative hypothesis $H1$, that decelerates the model as invalid under the mentioned conditions. Therefore, the evaluation will be based on the subjective approach using model behavior exploration and comparison of output results with real system. Although it is kind of deceptive, I want to display the data as survival curve, as it has been done by Radl [31, p. 143, figure 5.2], but also by a lot of other scientists dealing with populations besides the medical area. I used the technique explained by Bland, Martin and Altman [6] to create proper survival overall and conditional probabilities and then apply a macro-based transformation of the data to build an acceptable survival-curve graph. The technique, described by Khan and Haseeb [22] was applied to my data. Of course I can recommend other tools like R, that are appropriate to produce that output, but also include more complexity. The underlying data is an experiment output of NetLogo, measuring every period, the counting of retirements in all cohorts from 50 to 70. From each period, the survival fraction is calculated and yields the conditional probability.

Table 9.1: Survival curve data from the Main Association of Social Insurance Institutions

Period t	Retired D	Remaining R	Conditional Probability C	Probability P
50	0	63529	1	1
51	0	63529	1	1
52	0	63529	1	1
53	0	63529	1	1
54	0	63529	1	1
55	2618	60911	0.959	0.959
56	4048	56863	0.895	0.858
57	2708	54155	0.852	0.732
58	2353	51802	0.815	0.597
59	4728	47074	0.741	0.442
60	18160	28914	0.455	0.201
61	7324	21590	0.339	0.068
62	6540	15050	0.237	0.016
63	3084	11966	0.188	0.003
64	2387	9579	0.151	<0.001
65	6625	2954	0.046	<0.001
66	2121	833	0.013	<0.001
67	374	459	0.007	<0.001
68	217	242	0.003	<0.001
69	140	102	0.001	<0.001
70	102	0	0	<0.001

In the next step, the overall probabilities can be calculated followed by the adaption, described by Khan and Haseeb to produce a correct survival curve with the corresponding Plot. The table 9.1 includes the extracted and the calculated data for the survival curves with the Kaplan-Meier estimator, represented by the overall retirement probability $P(t_n)$. R_n are all current retirements and D_n all individuals.

$$P(t_n) = \prod_{n \leq m} 1 - \frac{R_n}{D_n} \tag{9.1}$$

Real System

Data from the statistical yearbook of the Association of Austrian Social Security Companies, 2012 [13, p. 131] is used for comparison. The focus is on the old-age pensions from 55 to 65, representing the eligible transitions in each cohort. Also to mention, that the data source includes male and female proportions on the retirement exit and my model is defined without gender. Therefore, each male and female results of the cohort are aggregated to one unified-gender value.

