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Pension Reforms and Adverse Demographics: The Case of the Czech Republic

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Pension Reforms and Adverse Demographics: The Case of the Czech Republic

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Abstract:

Unsustainability of pension systems particularly in developed economies looms large on the horizon due to increasing life expectancy and continuous drop in fertility. In spite of a broad awareness of the issues, there is no consensus on appropriate remedy and little action. In this paper, I present a comprehensive OLG model tailored for simulation of pension reforms and calibrated on real-world data that accounts not only for optimising agents but also for productivity shocks and financial market frictions. The model is used for assessment of alternative pension reforms in the Czech Republic, yet many of the conclusions apply to other countries as well. The estimates show that retirement age will need to increase constantly in the next decades in order to maintain the current levels of replacement rates in the existing PAY-GO scheme and that this result is virtually independent of the level of economic growth. On the other hand, a transition towards a fully funded scheme would be extremely costly and while it would improve system's resistance to demographic changes, it would also substantially redistribute wealth in the society and expose pensions to financial markets risks. The best option overall may then be a well designed multipillar pension scheme, which can provide an optimal balance of performance indicators without leading to excessive costs of transition.

Keywords: pension, OLG, simulation, ageing

JEL: H55, H68, I38, J32

1 Introduction

Sustainability of pension systems has been a particularly discussed topic among academics and policymakers in the recent decades and even more so after the Financial crisis of 2007–2008, which has put public finances under unprecedented pressure. Indeed, the continuous increase of average life expectancy combined with decreasing fertility has led to changes in population structure in economies at all stages of economic development, many of which are now in a dire need of pension system reforms in order to decrease their forecasted budget deficits in the years to come.

While there is a broad consensus that long-term fiscal sustainability of a status quo in countries like Greece or Japan is impossible (see e.g. [OECD 2015a](#) or [Finke and Sabatini 2016](#)), it is far from being clear what is the optimal solution for each country. Several authors argue that substituting the existing state-run PAY-GO schemes with private funded systems – where people contribute towards their own retirement rather than finance pensions for others – could raise savings and eliminate factor market distortions, increasing long-term growth and welfare levels (see e.g. [Kotlikoff et al. 1999](#) or [Homburg 1997](#)).

However, such structural changes are extremely costly as they require someone, either the current or future generations, to essentially double their contributions, the proposed schemes are often highly reliant on financial markets performance, and there may be other potential downsides to the financing structure (see e.g. [Barr 2002](#) or [Brooks 2000](#)). In particular, each generation in the last hundred years experienced momentous stock market falls and periods of sluggish economic growth and low asset returns, suggesting that conclusions based on ever-growing markets could be far from reality and need to be reconsidered.

Focusing on the Czech Republic, an exemplary country with ageing population and most pensioners wholly dependent on contemporaneous contributions from younger generations, this work provides an insight into performance of various pension systems in real-world circumstances using large-scale simulations of an overlapping generations (OLG) model. Building on the seminal work of [Auerbach and Kotlikoff \(1987\)](#) and the latest OLG models used e.g. in [Zodrow et al. \(2013\)](#), this study extends the pension system modelling framework presented in the prior literature by focusing on differences in characteristics of pension schemes, depicting in detail the way pensions are calculated rather than assuming a stylised, generally PAY-GO pension system used e.g. in [Börsch-Supan et al. \(2006\)](#). The model is then used for analysis of pension reform towards either a fully funded or multipillar system with real-world counterparts in Chile and Sweden, retrospectively. Additionally, parametric changes to the current PAY-GO system are also considered. And while the model is calibrated to the situation in the Czech Republic, most of the findings can be generalised to other countries with ageing population and generally unfunded pension schemes.

