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Nudging the Czech Pension System Towards Sustainability

Bachelor's thesis

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Abstract

This thesis explores possible improvements to the sustainability of the Czech pension system. The main focus is on nudges, which are suggestions that gently influence individuals' decision-making without restricting their freedom of choice. They have been successfully used in other countries, such as New Zealand and the United Kingdom. However, their effectiveness in the Czech Republic has not been comprehensively evaluated. To address this gap, a stylized agent-based model is utilized. This thesis extends an already existing model to incorporate real consumption and saving decision-making, as well as a simplified version of the Czech voluntary funded pension scheme. The model is parameterized using data specific to the Czech Republic. The analysis shows that in the current state of the Czech pension system, nudges exhibit only a marginal effect on improving its sustainability. However, as the government incentivizes individuals to save more and transition into higher-performing pension funds, nudges become a crucial tool for enhancing system sustainability. For instance, a policy implementing nudges and promoting access to higher-performing pension funds alleviates almost 50% of the financial constraints the Czech pension system faces.

JEL Classification	F12, F21, F23, H25, H71, H87
Keywords	nudges, agent-based model, pension systems, sustainability
Title	Nudging the Czech Pension System Towards Sustainability

Abstrakt

Tato práce zkoumá možné zlepšení udržitelnosti českého penzijního systému. Hlavní důraz je kladen na nudges, což jsou podněty, které jemně ovlivňují rozhodování jednotlivců bez omezování jejich svobody volby. Tyto nástroje byly úspěšně využity v jiných zemích jako na Novém Zélandu a ve Spojeném království. Nicméně jejich účinnost v České republice dosud nebyla komplexně zhodnocena. K vyřešení této mezery je využit stylizovaný agentně založený model. Tato práce rozšiřuje již existující model o reálné rozhodování o spotřebě a spoření, stejně jako o zjednodušenou verzi českého doplňkového spoření. Model je parametrizován pomocí dat specifických pro Českou republiku. Analýza ukazuje, že v současném stavu českého penzijního systému mají nudges pouze okrajový vliv na zlepšení jeho udržitelnosti. Nicméně, jakmile vláda motivuje jednotlivce k vyššímu spoření a přechodu do výkonnějších penzijních fondů, stanou se nudges klíčovým nástrojem pro zlepšení udržitelnosti systému. Například opatření, které implementují nudges a podporují přístup k výkonnějším penzijním fondům, zmírňuje téměř 50% finančních omezení, kterým čelí český penzijní systém.

Klasifikace JEL	F12, F21, F23, H25, H71, H87
Klíčová slova	nudges, agentní model, penzijní systémy, udržitelnost
Název práce	Nudging českého důchodového systému směrem k udržitelnosti

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Contents

List of Tables **viii**

List of Figures **ix**

Acronyms **x**

1 Introduction **1**

2 Design of the Czech pension system **4**

2.1 I. Pillar: Mandatory contributory old age pension scheme 4

2.2 III. Pillar: Voluntary funded pension 5

3 Literature review **7**

3.1 Pension systems 7

3.1.1 Pension reforms in recent years 8

3.1.2 Nudges 9

3.2 Sustainability of the Czech pension systems 10

3.2.1 Adjustments in the system 10

3.3 From traditional to agent-based models 12

3.3.1 Traditional methodology 12

3.3.2 Agent-based modeling 13

3.4 Contribution to existing research 14

4 Methodology **16**

4.1 Sugarscape Model 16

4.1.1 Sugarscape model and wealth distribution scenario . . . 16

4.1.2 Sugarscape model for exploring pension law and social security policies 18

4.2 Extension of the model 19

4.2.1 Permanent Income Hypothesis 19

4.2.2 III. pillar: Voluntary funded pension 22
4.3 Parameterization and Calibration 23
4.4 Validation 28

5 Results and discussion 31
5.1 Scenario analysis 31
5.1.1 Nudges 31
5.1.2 Higher-performing funds 32
5.1.3 Increasing savings 33
5.1.4 Savings more in higher-performing funds 33
5.2 Sensitivity analysis 34
5.3 Limitations 38

6 Conclusion 39

Bibliography 47

List of Tables

4.1 Table of parameter values 28

List of Figures

4.1 Original Sugarscape model (implemented in NetLogo). 18
4.2 Distribution of maximum age 24
4.3 Histogram of wealth in population 27
4.4 Box plot of Gini index 29
4.5 Lorenz curve 29
4.6 Graphical representation of the final model 30

5.1 Sensitivity analysis of interest rates 37

Acronyms

OLGM Overlapping Generations Model

ABM Agent-Based Model

PAYG Pay As You Go

Chapter 1

Introduction

Pension systems represent the cornerstone of social security, aiming to provide financial stability and support to individuals in their retirement years. However, two fundamental demographic trends are rising in the world. Developed countries are exposed to increasing life expectancy. At the same time, in economically successful economies, fertility rates have fallen below the replacement level. Increasing longevity and lower fertility rates dramatically change the proportion of pensioners to the working-age population. This aging pressure will lead to financial imbalances driven by higher pension spending (OECD, 2020). Confronted with a significant rise in the old-age dependency ratio, countries undertake pension system reforms to ensure long-term sustainability (Commission, 2010).

The Czech Republic is no exception. Although currently relatively stable, the pension system will face similar issues (Marek & Franče, 2019). The government has proposed a new pension reform to tackle the demographic shifts. However, there are still problems standing. For example, funded private pensions play a limited role, preventing reaping a diversified structure's benefits (OECD, 2020).

To enhance the role of the funded private pensions, one possibility is to "nudge" people to save more for retirement, reducing their reliance on pension benefits. A nudge is a method of choice architecture that influences people's behavior without removing any options. It motivates decision-making by making certain choices more attractive or easier to choose (Thaler & Sunstein, 2008). One of the most prominent nudges in pension systems is automatic enrollment, where employees are automatically enrolled in a savings plan by their employer unless they actively choose to opt out (Madrian & Shea, 2001).

Several countries, such as New Zealand and the United Kingdom, have already introduced automatic enrollment to induce participation in voluntary pension schemes (OECD, 2023). This thesis explores different scenarios for improving the sustainability of the Czech pension system, where the primary focus is on nudges. To our knowledge, no one has yet tried to evaluate their effect on the Czech pension system's sustainability.

Traditional models for assessing pension systems' sustainability feature certain simplifying assumptions, such that agents in these models are entirely rational and relatively homogeneous. To fully examine the effect of nudges on the Czech pension system sustainability, we utilize an Agent-Based Model (ABM) through computer simulation, which relaxes these assumptions. The methodology is based on creating models that resemble real systems with heterogeneous agents interacting with each other and the environment. We extend an already existing model employed to research pension law and social security policies. We adjust it for real consumption and saving decision-making of individuals using a macroeconomic concept of the Permanent Income Hypothesis. This theory suggests that consumption is determined by the net present value of lifetime earnings. The second main line of adjustments considers adding a simplified version of the Czech voluntary funded pension. ABMs have already been used to study pension systems in different countries (Murata & Chen, 2013; Lychkina & Morozova, 2015), but to our knowledge, none have been used in the Czech environment.

We parametrize and calibrate key parameter values, such as retirement age and life expectancy. To ensure the model's validity, we compare some outcomes to crucial patterns observed in reality such as the Gini index or wealth distribution. To even further ensure the robustness of our results, we conduct a thorough sensitivity analysis. Sensitivity analysis serves as a means to identify the degree of sensitivity of the model outcomes to variations in input values (Maverick, 2022).

Our results show that in the current state of the Czech pension system, nudges show only a marginal impact on its sustainability. This can be attributed to the fact that participants in the third pillar either contribute minimal amounts or opt for low-performing pension funds. However, they will become a crucial tool for its sustainability as the government incentivizes individuals to save more and people transition into participating funds in the future.

The structure of the bachelor's thesis is outlined as follows: Chapter 2 provides a brief overview of the Czech pension system and describes its main structure and components. Chapter 3 delves into the literature review. It addresses the prevailing challenges confronting pension systems, governmental strategies aimed at mitigating them, and the theoretical background essential for analyzing the pension system's sustainability. Chapter 4 introduces the core model and its framework, followed by the evaluation of its results in Chapter 5. In this chapter, we also investigate the model outcomes' sensitivity and robustness. Finally, the thesis concludes with a summary section.

Chapter 2

Design of the Czech pension system

This chapter focuses on a brief description of the Czech pension system, which is mainly based on OECD (2020). Given the evolving nature of pension systems, any necessary updates and additional details will be incorporated to ensure the relevance and accuracy of the information provided. The Czech pension system stems from the Pension Insurance Act, which in 1995 established a completely new pension system. Although there have been various changes, the principles and architecture of the system have remained similar over the last 29 years.

The architecture of the Czech pension system is based on "pillars", each serving a different purpose in providing retirement income. The first pillar sets up mandatory Pay As You Go (PAYG) pension insurance. The second pillar, enacted in 2013, was supposed to help the first pillar in the system's sustainability on a voluntary basis. However, after facing criticism, it ended in 2016. Therefore, we will not delve into it in this section. The third pillar is based on a voluntary funded pension.