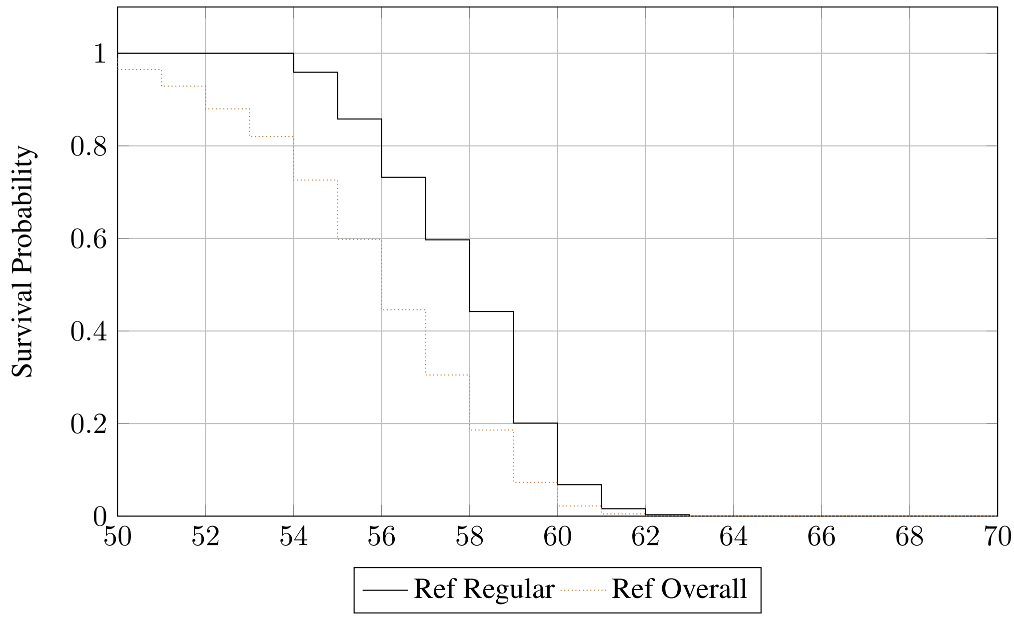


Figure 9.20: Survival Curves of actual Workforce Exits 2012

Simulation System

Figure 9.20 represents the results of the experiments applying four policies, where the correspondence to the configurations is stated below.

- Policy 1: Configuration 2
- Policy 2: Configuration 5
- Policy 3: Configuration 6
- Policy 4: Configuration 7

All experiments are performed with a majority of 80% imitator agents, enabled Sector Policy and the dual imitation mode. Policy 1 shows a majority of individuals, that are employed until the age of 63 and a strong decrease at the level of legal stipulation. Only a small fraction remain working longer than 65 including randoms and agents from the public sector 2. With the Policy 2 applied a different development is acknowledgeable, showing immediate retirements from 55 on with noticeable cohort fractions until 61, where already 70% are already retired. Policy 3 shows the same behavior as policy 2 until 57, that probably depends on the private sector, where the low threshold value is below the value of the policy 2. That is may reflected in the strong decrease between 57 and 59, where the majority retires.