The principal aim of this work is to determine whether there is a well-rounded optimal pension scheme that would provide future Czech pensioners with decent income in retirement without putting an excessive burden on the younger generations through accumulation of external debt or a raise of social security contributions. The simulation results do not lead to a definitive conclusion as there is some form of a trade-off in each system and none of the systems is optimal in all dimensions. Specifically, funded schemes provide better protection against adverse demographic changes but a single stock market crash shortly before retirement can lead to extreme differences in pension benefits of pensioners retiring in two subsequent years – or enormous burden on the government financing if there are safeguarding measures in place. Additionally, while economic downturn and related

decrease in pension system revenues have an immediately visible impact on the PAY-GO scheme budget, analogous, and potentially more severe, negative effect can be seen in funded systems as well, where particularly younger generations can be harshly hit by lack of compound interest being reflected in their pensions.

Given these findings and the current specifications of the pension system in the Czech Republic – particularly level of redistribution – a transition to a partially funded multipillar scheme promoted by the World Bank and implemented e.g. in Sweden, seems to be the most beneficial system. It does not show the best performance in all the assumed scenarios when compared to the other systems, but it is highly consistent and it is never the worst system. And because its outcomes and cost of introduction depend on the particular specification and distribution of funds between the pillars, it can be tailored in each country to meet the particular exact requirements.

2 Pension Systems and Ageing Populations

As the baby-boom generation slowly reaches retirement age, there has been a clear shift in demographic trends resulting in reduction of the working-age population share. In the Czech Republic, the old-age dependency ratio – the number of working-age to retired people – is expected to fall from 3.6:1 to 1.9:1 in just forty years if the minimum retirement age remains unchanged ([United Nations 2015](#)) with other countries following a similar trend. The demographic changes are expected to decrease economic growth ([Bloom et al. 2010](#)) and pose a particular threat to pension systems reliant heavily on intergenerational solidarity. [Blake and Mayhew \(2006\)](#) point out that the forecasted burden on workers to provide funding for their parents and grandparents will be in a bright contrast with surplus pension system balances of the past decades stemming from exploitation of demographic dividend – a combination of population ageing and declining fertility that lasts until the smaller newborn generations enter the labour market and the baby boom generations retire. Indeed, the very same changes that initially promoted the extensive economic growth in the second half of the 20th century now take its toll, requiring governments to react in order for pension systems to remain sustainable.

The way that governments should react remains unclear, partially due to inherent differences in population structures, economies, preferences regarding burden sharing, and type of existing pension scheme. On one side, unfunded PAY-GO schemes use tax revenues from workers to pay pension transfers for older generations within the same period, with only surplus funds set aside for the future. When outflow of funds exceeds revenues, taxes or retirement benefits (or both) can be adjusted to keep pension budget constant; however, both parameters are rigid in reality, heavily influenced by the public opinion and can be shifted only within limits. PAY-GO systems are also extremely vulnerable to adverse demographical changes and economic downturn due to reliance on intragenerational solidarity and little contingency funding, which leads to higher contributions required per head and lower overall tax revenues, respectively. At the same time, PAY-GO systems are generally immune to volatility of financial markets returns.

On the other side, funded schemes are arrangements where workers' mandatory regular contributions are saved on individual accounts at pension funds or used for purchase of non-financial assets, and subsequently serve as basis for pension transfers to the same people upon reaching retirement age. The benefits and downsides are opposite to the PAY-GO schemes: funded schemes are highly dependent on asset prices but they are considerably more resistant to demographical, political or

legislative changes, in a sense that the eventual returns in principle only return on the total savings accumulated at the retirement age, not on indexing approved by the government. Many (partially) funded pension systems such as those in the UK or US involve employers to a certain degree, often as contributors or fund holders.

An important difference between PAYG and funded pension systems is in contribution rate. In a PAYG system, social security contributions are subject to optimisation in a pension-indebtedness space that should allow government to provide stable pension transfers at a reasonable level in comparison to previous income (i.e. to keep constant replacement rates) without causing extensive explicit or implicit indebtedness. In particular, high-income classes are expected to contribute more in relative terms or, at least, in absolute terms compared with low-income classes in order to maximize social welfare, yet the differences in contributions may not be later transformed in variance of pensions. This arrangement is referred to as a defined-benefit scheme, where pension transfers are determined as a function of worker's history of pensionable earnings. Actual implementation varies, but the formula is often based on the person's final wage and length of service, or on salaries over given period of time.