2.1 I. Pillar: Mandatory contributory old age pension scheme

The mandatory Czech pension scheme is based on a PAYG architecture. This means that employees and their employers pay monthly contributions as a percentage of the employee's salary. The pension contribution rates stand at 28%, where employers contribute 21.5% and employees 6.5% (Ministerstvo práce a sociálních věcí, 2024a). Collectively, these contributions fund old age, disability, and survivor pensions. Survivor pensions are financial benefits provided to the surviving spouse or dependents of a deceased individual who used to receive pensions. Total contributions are pooled and distributed among current retirees, where each retiree is given their pension individually based on a basic, flat-rate component and earnings-related component. The basic, flat-rate component is a fixed amount; in 2024, it is 4,400 CZK. To this amount is added the earning-related component, whose calculation is rather complex. Simply described, it is calculated as an individual percentage of a retiree's reference wage. The individual percentage is based on how long the participant has been contributing to the system. The reference wage is based on the retiree's salary during his active work lifetime (Česká správa sociálního zabezpečení, 2024). The earnings-related component is highly re-distributive, meaning that people who have contributed higher amounts during their work active lifetime are getting pension benefits similar to those who have contributed profoundly less. This aims to mitigate income inequality amongst retirees. Everyone eligible for a pension is entitled to a minimum pension, which is 10% of the average wage. This number will change to 20% in January 2026 with a new pension reform according to Ministry of Labor and Social Affairs (Ministerstvo práce a sociálních věcí, 2024b).

Entitlement to the old age pension is conditioned on two criteria: to have contributed to the system for at least 35 years and to reach retirement age. For people born after 1971, the retirement age is set to 65 years. For people born before that year, the retirement age is based on their individual year of birth. The rationale behind these conditions is that requiring individuals to contribute to the pension system for several years helps ensure its financial stability. These conditions can be seen as rather strict. In comparison to other OECD countries,[1] the Czech Republic stands out as having the longest period for being able to claim the earnings-related pension at the legal retirement age. So far, the majority of people around the age of retirement fulfill the requirements.

2.2 III. Pillar: Voluntary funded pension

The third pillar is one of the tools to mitigate the drop in financial income associated with retirement. According to OECD (2020), it covers approximately

[1] 38 member countries that partnered with The Organisation for Economic Co-operation and Development (OECD) from all around the world

52% of the working-age population. It comprises a supplementary pension insurance scheme and a supplementary pension savings scheme. Both are based entirely on voluntary participation.

The supplementary pension insurance scheme, established in 1994, features the so-called transformed funds, through which participants can invest money and thus save for retirement. The state pays additional benefits to the participant's monthly contributions and allows a part of the paid contributions to be deducted from the income tax base. For example, if a participant contributes monthly 1,000 CZK, he will get an additional state benefit of 230 CZK. Any excess above 1,000 CZK (up to 3,000 CZK) can be deducted from the tax base. However, as of 1.7.2024, these numbers will change due to recent pension reform. Under certain conditions, the contributor can terminate the contract and receive accrued benefits. A critical characteristic of the transformed funds is that they guarantee a non-negative return on participant's investments. As of 2013, new participants cannot join them. Therefore, new participants can enter the second option, a supplementary pension savings scheme. Participants of this scheme can instead contribute to "participating funds", each with distinct risk profiles and strategies. The main difference from transformed funds is that participating funds no longer guarantee a non-negative return. Therefore, they can follow riskier investment strategies, and contributors can, over time, accrue higher investment returns. This was the main aim of the supplementary pension savings scheme when it was introduced in 2013. Individuals enrolled in the transformed funds can transition to the supplementary pension savings system and pick a participating fund they prefer. Based on data from Ministerstvo financí (2023), the majority (59.2%) of participants are still in transformed funds. The reason is that these funds offer a non-negative return and the option to make withdrawals without forfeiting state contributions from age 50.

Chapter 3

Literature review

3.1 Pension systems

There has been a rapid growth in population over the last few centuries. Since the 1800s, it has quadrupled to eight billion. The global population will peak at the end of this century at a total of 10.43 billion people (Ritchie *et al.*, 2023). Simultaneously, society is undergoing significant demographic shifts. The fertility rates, a measure representing the average number of children born to a woman over her lifetime and currently averaging 1.59, are projected to increase slightly to 1.63 across OECD countries by 2062. These figures fall beneath the anticipated replacement level — the number of children per woman required to maintain a stable population — of about 2.1 in developed nations for the year 2022 (OECD, 2023). Therefore, there will be relatively fewer young people of working age in the future. The projected labor force participation rates are declining (Amaglobeli *et al.*, 2019). The labor force participation rate expresses the proportion of the working-age population — typically people aged 15 to 64 years — that is either employed or actively seeking employment. At the same time, due to advances in medicine, technology, and other factors, life expectancy, which indicates the average number of years a person can expect to live, is projected to increase. Across OECD countries, life expectancy is projected to grow on average by 3.9 years among women and by 4.5 years among men in the next 31 years (OECD, 2021). Overall, demographic trends thus cause a significant transition to the older population. The reduction in labor force participation and the higher number of retirees will negatively impact the stability of social security systems, such as the pension systems, by reducing the proportion of contributors (employees) to beneficiaries (pensioners). In simpler terms, relatively fewer financial resources will be available from the PAYG part of pension systems to ensure a decent income in older age.

3.1.1 Pension reforms in recent years

Most countries have had to adopt pension reforms in recent years to counter the negative impact of population aging on pension systems. Increasing retirement age is a common strategy to improve financial stability without reducing pension levels. For example, the Slovak Republic and Sweden have introduced a gradual increase in retirement age based on life expectancy (OECD, 2023). Other significant types of changes include increasing the reward for continuing to work even after retirement, changes in how pension benefits are calculated, and changing the indexation of pensions, where some countries have moved away from indexing pensions based on wages towards increasing them based on prices, etc. (Whiteford & Whitehouse, 2006).

Several of the OECD countries have also introduced automatic enrollment programs to extend the coverage of pension schemes, such as Slovenia, Lithuania, Poland, New Zealand, Turkey, and the United Kingdom. Automatic enrollment usually enrolls employees into a savings plan as they start a new job. Participants then make monthly contributions to a pension fund to save for retirement. Still, they always have the option to decline and withdraw from the system. The difference is that without automatic enrollment, possible participants have to make an active decision to enroll themselves into the savings plan. Such reforms have already received comprehensive literature coverage and research, such as by Madrian & Shea (2001), who studies the effect of employees being registered by their employers in savings plans by default in the United States. They find that participation rates under the opt-in approach were 65%, where opt-in typically refers to a situation where individuals or entities consent or agree to participate in something in the savings plan. In comparison, after automatic enrollment, the participation rates in savings plans jumped to 98%. This addresses the issue that people often postpone joining pension funds due to inertia and other reasons, leading them to underestimate the amount they need to save for retirement. For some workers and households without alternative significant sources of income, the savings rates are unlikely to provide anything close to complete income replacement in retirement (Benartzi & Thaler, 2007; Skinner, 2007).

3.1.2 Nudges

As mentioned above, one solution for better sustainability of the pension system is to induce people to save enough and not rely only on state benefits. This can be achieved through the use of so-called nudges. "A nudge is any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives" (Thaler & Sunstein, 2008). According to the literature, nudges appear to significantly impact people's behavior, including savings decisions. One of the main nudges implemented in pension systems is the already mentioned automatic enrollment. Others include Forced choosing, where every employee is required to check a 'yes' or 'no' box at the beginning of their employment to be signed into a savings plan, or Simplified enrollment process, where employees are given an enrollment card during orientation with a 'yes' box which they can tick to join a savings plan with preselected asset allocation. All of these strategies aim to encourage employees to participate in savings plans by gently nudging them. Empirical tests have shown that these strategies increase participation rates (Carroll *et al.*, 2009).

Another significant nudge introduced by Thaler & Benartzi (2004) is called Save More Tomorrow. It allows participants to commit in advance to gradually increasing their contributions to the savings plan in sync with their pay rises, e.g., as their wage increases, their contributions increase as well. Participants do not perceive their higher contributions as losses by synchronizing contributions with pay rises. This program not only increases participation in savings plans but also boosts participants' contributions.

Some critical points could be raised against nudges. They influence immediate actions but typically do not change underlying values. Long-term interventions are essential instead of short-term results (Thaler & Sunstein, 2008). Therefore, it could be questioned whether nudges produce long-term, meaningful changes. This flaw may not be critical in terms of savings behavior, as it is essential to nudge people to enroll in voluntary funded pension schemes only once. Changing underlying values is not as important in this context. Some ethical concerns about the use of nudges can be raised as well. Critics argue that nudges can be manipulative, as they rely on influencing people's behavior without their full awareness. Nudges may undermine individual autonomy by subtly pushing individuals towards certain decisions, even if those decisions are in their best interest (Nys & Engelen, 2016).

Overall, although nudges are not without their critics who raise important questions about their effectiveness or ethics, they have gained popularity for influencing behavior in various domains. They exhibit a clear impact on people's savings behavior. Thus, if implemented, they have the potential to enhance the sustainability of the Czech pension system. In the later chapters, we introduce a model tailored to the environment of the Czech Republic to study the potential positive effect of nudges on the sustainability of the Czech pension system.