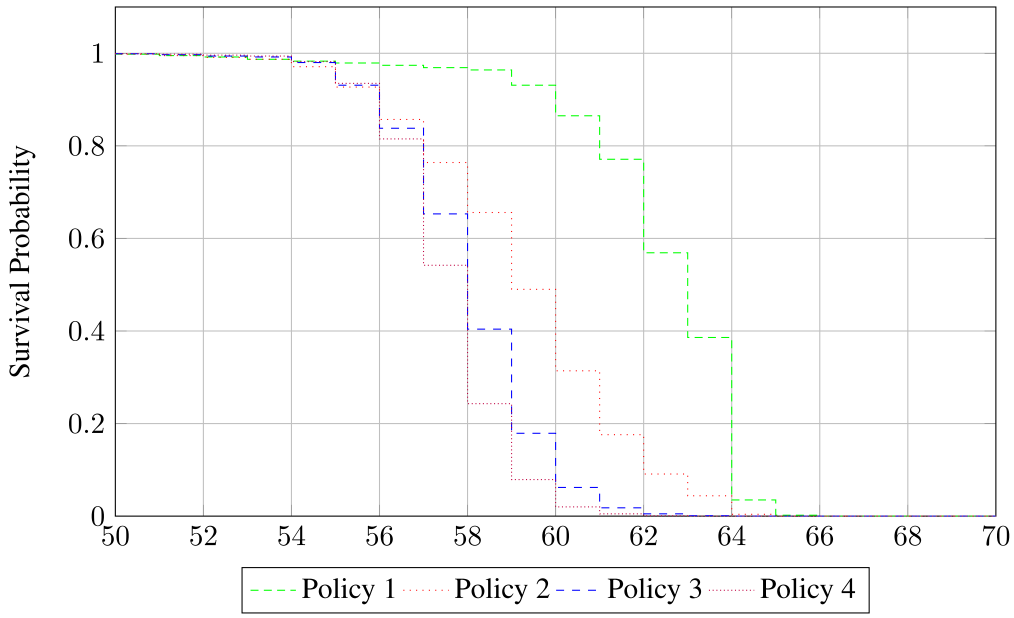


Figure 9.21: Survival Curves of Simulation Model

Comparison and Evaluation

The different results from the simulation model as well as the real system are normalized and put together in on graph to analyze the deviations under the defined accuracy of $0 \leq \lambda \leq \lambda\star = 0.2$. A reader may criticize the difference between the old-age reference curve and the overall retirement exit curve, that represents all retirements from 2012 including ill-health, hard-working or other exceptional early workforce exits and deviates from the old-age pension curves, where no non-conformal actions were performed. The overall line was introduced to show, that also in the real system are certain differences caused by different policies. And exactly these deviations can be observed in the output behavior of the simulation model (figure 9.21), where the majority of agents retire at a later point of time or much earlier as stipulated. In figure 9.22 all curves are consolidated to show the similarities but also differences. Generally, deviations at the beginning before 55 are justified with the model specifications, where retirements does not start before 55. At the cohorts between 54 and 58, the model produces mainly up to 13% more retirements, than actually occur, what is acceptable with the remark, that the data is only from 2012 and does not represent a general real world behavior. The imitation algorithm does not include weighing, what would represent an inappropriate intrusion. Therefore, agents retire earlier in a sense of *before 65*, but not *as early as possible*. From 58 upwards, the model yields lower results with decreasing deviations. The average deviation is 0.15 with a maximum of 0.24. I additionally want to reference to Radls acknowledgments, who also did a Kaplan-Meier survival estimates by Gender in Western Europe [31, p. 143] and want to point out the equivalences especially at the age cohort of 60 and 65, that can be interpreted as subjective acceptance of the output behavior and the underlying model.

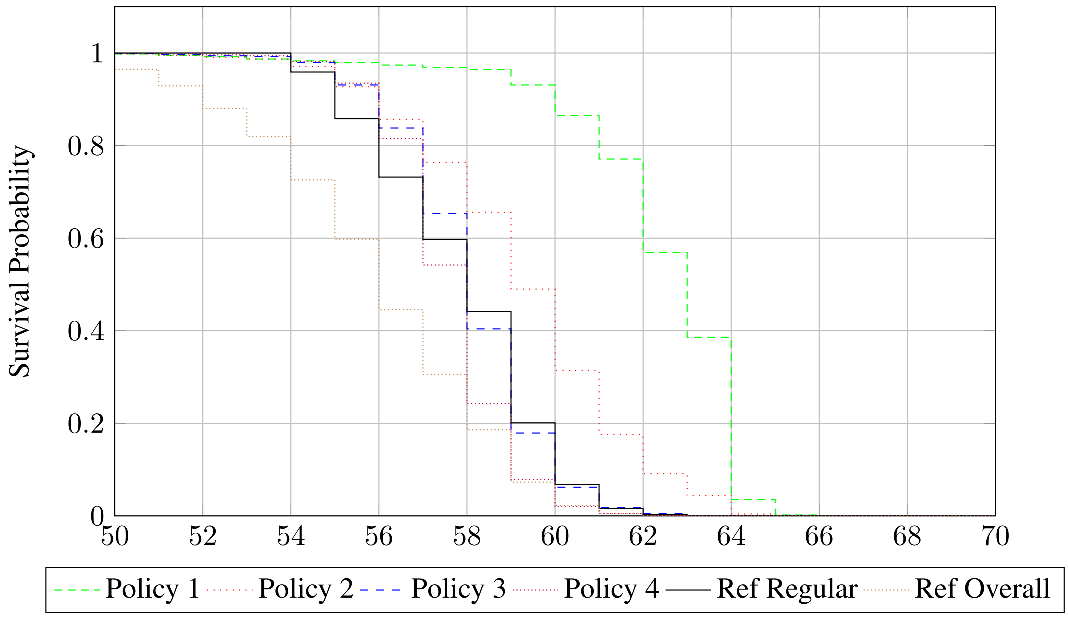


Figure 9.22: Comparison of Workforce Exits Survival Curves

Figure 9.22 displays the conditional probabilities of workforce exits of each cohort and reflect the proportions of agents, that are economically active on the left side and the retired fraction on the right side of the curve. In comparison to figure 9.21, the small parts of agents, that retire after 65 are better visible in this illustration and enable further differences between real system data and the simulation data. It can also be recognized, that policy 4 performs similar to policy 3 up to the period of 57. Then, the deviations are increasing with each period and converge to the reference line of the overall retirement.