Funded pension systems, on the other hand, are mostly defined-contribution schemes where a flat contribution rate is set for everyone regardless of their income and benefits are determined by the value of accumulated assets. Upon retirement, people may be allowed to purchase an annuity and thus imitate defined-benefit pensions, take benefits as a sequence of withdrawals, or as a lump sum. Such set-up leads to greater differences in retirement benefits as it is based on actuarially fair principle. On the other hand, while occasional inability to contribute into the social system has a little effect on pension transfers in a PAY-GO scheme, it has severe impacts in funded settings, particularly if people cannot contribute in early life.

An obvious solution to the problem of budget deficits is an increase of the minimum retirement age so that the old-age dependency ratio remains constant, as suggested e.g. by Nicholas Barr (Barr 2002; 2006; Barr and Diamond 2009). This may be, however, impossible for practical reasons as people live longer but their vitality does not change accordingly, with the elderly unable to perform particularly manual tasks. Alternatively, policymakers may want to adopt a funded system, where workers save for their own retirement and their eventual pension income is thus independent of the demographical structure, assuming that asset returns are unaffected.¹ Yet this is only at the cost of increased vulnerability to other risks and extreme burden on workers who must contribute to pension transfers of current pensioners and save for their own future pension at the same time – or at the cost of future generations through increased indebtedness.

The limited overlap between main risks of the two opposing pension schemes and lower transition costs suggest that a mixed multipillar system, with both funded and unfunded components, is a preferred solution. Indeed, such systems have been promoted by the World Bank (Holzmann et al. 2005) as well as other authors and institutions (see e.g. Sinn 2000, Barr 2006, or OECD 2015a). Multipillar systems typically contain a safety net for the poorest or those who participate only marginally in the formal economy (a non-contributory zero pillar) financed from general taxes; a PAY-GO defined-benefit scheme with mandatory contributions linked to prior earnings (first pillar); a defined-contribution funded scheme (second pillar) administered by the state or private pension funds; and a system of voluntary contributions into usually private pension funds (third pillar). The

¹Barr (2002) discusses that a substantial change in the demographic structure will lead to excessive supply of durable assets as new pensioners exchange their savings for lifetime annuities, which may negatively affect overall asset returns.

third pillar is implicitly involved in all types of pension systems as it consists of anyone willing to put money aside for their retirement, yet they can largely differ in terms of state support.

This study aims to fill the gap in analytical evidence, complementing the solid theoretical foundations of applicability and outcomes of the three pension schemes in the literature. This is done by comparing potential pension system reforms in the population and socio-economic settings of the Czech Republic, analysing robustness to real-world imperfections and sensitivity to parametric changes by looking at sustainability of public finances and income distribution. The work is in contrast with the often very specific orientation of other studies, either in terms of assumed reforms, selection of outcome variables, assumption of no market imperfections, or simply their empirical context and lack of suitable counterfactuals, which is circumvented through the simulation methodology. In this regard it is perhaps closest to the works of [Hviding and Mérette \(1998\)](#) and [Fougère and Mérette \(1999\)](#), yet it offers substantially broader range of assumed changes, factors and agents in the economy, and updated calibration.

2.1 Existing research

This study is broadly in line with the recent literature on country-specific comparative assessment of pension systems. For instance, [Olivera \(2016\)](#) evaluates the potential effects of a multi-pillar pension system on pension inequality, actuarial liability, and welfare in Peru using simulations of future distributions of pensions with social security administrative records. Looking specifically at the recent pension reform in Sweden, [Laun and Wallenius \(2015\)](#) develop a life cycle labour supply model to quantify the predicted labour supply implications of the reform, whereas [Blank et al. \(2016\)](#) compare the Austrian and German pension systems, suggesting reasons why Austrian pensioners are comparatively better-off despite similarities between the countries and social security frameworks.