3.2 Sustainability of the Czech pension systems

Similarly to other OECD countries, the Czech Republic faces inevitable upcoming demographic changes. The population has increased only slightly from 2011 until 2020, by 215 thousand (2%), reaching a total of 10 701 777 (Český statistický úřad, 2024a). This is also partly due to immigration. Although the population increase is not considerable, the fertility rate, which was 1.71 in 2018, is projected only slightly to rise to 1.72 by 2030 and then to 1.74 by 2050, which will remain thereafter more or less constant until 2100. This is below the above-mentioned estimated replacement level of 2.1. Due to improvements in medical treatment, the life expectancy is projected to increase for men from 76 years in 2017 to 88 years in 2100 and for women from 82 to 91 years (Marek & Franče, 2019). An added concern is that the most numerous age group, 40-49 years, will soon reach retirement age, i.e., a substantial shift of cohorts from the 1970s to a higher age category. At the same time, the least numerous group born at the turning point of the 20th and 21st centuries currently belongs to the youngest productive population (Český statistický úřad, 2024a). Therefore, there will be a relatively smaller working-age population and relatively more retirees. An overall measure of such demographic trends is the old-age dependency ratio. It measures the population at or above the retirement age relative to those of working age. This is projected to remain relatively stable until 2035. Then, it is expected to increase from 0.39 to 0.59 (by 50%) by 2060 (Fall & Cahu, 2021).

3.2.1 Adjustments in the system

The Czech pension system is currently relatively sustainable but at the cost of gradual devaluation of the ratio of pension benefits to the average wage in the future. The average pension benefits are already deeply below the EU average. In 2016, the average pension in the Czech Republic was 672 EUR compared to 1135 EUR on average in the EU, after adjusting for price differences across countries (Marek & Franče, 2019).

For all these reasons, there is a gap for a solution to the question of improving the current pension system. Therefore, the Ministry of Labour and Social Affairs has proposed a reform in the second half of 2023. The reform affects both the first and third pillars. One of the main changes to the first pillar is linking retirement age to life expectancy, ensuring that future generations spend approximately 21,5 years in retirement. Other aspects of the reform include changes to the calculation of new pensions, an increase in the minimum pension benefit, fundamentally stricter rules for early retirement, and a slowdown in the valorization of pensions (Ministerstvo práce a sociálních věcí, 2024b). The Czech government seems to follow a similar path as other countries (see section 3.1.1). The changes to the third pillar include increasing the minimum contribution needed to claim state benefits, where the participant will need to contribute at least 500 CZK monthly, increasing the maximum state contribution, where if the participant contributes at least 1700 CZK, they get maximum state contribution of 340 CZK, increasing the maximum tax-deductible amount (Komerční banka, 2024), or extending the minimum savings period needed to claim accrued state benefits (NN pojišťovna, 2023). However, these reforms have sparked some controversy. For example, increasing retirement age might not be as simple as in other countries. The Czech Republic has a large representation of demanding work in the industry, issues concerning obesity, or a high number of diseases that make it very difficult to work at an older age (Prokop, 2023). These reforms could also be seen as "mere" parametric changes that lack complexity (Dolejší, 2023). Therefore, there still appears to be room for improvement. One suggestion is to deepen the role of the supplementary voluntary funded pension.

The third pillar will play a vital role. For today's younger generation, prioritizing savings for the future will become crucial to guarantee financial security during retirement (Amaglobeli *et al.*, 2019). One of the issues still standing is that participation in savings plans is the lowest for people under 30. Many people begin preparing for retirement very late; for example, 26% of savers in funds are already of retirement age (Prokop, 2023). As mentioned by OECD (2020), one approach to incentivize participation in the supplementary pension system is for the Czech government to implement an automatic enrollment mechanism within pension plans. As hinted in section 3.1.1, the Czech government could learn from the practices of ten OECD nations where automatic enrollment is already allowed. Different sources seem to support the hypothesis that motivating and supporting people towards better individual savings for old age is beneficial for pension sustainability (Pastuszek, 2020) and using automatic enrollment to do so (OECD, 2018). OECD (2020) also suggests using automatic contributions increases to mitigate inertia, similar to the methods utilized in the previously mentioned Save More Tomorrow. Therefore, nudges appear to be a viable tool for improving the sustainability of the Czech pension system.

3.3 From traditional to agent-based models

3.3.1 Traditional methodology

Pension systems are significant political and economic topics. Consequently, they are also a common topic across various literature sources, covering a wide range of subtopics, from describing and comparing current systems to making projections using distinct models. OECD (2020) develops a cohort model to simulate and project future government spending on pensions. Marek & Franče (2019) develops their model to study future pension system development scenarios. However, the most prominent method for analyzing either the effects of aging or pension system sustainability is the Overlapping Generations Model (OLGM) (Buyse *et al.*, 2017; Bielecki *et al.*, 2014; Amaglobeli *et al.*, 2019), which features agents belonging to different age classes. Individuals in one generation interact with those in other generations through various mechanisms like bequests, inter-generational transfers, or government policies. These interactions shape economic outcomes and behaviors. OLGMs are used to study equilibrium conditions, such as steady states. Although traditional general equilibrium theory is widely accepted and such models can be simply and easily interpreted, they essentially represent how the whole system as a unit behaves. Apart from the distinction between different generations, individual agents in these models are relatively homogeneous: they share similar goals and behavior and work under strict assumptions such that they are perfectly informed and representative and exhibit perfectly rational behavior. This particular assumption has been questioned mainly by behavioral economists. Behavioral economics suggests that people are boundedly rational (Simon, 1957) with limited cognitive skills and computational power and use simple behavioral heuristics. Heuristic is an approach to solving problems that is quick and sufficient to deliver results given time constraints. However, it is not necessarily optimal or rational. (Chen, 2023).

3.3.2 Agent-based modeling

Due to the strict assumptions of traditional methodology, such as perfect rationality or relatively homogeneous agents, new approaches like ABMs are widely used. They are based on computer simulation in order to overcome the limitations of mathematical tractability. ABMs use one specific and essential feature: instead of describing variables representing the overall system state, they model the system's individual components (agents) and their behavior. Agents, described as unique and autonomous, interact locally with each other and their surroundings to produce emergent outcomes (Railsback & Grimm, 2011). Unique, in this case, means that all agents are different from each other in terms of location, income, and other characteristics. Autonomous agents are independent of each other and aim to pursue their own objectives. As such, we can examine the impacts on individual agents resulting from changes in the system, as well as the effects on the system caused by individual actions. This brings a new and interesting perspective on highly complex and heterogeneous systems. ABMs have been used in various fields like biology and ecology (Zhang & DeAngelis, 2020), sociology (Epstein & Axtell, 1996; Schelling, 1969), game theory (Axelrod, 1980) and other fields. Additionally, several research papers study topics related to pension systems using ABMs. Some are concerned with the macroeconomic consequences of aging (Chen & Desiderio, 2023; Silverman *et al.*, 2013), and some focus on the savings behaviors of people in pension systems (Király & Simonovits, 2018).

A vast amount of ABM literature studies the sustainability of pension systems in various countries. For example, one of the most studied cases is the effectiveness of the Japanese pension system, given Japan has one of the most aged populations in the world (Murata & Chen, 2013). Lychkina & Morozova (2015) proposes an agent-based model to study the pension system of the Russian Federation. Serrano & Satoh (2019) extends the so-called Sugarscape model, introduced in Epstein & Axtell (1996), to study the sustainability of Spanish and Japanese pension systems. The original Sugarscape model was designed to represent wealth distribution and inequality in a society, where wealth inequality emerges from simple local interactions of agents. They extend it by introducing a PAYG pension system, in which agents' incomes are taxed, and tax revenue is allocated to social security and pensions. We extend this model even further in the upcoming chapters to suit the environment of the Czech Republic. This adaptation enables us to study specific effects, primarily those of nudges, and analyze whether they significantly impact the sustainability of the Czech pension system.

Similarly to any modeling approach, ABM comes with its own issues and challenges. As ABM mainly focuses on modeling individual agents and the environment in which they interact, it can create complex systems. Understanding underlying mechanisms that drive the overall system behavior can be challenging (Railsback & Grimm, 2011). Another issue concerns model calibration and sensitivity analysis. ABMs can be very dynamic models, where minor alterations in parameter values can result in significantly different model outcomes (Gianluca, 2014). Therefore, conducting sensitivity analysis is crucial for understanding the robustness of the model, but this action can be computationally demanding. Last but not least, model validation and verification can be challenging. Validating the model against empirical data is crucial for the reliability of the results. However, this can be difficult for complex models, especially with limited observational data or conflicting evidence (An *et al.*, 2021).

To summarize, as the topic of pension systems is important, it commonly gets attention in scientific literature. A common methodology for assessing the sustainability of pension systems are OLGMs, which, however, feature specific restrictions. As an alternative are sometimes used ABMs, which have their own limitations but offer a different and, in specific ways, better approach to analyzing complex systems such as pension schemes.

3.4 Contribution to existing research

The main contribution to existing research will be using an ABM to study potential improvements to the sustainability of the Czech pension system. We extend an already existing model featured in Serrano & Satoh (2019) to better suit the environment of the Czech Republic. As seen in 3.3.2, ABMs have already been used to study pension systems in different countries, but to our knowledge, none have been used in the Czech environment. The primary focus will be on nudges, which have been widely studied to improve people's savings behavior and have been mentioned in various sources, such as OECD (2020), as a possible reform for the Czech pension system. However, to our knowledge, no one has yet tried to evaluate their effect on the Czech pension system.

Chapter 4

Methodology

4.1 Sugarscape Model

We utilize an ABM to examine potential improvements to the sustainability of the Czech pension system through computer simulation. Our methodology builds upon an existing model initially formulated by Epstein & Axtell (1996) and subsequently extended by Serrano & Satoh (2019). We begin with a detailed overview of the original model and its subsequent extension.