Effects on the System

After the evaluation of quantitative results, produced by the simulation model, some qualitative effects are conducted, focusing on the purchasing power, overall retirements, financing, pension payments and possible long-term impacts on the social security system. In the simulation results, the development of the purchasing power in the different simulation configuration setups has been observed and showed a down warding trend with increasing imitation ratio, network size, population and agent awareness depending on the sector policies. This relative reduction can be evaluated as elasticity of n from the lower purchasing power over the taxes to the pension payments. In Austria, taxes mainly finance the social security system and therefore the pension system as derivate. Because of the elasticity, an impact on the pension payment shift in future reforms may be assumed. And currently, some of this financing issues are already visible and are a validation for this effect. Holzmann, 2001 states the financing problem of the public pension scheme as a huge burden for the budget and that the earnings cover only 66 percent of the expenditures for the pension payments, what causes monetary transfers [20, p. 15]. He

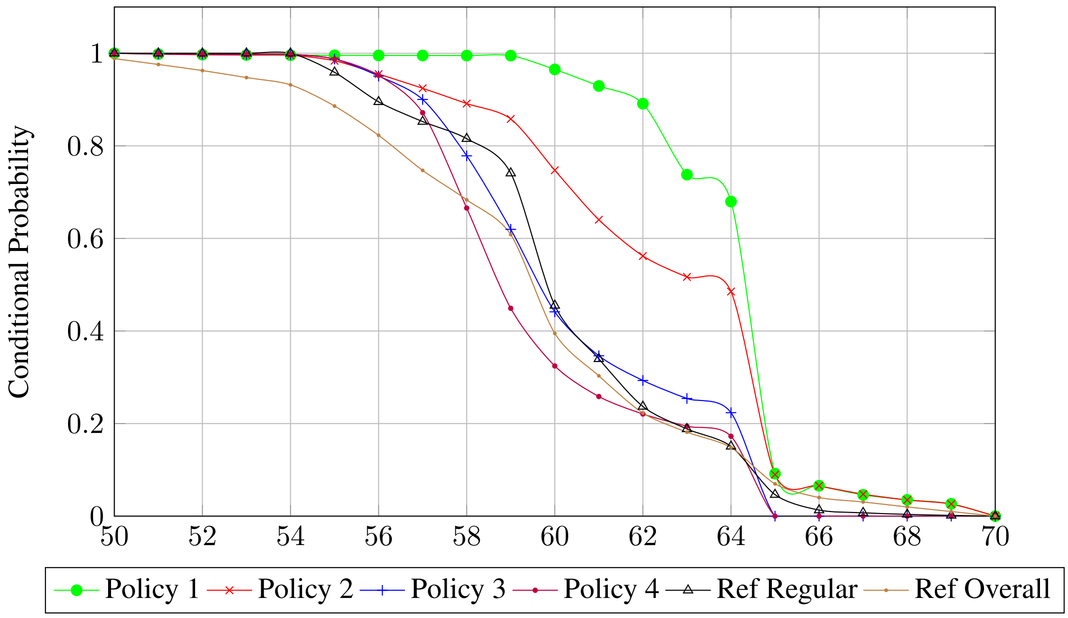


Figure 9.23: Comparison Workforce Exit Fractions - Conditional Probability

also projects, that twice the value of 2000 of old people will cause half the pension for each individual [20, p.19]. But I do not want to proceed further in analysis on prospective reforms and payments, because several, not mentioned parameters would have to be included and several investigative people have done a lot of analysis in the financing issue. But as imitation is a fundamental pattern of individuals, it is suggested, that administrative limitations may not be completely successful, as the simulation results show.

Acknowledgments on Netlogo

In this section, I want to reflect on experiences on Netlogo including positive as well as curious effects. Really helpful was the online resource, that provided good tutorials as well as a detailed and efficient API documentation. Logo is self-explaining and the programming was done mainly straight forward. On performance issue emerged through the default display settings of links in NetLogo. If they are created, they are visible and produce huge load on the GPU, trying to render all connections, that are $n * n_M$, where n is the size of agents (default: 81.600) and N_M is the maximum size of each social network ($0 \leq n_M \leq 20$). With the following code, this leak could be fixed.

```
if (show_social_network)
[
  ask links [ hide-link ]
]
```