A major point of interest for both predictive and retrospective studies was the 2011 pension reform in Spain. [De La Fuente and Domenech \(2013\)](#) analyse its financial impact using a simple comparative framework and series of assumptions on the future development of employment, productivity, and demographics. [Patxot et al. \(2017\)](#) then utilise a generalised microsimulation model to assess the reform's effects on adequacy of pension benefits and income redistribution, while [Vidal-Melia \(2014\)](#) compares the approved structural changes and their impact on actuarial fairness, transparency, and solvency using the Swedish pension system as a benchmark.

While some of these studies aim to estimate the future costs and benefits, they are all based on a series of scenarios explicitly determining some of the main factors in the economy. Opposite to this approach, computable general equilibrium (CGE) models assume an economy to fit a predefined, appropriately calibrated theoretical framework and determine the future outcomes through simulation of interactions in the economy. One of the first studies using computer simulations in the area of pension systems were [Arrau \(1993\)](#), [Cifuentes and Valdés-Prieto \(1996\)](#), [Cifuentes and Valdes-Prieto \(1997\)](#), or [Kotlikoff et al. \(1999\)](#), who analysed alternative ways to privatize the U.S. Social Security System using a modified overlapping generations (OLG) model. They concluded that a transition towards funded system may result in long-run benefits and raise living standards but only at the cost of current pensioners being worse off, unless they are offered a chance to remain in the original unfunded scheme.

The OLG model used in this study is tailored for a detailed analysis of pension systems as it explicitly differentiates economic agents by their age and allows examination of their behaviour at

different stages in life. It was developed by [Samuelson \(1958\)](#) and [Diamond \(1965\)](#) and recently used in a similar context by e.g. [Annicchiarico and Giammarioli \(2004\)](#) or [Michel et al. \(2006\)](#), who use a simple two-period OLG model to investigate fiscal rules required to maintain sustainability of public finances in economies with a PAY-GO pension scheme, whereas e.g. [Nishiyama and Smetters \(2007\)](#) analyse a partial privatisation of an unfunded scheme in a model with elastic labour supply facing idiosyncratic earnings shocks and longevity uncertainty. The problem of adverse population changes is then addressed e.g. in [Oksanen \(2009\)](#), who develops a computable OLG model with uniform labour supply and exogenously determined interest rate, wage, and labour productivity.

This work is essentially combines some of these studies in a complex theoretical OLG framework with multiple pension schemes explicitly modelled to correspond to existing pension systems in the Czech Republic, Sweden, and Chile. These are described in the next section.

2.2 Pension System in the Czech Republic

The Czech pension system is a classic example of a PAY-GO scheme with no mandatory savings into pension funds, yet with additional state support for individuals who make voluntary savings.² Retirement ages differ for men and women, depend on the number of children raised by women, and are currently set at 63 years of age for men and 62 years for women. According to the existing legislation, retirement age will increase by two months per additional year of birth and the retirement ages for men and women will converge, resulting in the projected retirement age for both men and women born in 1965 of 65 years and for those born in 1971 of 66 years. There is currently no upper bound set on the increase, although the current government discusses possibility to cap retirement age at 65 years from 2030 onwards. The existing social security taxes financing retirement benefits are set at 6.5% paid by employees and 21.5% paid by the employer.

Pension transfers consist of a flat minimum benefit (CZK 2,440 in 2016) calculated as 9% of the average wage (CZK 27,006 in 2016) and a variable benefit determined as follows. The number of years that an individual contributed to the social security system is multiplied by 1.5% and determine the replacement rate factor. This is then multiplied by an income base calculated from the average reported income over the years the individual paid social contributions for (where income in previous years is multiplied by a predefined coefficient to reflect changes in prices), proportionally reduced for higher income:

$$B_i = \frac{1}{T} \sum_{t=1}^T \delta_t \times \max(0.25 \times a_t, i_{i,t}) \quad (1)$$

$$i_{i,t} = \begin{cases} I_{i,t} & \text{if } I_{i,t} \leq c^1 \\ I_{i,t} \times 0.26 & \text{if } (I_{i,t} > c^1 \wedge I_{i,t} \leq c^2) \\ 0 & \text{if } I_{i,t} > c^2 \end{cases} \quad (2)$$