4.1.1 Sugarscape model and wealth distribution scenario

Epstein & Axtell (1996) introduced the Sugarscape model. "Sugarscape" is a spatial distribution or topography of sugar, a vital source for agents' survival. The topography is structured as a two-dimensional 50 x 50 grid, with every point on the grid possessing varying levels of sugar and an (x,y) coordinate. The sugar is concentrated the most at two peaks, located in the northeast and the southwest quadrants of the grid, and diminishes further from the peaks.

The sugar within the model mirrors real-world income and wealth, while the agent's behavior parallels employment changes or migratory movements. The wealth distribution scenario of the model is designed to investigate the emergence of wealth distribution patterns among the population. Emergence is here understood as a "system dynamics that arise from how the system's individual components interact with and respond to each other and their environment" (Railsback & Grimm, 2011).

The sugarscape topography is inhabited by agents that are characterized by a set of fixed and variable characteristics and adhere to predefined behavioral rules. Each agent has a location given by the horizontal and vertical coordinates (x,y), age, initial wealth endowment, and genetic traits consisting of metabolism and a level of vision. These attributes are randomly distributed among agents, resulting in a heterogeneous agent population. The agent's behavior is the following. In each time step representing one year, an agent surveys its surroundings based on its vision, moves to an unoccupied site with the highest salary within his visual range, earns all the income available at that site, consumes a portion of it based on his metabolism, and the rest is accumulated as wealth. If the agent reaches a certain age or lacks sufficient wealth to satisfy his metabolic demands, he is considered to have died and is subsequently removed. When an agent dies, he is replaced by an agent of age 0 to keep the population constant.

The authors also examine a histogram of wealth animated over time, with the wealth levels of agents depicted on the x-axis and the number of agents that have accumulated such wealth on the y-axis. The histogram ends up highly right-skewed, which is characteristic of systems with heterogeneous agents extracting resources from a landscape. Additionally, the authors analyze a Lorenz curve and a Gini index animated over time, serving as metrics for assessing wealth inequality within the population. Lorenz curve graphs percentiles of the population against the cumulative wealth of people at or below that percentile (Investopedia, 2022). The Gini index of value 0 represents perfect wealth equality, and value 1 represents maximum inequality. All of these outputs are visually represented on the right-hand side of Figure 4.1. In the middle is a graphic visualization of the model. Plain fields represent the topography, and the dots are the agents. On the left-hand side are some variable inputs and buttons to start the model. The model has been implemented using Netlogo, a software package commonly used to implement ABMs.

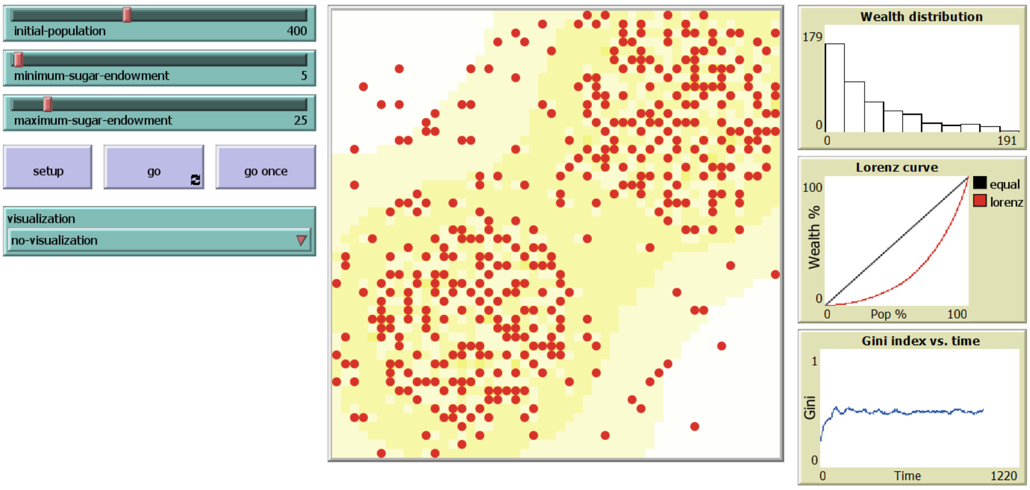

Figure 4.1: Original Sugarscape model (implemented in NetLogo).

4.1.2 Sugarscape model for exploring pension law and social security policies

Serrano & Satoh (2019) expand the original Sugarscape model to suit the environment of Spanish and Japanese pension systems for analyzing pension law and social security policies.

The main change in the model lies in the consumption rule of agents. Previously, after moving, agents would update their wealth by receiving all available income on the new site and consuming a portion of it based on metabolism. The new rule considers:

1. Retirement age: after reaching the designated retirement age, agents stop receiving their salary and transition into retirement.

2. Government budget: working agents contribute a portion of their earned salary relative to taxes to a government budget, from which retired agents receive pensions.

3. Pension taxes: taxes are levied on the income earned by working agents and deposited into the government budget to fund pension payouts.

4. Productivity decay: agent productivity diminishes with age, impacting their ability to earn income.

5. Social services: socially excluded agents gain extra financial help from the government. Socially excluded agents are agents that do not possess enough financial resources to support themselves.

6. Flat-rate premium: working agents with sufficient wealth reserves have to contribute a flat-rate premium to the government budget. This premium contributes to the budget's sustainability and is only used to study the Japanese pension system.

7. New outputs for sustainability analysis: additional model outputs are introduced to assess the pension system's sustainability, including the number of retired and working agents and the number of agents in social exclusion.

Therefore, this model version represents a PAYG pension system. Upon evaluating the pension system's sustainability, the authors conclude that population growth within resource-constrained settings leads to increased societal instability and heightened levels of social exclusion. This indicates that with a growing population, the financial stability of PAYG pension systems is endangered. These findings are in line with our literature review.

4.2 Extension of the model

In this section, we implement further modifications to the existing model to primarily study the effect of nudges on the sustainability of the Czech pension system. We consider two different lines of adjustment.

4.2.1 Permanent Income Hypothesis

In the previous iterations of the model, the authors assume that when agents earn their income and consume a portion of it, they do so based on their metabolic needs. This symbolizes a behavior in which agents spend only enough of their income to meet their basic survival requirements. However, real-world consumption decisions are influenced by many different factors beyond just consuming enough to survive. Thus, we relax this assumption.

The consumption decision has been widely studied in macroeconomics, with significant contributions made by John Maynard Keynes, who tracks the connection between income and spending (Kenton, 2023). Subsequent theories, such as Franco Modigliani's life cycle hypothesis, assume that economic subjects plan their consumption and savings for a long period ahead and try to allocate them optimally (Hlavacek, 2023). Similarly, Milton Friedman's Permanent Income Hypothesis, introduced in 1957, predicts that consumption is determined by permanent income, i.e., by the net present value of lifetime earnings. Despite facing criticism (Carroll, 1997), there is empirical evidence supporting this hypothesis, and, in theory, it is widely accepted (Hall, 1978). Moreover, it has been used in ABMs to simulate individuals' savings behavior (Varga & Vincze, 2017). Given also its mathematical properties, the Permanent Income Hypothesis seems to be an appropriate way to model consumption behavior in our model.

To incorporate the Permanent Income Hypothesis in our model, we adopt a similar approach as Steinsson (2023). The method introduces first a series of simplifying assumptions:

1. Known finite horizon T, where T is the maximum age of an agent.
2. No uncertainty.
3. Constant interest rate r.
4. No durable goods that can last multiple periods, such as houses or cars.
5. Exogenous income process.
6. Costless enforcement of contracts.
7. No bankruptcy. Agents must repay their debt.
8. Natural borrowing limit. The agent is able to borrow up to a certain amount.

We consider agents with initial assets A_{-1}, receiving a stream of income Y_t at each period t and characterized by preferences with exponential discounting $\sum_{t=0}^{T} \beta^t U(C_t)$, where β represents a time discounting factor and $U(C_t)$ denotes utility derived from consumption at time t (Bauer, 2022). Agents can save at rate r and borrow at rate r up to the natural borrowing limit. The natural borrowing limit assumption implies that $A_T \geq 0$, i.e., agents cannot die with a debt. With this natural borrowing limit, agents are subject to an intertemporal budget constraint:

$$\sum_{t=0}^{T} \frac{C_t}{(1+r)^t} \leq A_{-1} + \sum_{t=0}^{T} \frac{Y_t}{(1+r)^t} \tag{4.1}$$

This inequality signifies that the present value of consumption cannot be larger than the present value of income and initial assets. Overall, agents are trying to maximize their preferences $\sum_{t=0}^{T} \beta^t U(C_t)$ subject to the intertemporal budget constraint 4.1. This optimization problem can either be solved by setting up a Lagrangian or using calculus of variations. Both mathematical methods are often used for solving optimization problems. Regardless of the method, the solution leads to the consumption Euler equation:

$$U'(C_t) = \beta(1+r)U'(C_{t+1}) \tag{4.2}$$

Based on the Euler equation, an individual should feel equally inclined towards consuming one additional unit today or saving it for future consumption adjusted for the discount factor and an interest rate. We further assume a specific form of the utility function $U(C_t) = \log C_t$, which is common due to its mathematical properties such as $U'(C_t) = \frac{1}{C_t}$ (Jones, 2017). For simplicity, we assume that $\beta(1+r) = 1$, implying that individuals discount the future based on interest rates. With these assumptions, the consumption Euler equation 4.2 becomes:

$$U'(C_t) = U'(C_{t+1})$$

which implies:

$$C_t = C_{t+1} \tag{4.3}$$

Equation 4.3 embodies one of the main ideas of the Permanent Income Hypothesis, that consumers optimally smooth their consumption over time. By further substituting the derived equation 4.3 into the intertemporal budget constraint 4.1, we can solve for the current value of consumption:

$$\begin{aligned} C_0 &= \phi(r)(A_{-1} + \sum_{t=0}^{T} \frac{Y_t}{(1+r)^t}) \\ \phi(r) &= \frac{1 - \frac{1}{1+r}}{1 - (\frac{1}{1+r})^{T+1}} \end{aligned} \tag{4.4}$$

Due to equation 4.4, agents in our model can determine their current consumption by considering their initial assets, future income stream, interest rate, and maximum age. If the value of consumption exceeds their current wealth, they incur debt. Conversely, if consumption is less than their current wealth, any remaining money is saved for the future.