Of course, this command is executed with every tick and seem to be quite inefficient, but because networks are created between random agents of the whole population, additional queries would increase the runtime. The next code snippet presents the retirement eligibility check process, where the first public sector with its breeds checks the eligibility of each agent if retirement, before, at or after the stipulated level is possible. I have to apologize in advance for the partly rough indents of the code.

```
ask publicSector1AgentBreed with [person_status = 0]
[
  ifelse (person_type = 0)
  [
    ifelse (person_calculated_retirement_age >=
      stipulated_low and
      person_calculated_retirement_age < stipulated_high and
      person_age < stipulated_retirement_age)
    [
      if (person_age = person_calculated_retirement_age)
      [
        agents_retire
      ]
    ]
    [
      if (person_age >= stipulated_retirement_age)
      [
        agents_retire
      ]
    ]
  ]
  [
    ifelse (person_type = 1 or person_type = 2)
    [
      ifelse (person_retirement_reservation_age <
        person_calculated_retirement_age and
        person_retirement_reservation_age >= stipulated_low and
        person_retirement_reservation_age < stipulated_high and
        person_age < stipulated_retirement_age)
      [
        if (person_age = person_retirement_reservation_age)
        [
          agents_retire
        ]
      ]
      [
        ifelse (person_calculated_retirement_age >=
```

```
          stipulated_low and
          person_calculated_retirement_age <
          stipulated_high and
          person_age < stipulated_retirement_age)
        [
          if (person_age = person_calculated_retirement_age)
          [
            agents_retire
          ]
        ]
        [
          if (person_age >= stipulated_retirement_age)
          [
            agents_retire
          ]
        ]
      ]
    ]
    ; else person_type = 3
    [
      ; check and retire agents of random type (type = 3)
      ; ask n turtles (random_retire_prob) of all that are
      ; eligible to retire

      ask n-of floor(random_retire_prob *
          count publicSector1AgentBreed with [
            person_type = 3 and person_status = 0])
      publicSector1AgentBreed with [
        person_type = 3 and person_status = 0
      ]
      [
        agents_retire
      ]
    ]
  ]
]
```

The programming does not include very complex methodology and more nested if as well as ask constructs, but other approaches like grouping implementations failed because they resulted in a higher runtime(measured through reporters) than those structures. Therefore the goal was to keep the query run-times at $t = \mathcal{O}(n)$ and in the worst-case $t = \mathcal{O}(n^2)$.

CHAPTER 10

Conclusions

In this final section I want to guide shortly through the project starting from the point of origin, the problem statement as well as stated question I want to answer, followed by State of the art literature including findings of other scientists, but also unsolved issues. Consecutively, applied techniques and solving approaches are discussed leading to the model description, execution and the evaluation of the results with the afore mentioned methods. Additionally, some personal opinions about the structure and purpose as well as critics and future research implications will be added. At the point of origin, no models were elaborated, that have focused on imitation, individual employer-to-employee agreements and subsequent effects on the social security system. Therefore, a model was conducted, that combines social, legislative and mathematical theories as well as assumptions. They are aligned with simplifications and limitations but should provide the flexibility of executing experiments with different parameter settings. The theories were mainly derived from Axtell, Epstein and Radl, covering the topics of retirement timing as well as individual determinants of retirement entries and have been a perfect theoretical framework for many settings and limitations. Giovanni Mastrobuoni states some valuable knowledge regarding retirement choices and the bounded rationality of individuals as well as the role of information for retirement behavior, that could be successfully implemented in the decision algorithms. With the research about demographic development, trends in corporate culture [19] (Hermalin, 2000), social networks (Young, 2000) and Aging, Productivity and Wages in Austria, the conceptual model was enriched with calculations and the corporate retirement eligibility decision engine. The data was supplied from the Statistik Austria and the Main Association of Austrian Social Insurance Companies and enabled partly the validation of the simulation output, what is a difficult part, applying it to a model with a high level of abstraction. It was astonishing, how much research in the field of retirement and social connectedness as well as in future prospect of the financing situation of public systems has been done. Most of the projects were using panel studies and several statistical methods, what is fine and correct, but I missed the flexibility, that allows further analysis. That was one reason for this model creation, although it contains some simplifications. Gender distinction led to complications in the evaluation phase. This problems could be bypassed by using aggregated data from the real system to enable comparability. The next phase included the validation of the conceptual model, using the Modeling Evaluation Framework from Sargent, where all parts could be positively validated except the policy low and high threshold values. Until now, those values are pure assumptions, where I place self-criticism, although ranges yield acceptable results. From this stage, the simulation model in NetLogo was created, leading to the verification of the computerized model, that was divided in two sub-steps. The first was applied permanently during the development phase including the correct programming style to avoid long runtime, unnecessary memory usage and weak structures, while the second stage yielded correct procedure output, making use of fundamental validation and verification techniques. Recognized failures, that would have caused wrong model behavior, were eliminated to start the experiment phase. This was the second of three big steps during this project. Several experiments with different parameter setups, were executed, that are not mentioned in this thesis, but were necessary to prove correct execution, stability and credibility of the output. The overall results are of course documented. Some parameters like the social network size, imitation ratio or the size of the population caused long runtime. Then the third and most difficult step has been performed, to evaluate the model output against the problem definition and the real system. The comparison to the problem statement is applied quite simple, in contrast to the real system, that needs to diverge to a model, that has a high level of abstraction. The results have confirmed a clear cohesion of early retirements to the ratio of imitators, leading to a lower average retirement age as well as a decreased purchasing power. The results can be compared to the findings from Lancee and Radl (2012), where higher contact lead to higher withdrawals from the labor market. It has been shown, that the retirement time-point definitely depends on the imitation of individuals and is strongly influenced by the corporate sector with different culture and eligibility ranges. The more open and accommodative the sectors act, according to the defined policy, the more agents could make use of these special agreements and exit from workforce before the national stipulation and vice versa in the case of a closed and restrictive policy. The results also revealed differences between retirement caused by imitation and total early retirements, where rationals also could make use of different sector policies. The reader may has observed, that some experiments are conducted with parameter ranges, that have actually been fixed previously. The intention is the expression of the model variability. Holzmann defines the financing problem of the public pension scheme as a huge burden for the budget and that the earnings cover only 66 percent of the expenditures for the pension payments, what causes monetary transfers [20, p. 15]. This problem could be projected through the reduction of the workforce purchasing power down to 88 percent. Of course, the corresponding purchasing power of the pensioners is rising, but the expenditures are not affecting the budget of the social security system and underlines the mentioned money transfer from the official budget to the pension account, leading to a possible elevated deficit.