To incorporate this consumption theory, some processes need to be changed. Agents are no longer constrained by the need to satisfy metabolic demands and instead decide on their consumption. They can also incur debt as a result. If the debt is too excessive beyond their capacity to repay it, agents are deemed socially excluded. In this context, social exclusion signifies the inability to participate financially in society. This represents, for example, becoming homeless or, in extreme cases, death. Similarly, as in the previous model, if they fall into debt, they can use social services to gain extra help from the government.

The previous models also utilize various outputs to study the wealth distribution amongst the population, including the histogram of wealth, Lorenz curve, and Gini index. However, it is more common for the Lorenz curve and Gini index to be used in measuring an income rather than wealth distribution (Hayes, 2024; Hasell, 2023). Therefore, we change them accordingly in the model to measure income rather than wealth inequality. To ensure the validity of our model, we aim to compare the outcomes of the Gini index and the Lorenz curve to their real-world counterparts, such as to the data provided by World Bank (2024).

As a final remark, in the previous iterations of the model in sections 4.1.1 and 4.1.2, agents make consumption decisions solely based on metabolic needs, thus consuming only just enough to survive. We use the Permanent Income Hypothesis under some simplifying assumptions mentioned at the beginning of this section to better simulate agents' decision-making. While these assumptions may appear restrictive, we believe that the resulting consumption decisions of agents are a more realistic portrayal of real-world behavior.

4.2.2 III. pillar: Voluntary funded pension

Our model contains the I. pillar, i.e., the PAYG part of the pension system developed in 4.1.2. Moving forward, we proceed with the second line of adjustments and consider adding a simplified version of the III. pillar of the Czech pension system, i.e., the voluntary funded pension, based on our description in 2.2.

We thus adjust the behavior of agents accordingly. After having decided on consumption, a portion of the agents now have the possibility to allocate part of their savings into a pension fund, provided they are enrolled in the voluntary funded pension scheme. In addition to their contribution, they also receive a small benefit from the government. The savings accumulated in the pension fund then accrue based on a specific rate of return. The agents can thus additionally save for retirement. In reality, voluntary pension participants can withdraw their savings and accrued state benefits after ten years of participation. However, the underlying principle of the III. pillar is to allow individuals to save extra funds for retirement. Therefore, for the sake of simplicity, agents in the model gain access to their funds only after retirement age.

In summary, we consider two adjustments to better suit the environment of the Czech pension system: The Permanent Income Hypothesis and the voluntary funded pension. These adjustments primarily alter the behavior of agents within the model. The complete behavior of agents is now as follows:

1. Working agents assess job opportunities and move to an unoccupied position offering the highest wage. Upon reaching a certain age, agents transition into retirement and stop working. Retired agents do not seek employment opportunities and thus do not move.

2. Working agents receive their wages reduced for taxes. Taxes are collected by the government and redistributed to the pensioners. Pensioners receive pensions and any accrued savings from pension funds.

3. Each agent decides on their consumption based on the Permanent Income Hypothesis and consumes part of their wealth. The remaining wealth is saved for the future. If an agent's consumption exceeds his wealth, he incurs debt and may seek assistance from the government.

4. When the agent cannot repay his debt, he is deemed socially excluded and subsequently replaced by an agent of age 0 to maintain a constant population. Similarly, an agent is replaced when they reach their maximum age.

4.3 Parameterization and Calibration

We have concentrated on formulating effective model designs, patterns, and agent traits to align the model's structure with that of the Czech pension system. In this phase, we focus on the quantitative results of the entire model. "Parametrization is the word modelers used for the step of selecting values for a model's parameters. One of the most important tricks for credible parametrization is to design the model so its parameters represent real quantities or rates that could, at least in principle, be measured empirically" (Railsback & Grimm, 2011). According to this principle, we select values for key parameters within our model, which represent real measurable quantities:

Retirement age The retirement age signifies the point at which agents retire from active employment and start receiving pension benefits. This transition also directly affects the Permanent Income Hypothesis, as agents have to account for a different stream of income. According to the Ministry of Labour and Social Affairs (Ministerstvo práce a sociálních věcí, 2022), the retirement age stands at 65 years for individuals born after 1971. For those born prior to 1971, determining the retirement age is rather complex and depends on various factors such as birth year, gender, and the number of raised children. For simplicity, we set the value of the retirement age to 65.

Pension taxes Another vital factor is the imposition of pension taxes, which serve as the primary funding source for pension benefits. Furthermore, since these taxes are deducted from workers' incomes, they inherently contribute to income inequality, thus influencing the shape of our Lorenz curve and Gini coefficient. As mentioned in section 2.1, the pension tax rate accounts for 28% of income. Additionally, we consider an extra 1,2% income tax rate related to state employment policy, as agents in our model may seek additional assistance from social services (Ministerstvo práce a sociálních věcí, 2024a).

Maximum age When an agent reaches their maximum age, they die and are removed from the model. Utilizing the most recent mortality table provided by the Czech Statistical Office (Český statistický úřad, 2022), we can model the distribution of this maximum age. This distribution is graphically represented in Figure 4.2, which we input into the model.

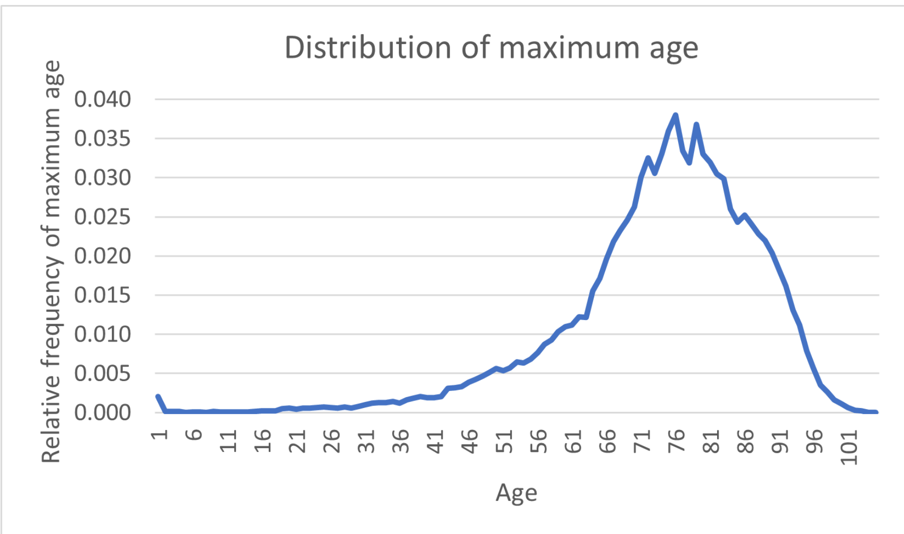

Figure 4.2: Distribution of maximum age

Life expectancy Agents in our model, as in real life, are unable to know their maximum age. Nevertheless, this information holds significant importance for making informed decisions regarding future plans, such as consumption or savings strategies. One potential approach is for individuals to estimate their maximum age based on life expectancy data. According to the most recent statistics provided by the Czech Statistical Office (Český statistický úřad, 2024b), the life expectancy at birth in the Czech Republic stands at 79 years.

Share of the working population participating in voluntary funded pension scheme Employees participating in the voluntary pension scheme also contribute to pension funds for their retirement. As per OECD's latest available data OECD (2020), the voluntary funded pension scheme covers 52% of the working-age population. However, it is worth noting that this information might be considered outdated. According to the Ministry of Finance (Ministerstvo financí, 2023), the number of active contracts in the voluntary scheme has changed only marginally since 2020. Therefore, we assume that 52% of agents in our model are actively enrolled in the voluntary funded pension scheme.

Interest rate This parameter holds significant importance for people's consumption decisions in our model. Either they can take a loan against their future income or deposit their wealth into a savings account. Referring to the time series data provided by the Czech National Bank (Česká národní banka, 2024), we found that the average interest rate over the past ten years for savings accounts was 0.81% and the average interest rate over the past twenty years was 5.74% for consumption, housing, and other loans. To calculate the consumption decision, the Permanent Income Hypothesis assumes a unified interest rate. Therefore, we derive the average of these two figures as the interest rate for consumption decision.

We are aware that interest rates in the economy are volatile. They have been especially higher in the recent years. Therefore, we subsequently evaluate how all possible values of the interest rate affect the model's validity.

Rate of return in pension funds Agents in our model have the option to save in supplementary pension funds, where their savings grow based on the fund's performance. As mentioned in section 2.2, the majority of participants are currently participating in transformed funds, which historically yield a low performance rate of around 1.1% due to the guarantee of non-negative returns (Asociace penzijních společností ČR, 2024). Therefore, we set the rate of return to 1.1%. Additionally, in scenario analysis, we explore what happens when people switch to better-performing funds.

"Calibration is a special kind of parametrization in which we find good values for a few especially important parameters by seeing what parameter values cause the model to reproduce patterns observed in the real system" (Railsback & Grimm, 2011). Calibration becomes necessary when some of the model's parameters cannot be as easily estimated. To estimate these parameters, we utilize BehaviorSpace, a software tool incorporated into NetLogo that enables users to iteratively run the model and systematically vary the model's settings. This allows to quickly test various model configurations and eliminates stochasticity and randomness as we run the model multiple times. We compare the outcomes generated by BehaviorSpace to patterns observed in reality. The examined parameters are:

Contributions and state benefits to pension funds Agents enrolled in the voluntary funded pension scheme contribute to pension funds and receive state benefits based on their contributions. However, calibrating the amount of contributions they invest and the state benefits they receive is not as straightforward as using real-world values, as agents in our model consume a virtual source. To address this, we utilize BehaviorSpace and allow the model to run for 750 periods, each representing a year. This number was chosen similarly as by Serrano & Satoh (2019), who consider running the model for 1000 periods. The exact number of periods is unimportant, as we do not have a predictive model. The only purpose is to achieve a stable state of the model and to mitigate any stochasticity. In each period, we record the average wage of agents. The average wage in our model is 1.499. According to data from the Ministry of Finance (Ministerstvo financí, 2023), the average participant's contribution to pension funds is 804 CZK, roughly 1.86% of the average wage in the Czech Republic. Therefore, participants' contributions in our model amount to approximately 0.0279. The average state benefit paid out is 149 CZK, roughly 18.53% of the contribution. Therefore, in our model, agents receive 0.0052 as state benefits.

Minimum wealth endowment Each time an agent is born, they are endowed with an initial wealth, symbolizing assets received from parental sources, inheritance, and similar origins. This value is challenging to estimate, so we have to calibrate it by analyzing which parameter values reproduce patterns observed in reality. One of those patterns is the wealth distribution, which should be right-skewed, characteristic of systems with heterogeneous agents extracting resources from a landscape, as mentioned in section 4.1.1. In our model, we observe the emergent wealth distribution and how it responds to different levels of minimum wealth endowment.

After varying the minimum wealth endowment across possible values, we find that the wealth distribution is best reproduced by values in the interval $\langle 1; 10 \rangle$. Using sensitivity analysis, we subsequently show that this parameter is not particularly influential in the model. Therefore, we set it to 5, the value initially used in the original versions of this model. The resulting histogram, representing the number of people within each wealth category, is shown in Figure 4.3.

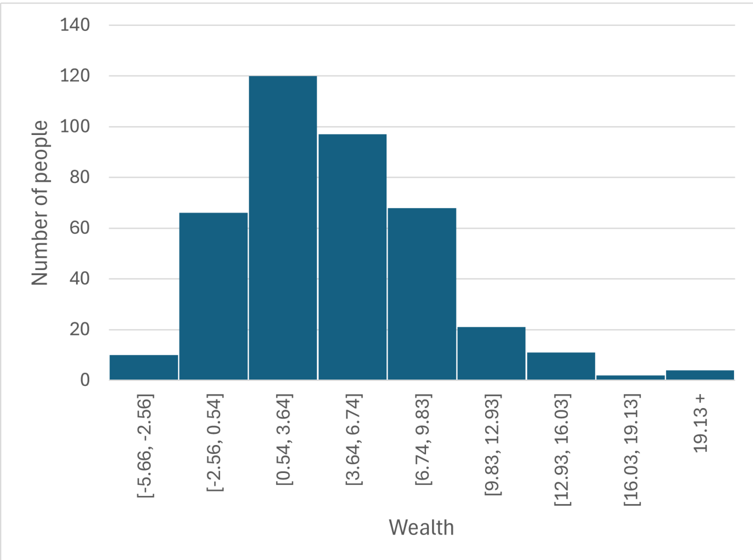

Figure 4.3: Histogram of wealth in population

Table 4.1 shows the parameterized values in a summary. It is important to note that we parametrize the values to resemble the Czech pension system's current state and to create a benchmark model. Some of the values are simplified or, in reality, volatile. Therefore, we explore how different values affect our model results in scenario and sensitivity analysis. For the sake of simplicity, we have left certain parameters parameterized to values initially set in the original model by Serrano & Satoh (2019).

Parameters	Values
Retirement age	65
Income taxes	29.2%
Life expectancy	79
Share of the working population in voluntary funded pension	52%
Interest rate for savings accounts	0.81%
Interest rate for loans	5.74%
Rate of return in pension funds	1.1%
Minimum wealth endowment	5
Savings in pension funds	0.0279
State benefits	0.0052

Table 4.1: Table of parameter values

4.4 Validation

To validate our model, we compare its emergent outcomes to patterns observed in reality. We have already demonstrated, through the calibration of minimum wealth endowment, that the model produces a realistic right-skewed wealth distribution. Additionally, we analyze the Lorenz curve and the Gini index, similarly as Epstein & Axtell (1996).

According to the most recent data from the World Bank, the Gini index in the Czech Republic stands at 26.2 (World Bank, 2024). We conducted simulations using BehaviorSpace, allowing the model to run for 750 periods. At each step, we measured the Gini index to mitigate any stochasticity. The results, depicted in the box plot in Figure 4.5, show that the Gini index stabilizes around an average value of 26.79. This value closely aligns with the latest Gini index reported for the Czech Republic.

The Lorenz curve is a graphical representation of the Gini index. It is typically an upward-sloping convex function. The lower the Gini index, the closer the Lorenz curve resembles a line of equality: a 45-degree upward-sloping line (Investopedia, 2022). The resulting Lorenz curve from our model is depicted in Figure 4.5, showing a slightly increasing convex curve. It also approaches in shape the line of equality, reflecting the relatively low Gini index of the Czech Republic.

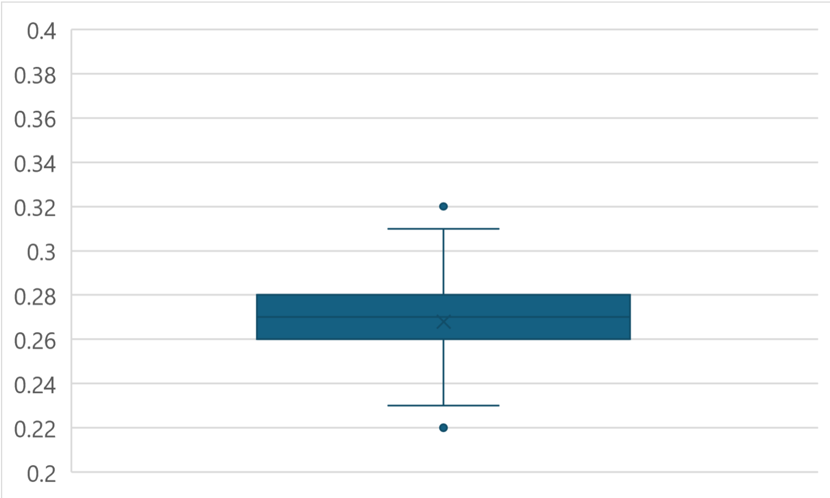

Figure 4.4: Box plot of Gini index

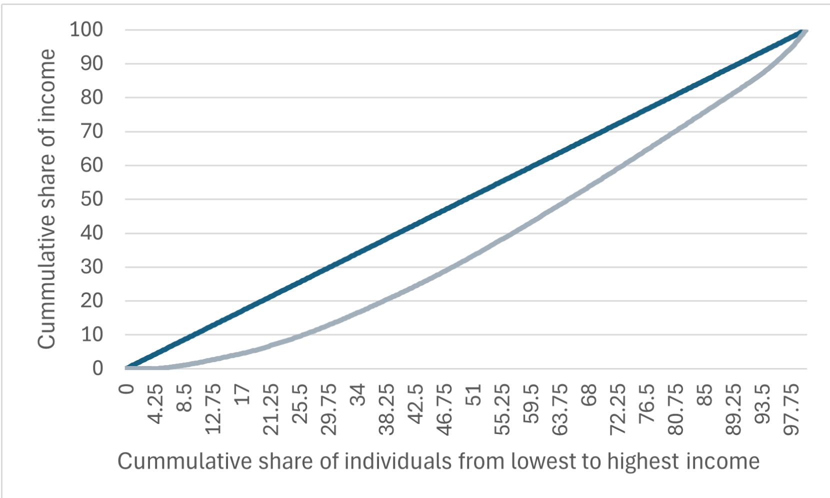

Figure 4.5: Lorenz curve

Figure 4.6 shows the graphical representation of the final model. In the middle is a visualization of the model. On the left-hand side are the parameterized input variables and buttons to start the model, and on the right-hand side are the output graphs such as the wealth distribution, Lorenz curve, or Gini coefficient.