Future Work

Although the main questions of the thesis have been answered, there are some open issues. Future work should imply more realistic system behavior, less assumptions that blur the model output and may be implemented in alternative software, that is more powerful than NetLogo. Eventually, further projects have access to more statistical data, that enable extended comparability.

Bibliography

[1] Statistik Austria. Bruttojahreseinkommen der unselbständig erwerbstätigen 1997 bis 2012. Website, 12 2013. Lohnsteuerdaten - Sozialstatistische Auswertungen.

[2] Statistik Austria. *Verdiensstrukturerhebung, Struktur und Verteilung der Verdienste in Österreich*. Bundesanstalt Statistik Österreich, 2013.

[3] Robert L Axtell. Coordination in transient social networks: An agent-based computational model of the timing of retirement robert l. axtell and joshua m. epstein. *Generative social science: Studies in agent-based computational modeling*, page 146, 2006.

[4] Helen Barnes and Jane Parry. Renegotiating identity and relationships: Men and women's adjustments to retirement. *Ageing and Society*, 24(2):213–233, 2004.

[5] Nicholas Barr and Peter Diamond. The economics of pensions. *Oxford review of economic policy*, 22(1):15–39, 2006.

[6] J Martin Bland and Douglas G Altman. Survival probabilities (the kaplan-meier method). *Bmj*, 317(7172):1572–1580, 1998.

[7] Austrian Workers Compensation Board. Information about the auva, December 2014.

[8] Eric Bonabeau. Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences of the United States of America*, 99(Suppl 3):7280–7287, 2002.

[9] Raymond Bossé, Carolyn M Aldwin, Michael R Levenson, Avron Spiro, and Daniel K Mroczek. Change in social support after retirement: Longitudinal findings from the normative aging study. *Journal of Gerontology*, 48(4):P210–P217, 1993.

[10] Laurie Brown and Ann Harding. Social modelling and public policy: application of microsimulation modelling in australia. *Journal of Artificial Societies and Social Simulation*, 5(4), 2002.

[11] Gary Burtless. Assessing the rationality of workers' choice of retirement age and saving accumulation.

[12] Gary Burtless. Social norms, rules of thumb, and retirement: Evidence for rationality in retirement planning. *Social structures, aging, and self-regulation in the elderly*, pages 123–160, 2006.

[13] Hauptverband der Österreichischen Sozialversicherungsträger. *Statistisches Handbuch der österreichischen Sozialversicherung*. Hauptverband der Österreichischen Sozialversicherungsträger., 2012.