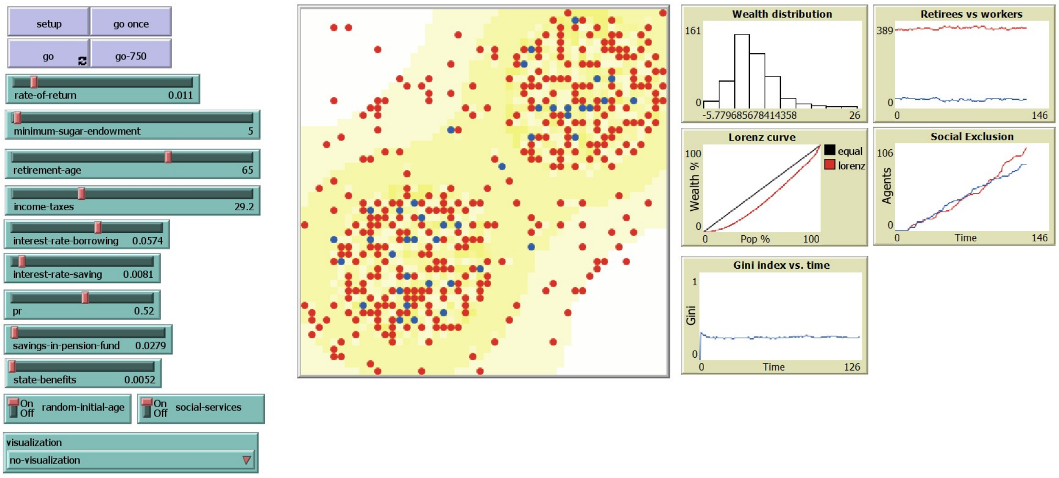

Figure 4.6: Graphical representation of the final model

Chapter 5

Results and discussion

5.1 Scenario analysis

In this chapter, we employ the model to explore various scenarios to improve the sustainability of the Czech pension system. A pension system is deemed sustainable if future pension expenditures do not lead to prolonged or permanent financial constraints over a suitable long horizon (International Monetary Fund, 2022). To do so, we adopt a similar methodology as Serrano & Satoh (2019). In each scenario, we alter a critical parameter within the model and conduct 100 simulations to mitigate stochastic effects. At the end of each simulation, we measure the number of socially excluded agents and compare this figure to the original model. Socially excluded agents represent individuals lacking the finances to actively participate in society, often due to insufficient pension benefits or retirement savings. In reality, governments may incur deficits to address such financial constraints. Given that in our model, government expenditures cannot go beyond a limit, e.g., the government budget has a zero lower bound, socially excluded agents serve as a crucial indicator of pension system sustainability.

5.1.1 Nudges

One of the primary objectives of this thesis is to examine the potential positive impacts of nudges on the Czech pension system. As detailed in section 3.1.2, nudges are a powerful tool for inducing an individual's savings behavior. The underlying idea is that increased savings for retirement could lead to reduced reliance on state pension benefits provided by the first pillar. Specifically, Madrian & Shea (2001) conducted a study on automatic enrollment and discovered a significant 33 percentage point increase in participation rates in savings schemes when it is introduced. To investigate the potential positive impact of automatic enrollment on the sustainability of the Czech pension system, we increase the proportion of the working population enrolled in a voluntary funded pension plan by 33 percentage points. Surprisingly, despite increasing the enrollment rate from 52% to 85%, the reduction in the number of socially excluded agents is only marginal, at 2.55%.

This trend is also observable for other forms of nudges such as Forced choosing or Simplified enrollment process, which have been found to boost participation rates in savings schemes by 25% (Carroll *et al.*, 2009). When we increase the proportion of the working population in our model by 25 percentage points, the reduction in socially excluded agents remains unsurprisingly minimal, at 2.35%. In summary, at the current state of the system, nudges do not significantly affect the sustainability of the Czech pension system. The main reason appears to be that the majority of individuals invest minimal amounts, approximately 1.86% of the average wage, into pension funds with low rates of return.

5.1.2 Higher-performing funds

One of the factors making nudges underperform is the tendency of participants to allocate their savings into transformed funds with low performance. In reality, individuals also have the option to invest in participating funds. Additionally, since 2013, new participants can no longer join transformed funds. Therefore, as more people opt for participating funds in the future, the choice of investment strategy will be even more crucial. We analyze how different investment strategies affect the sustainability of the pension system and the efficiency of nudges.

First, we explore a scenario where participants allocate their savings into balanced funds, which offer a higher rate of return at 3.35%, as per data from the Association of Pension Companies (Asociace penzijních společností ČR, 2024). This adjustment leads to a reduction in the number of socially excluded agents by approximately 9%. Furthermore, the impact of nudges becomes more pronounced. When automatic enrollment is introduced, this scenario now results in a total of 20.03% decrease in socially excluded agents compared to the original model. These effects are even more substantial when considering a scenario where most participants allocate their savings into progressive funds, which offer a rate of return of 5.61%. Compared to our original model, this scenario reduces the number of socially excluded agents by 31.44% and by 51.17% when automatic enrollment is considered.

5.1.3 Increasing savings

The second factor contributing to the underperformance of nudges is that participants tend to save insufficiently. In the new pension reform, the government tries to incentivize individuals to increase their contributions by raising the state benefit to 340 CZK for contributions totaling at least 1700 CZK. We evaluate the effectiveness of this reform through a scenario where participants increase their contributions to attain the maximum state benefit, aligning with the reform's underlying principle. We adjust the parameters of state benefits and savings in pension funds in our model similarly as in section 4.3. The increased contributions amount to approximately 3.9% of the average wage in the Czech Republic. Therefore, we set the new contributions to 0.0588. The increased state benefits, amounting to 340 CZK, constitute roughly 20% of the new contributions. Consequently, in our model, agents now receive 0.012 in state benefits.

While the reform yields a modestly positive effect in our model, reducing the number of socially excluded agents by 5.47%, it remains minimal compared to the scenario where people choose better investment strategies. Upon introducing automatic enrollment, the number is reduced in total by 13.78%. Therefore, higher contributions also enhance the impact of nudges. Save More Tomorrow, which increases participation rates and contributions, might be the most effective nudge compared to others that only increase participation rates. In conclusion, further promoting higher contributions will continue to be essential for future governments.

5.1.4 Savings more in higher-performing funds

Lastly, we examine a scenario where agents contribute more, as in the last section, to higher-performing funds. Initially, we assume that most participants allocate their savings to balanced funds. This adjustment results in a 30% reduction in socially excluded agents compared to the original model. Upon the introduction of automatic enrollment, the number is reduced in total by 49.56%. Subsequently, we explore a scenario where most participants allocate their savings to progressive funds. As expected, the impact is even more substantial. The number of socially excluded agents decreases by 32.15%, and with the introduction of automatic enrollment, this number diminishes by 53.41% compared to the original model.

To summarize, in the initial setup, automatic enrollment reduces the number of socially excluded agents by a mere 2.55%. However, when considering a policy that motivates individuals to contribute more and incorporates automatic enrollment, the total effect increases more than fivefold. A policy that promotes access to a suitable default investment strategy alongside automatic enrollment would be even more significant. If individuals were to transition to at least balanced funds, the total effect would be almost ten times higher than in the initial setup. The most impactful policy, which motivates people to transition to progressive funds, promotes higher contributions and implements automatic enrollment, has an effect almost twenty-one times greater than the initial setup.

These findings underscore the main conclusions of this thesis. Nudges do not seem to significantly improve the current state of the Czech pension system. The main reason appears to be that the majority of individuals invest minimal amounts, approximately 1.86% of the average wage, into pension funds with low rates of return. However, nudges become a crucial tool for its sustainability as the government incentivizes individuals to save more and people transition into participating funds with better investment strategies in the future.

5.2 Sensitivity analysis

Certain model parameter values remain uncertain as they simplify a process that is inherently more complex, volatile, or represents something that has not been measured precisely. Therefore, this section examines the sensitivity of our principal observed dependent variable: the effect of nudges. Sensitivity analysis serves as a means to identify the degree of sensitivity of the model outcomes to variations in input values (Maverick, 2022).

Our methodology follows a procedure outlined by Railsback & Grimm (2011). We first identify a range with which the input parameter is varied. These ranges are typically within a narrow margin of +/-5% around a reference value. For instance, if our reference value is denoted as P, the parameter values analyzed would be $0.95P$ and P. This margin is usually small, as ABMs are very dynamic, where alterations in parameter values can result in different model results. The reference value is here understood as the value initially parameterized in section 4.3. We execute 100 replicates of the model for each alteration in parameter value to ensure robust estimation of results. The standard approach is that the model has to be modified when an abnormal or unexpected situation occurs to maintain the result's credibility.

In our prior scenario analysis, we have already observed the impact of varying input variables on the effectiveness of nudges, particularly regarding the variability in factors such as the rate of return, savings, and state benefits in pension funds. Our findings indicated that adjustments to these parameters, often exceeding the 5% range, generally produced expected deviations in results. Now, we focus on the remaining parameters.

Income tax rate Initially, we set the income tax rate to 29.2%, comprising mostly pension taxes and taxes associated with state employment policy.

We first examine the scenario where the income tax rate is adjusted to $0.95P = 27.7$. Under this setting, the effect of automatic enrollment becomes 2.97% of decreasing the number of socially excluded agents. Similarly, raising the income tax rate to $1.05P = 30.7$ yields a 2.89% impact of automatic enrollment. Compared with our original model, where automatic enrollment's effect stands at 2.55%, the results exhibit resilience concerning the income tax rate parameter. Interestingly, we would expect to observe some trend in the sensitivity analysis of the income tax rate, but this is not the case. This lack of trend could be attributed to stochasticity or certain underlying interactions within the model.

Minimum wealth endowment The baseline reference value for the minimum wealth endowment is set at five units, $0.95P = 4.75$ and $1.05P = 5.25$. Due to the discrete nature of this parameter, a broader range is considered for the sensitivity analysis.