[14] Erwin Eckhart. *Krankenversicherung in Österreich*. PhD thesis, uniwien, 2009.

[15] Oliver Gassmann and Gerrit Reepmeyer. *Wachstumsmarkt Alter*. Hanser, 2006.

[16] Rudolf Gert. *100 Jahre österreichische Sozialversicherung 1889-1989*, volume 6. Bundesministerium für Arbeit und Soziales, 1989.

[17] Nigel Gilbert. *Agent-based models*. Number 153. Sage, 2008.

[18] Hardy Hanappi, Edeltraud Hanappi-Egger, and Edeltraud Hanappi. Aging-knowledge accumulation–capital accumulation. In *Technical and social innovations in aging societies, paper presented at the 11th ISS Conference on 'Innovation, competition and growth: Schumpeterian perspectives' in Sophia-Antipolis, Nizza (France)*, pages 22–24, 2006.

[19] Benjamin Hermalin. Economics & corporate culture. *Available at SSRN 162549*, 1999.

[20] Robert Holzmann and Karin Heitzmann. *Die Reform der Alterssicherung in Österreich*. Ludwig Boltzmann-Inst. zur Analyse Wirtschaftspolitischer Aktivitäten, 2001.

[21] Helmut Ivansits. Pensionsversicherung und pensionsreformen. *Auszug aus Wiso*, pages 14–45, 2000.

[22] Haseeb Ahmad Khan. Scew: a microsoft excel add-in for easy creation of survival curves. *Computer methods and programs in biomedicine*, 83(1):12–17, 2006.

[23] Martin KOHLI and Harald KÜNEMUND. Social networks. 2010.

[24] Bram Lancee and Jonas Radl. Social connectedness and the transition from work to retirement. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 67(4):481–490, 2012.

[25] Bernhard Mahlberg, Inga Freund, Jesús Crespo Cuaresma, and Alexia Prskawetz. Ageing, productivity and wages in austria. *Labour economics*, 22:5–15, 2013.

[26] Jan E Mutchler, Jeffrey A Burr, and Francis G Caro. From paid worker to volunteer: Leaving the paid workforce and volunteering in later life. *Social Forces*, 81(4):1267–1293, 2003.

[27] Chris Phillipson, Allison Smith, and Great Britain. *Extending working life: A review of the research literature*, volume 299. Corporate Document Services Leeds, UK, 2005.

[28] Sarah D Pressman, Sheldon Cohen, Gregory E Miller, Anita Barkin, Bruce S Rabin, and John J Treanor. Loneliness, social network size, and immune response to influenza vaccination in college freshmen. *Health Psychology*, 24(3):297, 2005.

[29] Christopher Prinz and Bernd Marin. *Pensionsreformen*. Campus-Verlag, 1999.

[30] Jonas Radl. Individuelle determinanten des renteneintrittsalter. eine empirische analyse von übergängen in den ruhestand. *Zeitschrift für Soziologie*, 36(1):43–64, 2007.

[31] Jonas Radl. *Retirement Timing and Social Stratification: A comparative study of labor market exit and age norms in Western Europe*. PhD thesis, 2010.

[32] Robert G Sargent. Verification and validation of simulation models. In *Proceedings of the 37th conference on Winter simulation*, pages 130–143. Winter Simulation Conference, 2005.

[33] James H Stock and David A Wise. Pensions, the option value of work, and retirement, 1988.

[34] Maximiliane E Szinovacz and Adam Davey. Predictors of perceptions of involuntary retirement. *The Gerontologist*, 45(1):36–47, 2005.

[35] Christina Teipen. *Die Frühverrentung im Wandel betrieblicher Strategien*. Rainer Hampp Verlag, 2003.

[36] Seth Tisue and Uri Wilensky. Netlogo: Design and implementation of a multi-agent modeling environment. In *Proceedings of agent*, volume 2004, pages 7–9, 2004.

[37] H Peyton Young. The diffusion of innovations in social networks. *Economy as an Evolving Complex System. Proceedings volume in the Santa Fe Institute studies in the sciences of complexity*, 3:267–282, 2002.

[38] Margarethe Zeller. *Systematik der Wirtschaftstätigkeiten, ÖNACE 2008*. Bundesanstalt Statistik Österreich, 2008.