Decreasing the minimum wealth endowment to 4 yields a 2.62% effect of automatic enrollment. Conversely, increasing the value to 6 results in a 2.76% impact of automatic enrollment. Therefore, variations in the minimum wealth endowment exhibit minimal influence on the overall results.

In summary, although we initially set the value arbitrarily to 5 units, this assumption does not significantly impact our results.

Life expectancy The initial parameterized life expectancy value is 79 years, serving as a reference value.

Decreasing the value to $0.95P = 75$ and introducing automatic enrollment yields a reduction in the number of socially excluded agents of 10.74%. Conversely, increasing life expectancy to $1.05P = 83$ and introducing automatic enrollment yields a 6.63% reduction in socially excluded agents. The outcomes suggest a higher sensitivity than the other parameters examined so far and are further discussed.

Retirement age The reference value for retirement age is 65 years. Decreasing the value to $0.95P = 62$ and introducing automatic enrollment yields a reduction in the number of socially excluded agents of 3,12%. Conversely, increasing the retirement age to $1.05P = 68$ and introducing automatic enrollment yields a 13% reduction in socially excluded agents.

The outcomes for both retirement age and life expectancy suggest a higher sensitivity than the other parameters examined so far. The sensitivity arises due to the correlation between life expectancy and retirement age. In reality, life expectancy is an essential factor for setting the retirement age in many countries, as highlighted in section 3.1.1. Even the new Czech pension reform considers adjusting the retirement age based on life expectancy trends. The results exhibit reduced sensitivity when we simultaneously consider decreasing life expectancy and retirement age. In this scenario, automatic enrollment demonstrates a comparable effect to our original model of 3.54%. Similarly, increasing both life expectancy and retirement age yields an impact of automatic enrollment of 1.8%. Therefore, the results are much less sensitive when simultaneously considering life expectancy and retirement age parameters.

Interest rate The interest rate parameters in our model are derived based on the average of time series interest rates for savings accounts and loans. However, interest rates can be volatile. Therefore, we consider a more robust approach for a comprehensive assessment of result sensitivity.

Drawing from the time series data provided by the Czech National Bank (Česká národní banka, 2024), the minimum savings account interest rate over the past ten years stood at 0.16%, while the minimum loan interest rate was 2.82%. On the contrary, the maximum savings account interest rate over the same period was at 3.13%, while the maximum loan interest rate was 6.97%. Employing BehaviorSpace, we systematically vary both parameters from their minimum values to their maxima, observing the effects of nudges. The analysis result is depicted in Figure 5.1, which presents a contour plot. The x-axis denotes loan interest rates, while the y-axis represents savings account interest rates. The shading within the plot indicates the diverse effects of automatic enrollment across varying interest rate scenarios.

The contour plot reveals that the impact of automatic enrollment falls within a 2-4% range across most interest rates. Therefore, the results suggest a limited sensitivity to changes in the interest rate parameter. Only for extreme values of interest rates in savings accounts is the effect of automatic enrollment slightly higher. In conclusion, the exact interest rate parameter values do not significantly affect our results.

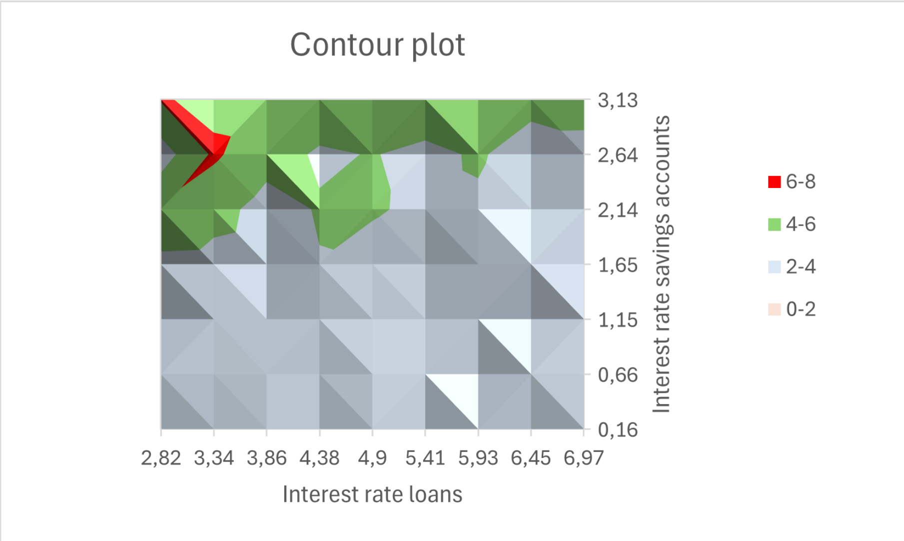

Figure 5.1: Sensitivity analysis of interest rates

Overall, we have demonstrated the sensitivity of the results to variations in individual parameter values. The results of the sensitivity analysis show, that our model is not significantly sensitive to most parameter values. Specifically, we found that the model is more sensitive to changes in life expectancy and retirement age. This is not surprising, as both are key parameters in our model. We observed that the sensitivity is reduced when considering retirement age and life expectancy simultaneously. However, the higher sensitivity of these two parameters could be seen as a limitation of our model.

5.3 Limitations

Our model incorporates several assumptions. Firstly, we based our methodology on a relatively simple underlying ABM and maintained certain procedures unchanged for simplicity. For instance, instead of modeling a labor market, our agents select job opportunities based solely on the highest available salary. An additional assumption is that we maintained a constant population within the model. Furthermore, we assumed that participants in the voluntary pension scheme can only withdraw their contributions after retirement. Moreover, we made specific assumptions about parameter values, such as assuming that all participants in the voluntary funded pension scheme invest in transformed funds with a low rate of return.

All of these assumptions could slightly impact our results. Nonetheless, a common aim of ABMs is to develop models that represent real systems in a simplified way (Railsback & Grimm, 2011). In line with this objective, we stylized our model to capture the essential aspects of the Czech pension system and primarily examine the impact of nudges.

One further limitation of this study is the use of socially excluded agents as the primary indicator of pension system sustainability. While this approach provides a valuable insight into the potential financial constraints faced by individuals within the pension system, it is a rather simplified indicator. In reality, governments may have the capacity to incur deficits to address financial constraints.

To be able to analyze the effect of nudges within our model, we assumed that they would have the exact same effect in the Czech Republic in increasing the participation rates in voluntary funded pension schemes as in their original studies. For example, Madrian & Shea (2001) studied the effect of automatic enrollment in the United States and found a 33% increase in participation rates under automatic enrollment. However, the exact effect could be different in the Czech Republic, potentially leading to modest changes in our results.

Chapter 6

Conclusion

As the Czech pension system will face demographic challenges in the foreseeable future, this thesis explores how different policies impact its sustainability. Our primary focus centered on nudges, which have been widely studied to improve people's savings behavior (Thaler & Sunstein, 2008) and have been implemented in various countries in the form of automatic enrollment (OECD, 2023). However, to our knowledge, no comprehensive assessment of their impact on the sustainability of the Czech pension system has been undertaken.

To fully examine the effect of nudges on the sustainability of the Czech pension system, we designed a stylized ABM through computer simulation. We expanded the scope of an existing model used to research pension law and social security policies. The main adjustments include incorporating real consumption decision-making of individuals using the Permanent Income Hypothesis and key structural components of the Czech pension system, including the voluntary funded pension scheme.

We used current data regarding the Czech Republic to parameterize and calibrate key parameter values of the model, such as retirement age, life expectancy, or income taxes, to analyze various scenarios precisely. To ensure the validity of both the model and the results, we compared specific emergent outcomes of the model to patterns observed in reality. These outcomes included a realistic wealth distribution among society, a Gini index closely mirroring the latest Gini index reported for the Czech Republic, and a realistic Lorenz curve.

Our main findings indicate that nudges exert only a marginal influence on the sustainability of the current Czech pension system. The main reason appears to be that the majority of individuals invest minimal amounts, approximately 1.86% of the average wage, into pension funds with low rates of return. Contributions to supplementary pension schemes are generally insufficient to substantially supplement participants' state pensions. This finding is consistent with other literature sources such as OECD (2022). While the current pension reform encourages higher individual contributions and represents a promising advancement, our findings indicate that it will remain a significant subject of consideration in the future. The government should also incentivize participants to transition towards funds without a capital guarantee or promote access to a suitable default investment strategy. As participants switch to higher-performing funds and increase their contribution levels, nudges become a viable and potent tool for enhancing the sustainability of the Czech pension system.

To assess the robustness of our findings, we conducted a thorough sensitivity analysis to examine the degree of sensitivity of the model outcomes to variations in input values. The results of the sensitivity analysis show that our model is not significantly sensitive to most parameter values. However, it is specifically more sensitive to changes in life expectancy and retirement age. This is not surprising, as both are key parameters in our model. We observed that the sensitivity is reduced when considering retirement age and life expectancy simultaneously.

As our final model is already relatively complex, future research could focus on refining some of our underlying assumptions instead of further expanding the model. For example, a more detailed representation of the labor market could be included. While this thesis primarily focuses on the pension system of the Czech Republic, future research could slightly modify the model to suit the pension systems of other countries and examine the impact of nudges. This would also provide another validation of the model. Finally, while we have focused on the benefits of nudges and how effectively they improve the sustainability of the Czech pension system, it is imperative to consider the potential costs associated with their implementation. Therefore, future research could explore the cost implications of nudges, including administrative, enforcement, and regulatory costs.

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