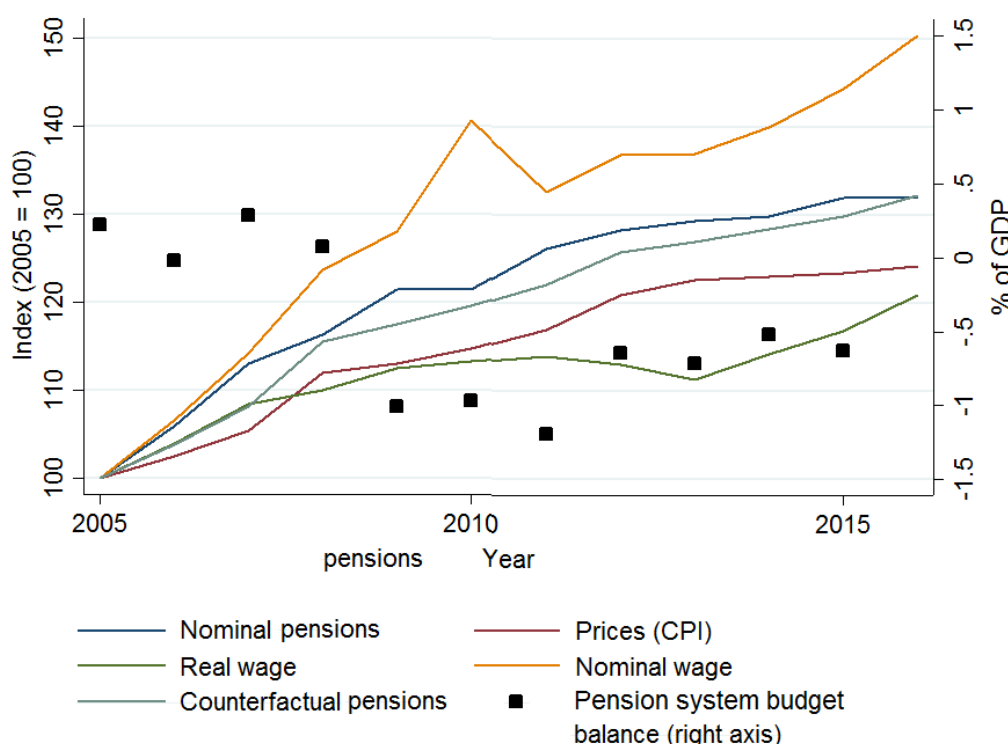
where B_i is the income base of individual i who contributed to the social security system for T years, a_t is the average wage in year t , $I_{i,t}$ is the total reported income, δ_t is time-varying multiplier reflecting changes in price levels and real wages, and c^1 and c^2 are regularly updated cut-offs currently set at

²The following information and statistics were obtained from the Ministry of Labour and Social Affairs of the Czech Republic (www.mpsv.cz) and Czech Social Security Administration (www.cssz.cz) as of March 2017.

CZK 12,423 and CZK 112,928, respectively. For comparison, average wage in the Czech Republic in 2016 was CZK 27,006.

According to the formula, there is an implicit upper bound on pension benefits, currently at approximately 85.7% of the average wage for anyone who retired after forty years of contributing into the system. Hence, the pension system is highly redistributive by nature, with the replacement rates for the lowest income classes near 100%, the average reported ratios at 41.6% and 54.3% of the pre-retirement gross and net wage, respectively, and less than 25% for individuals with income at or above quadruple of the average income. The average replacement rates reported by the Czech Social Security Administration are slightly different than those calculated by OECD,³ which reports gross replacement rates for both men and women at 49% and net replacement rates at 64%.

Figure 1: Pensions and main macroeconomic indicators in the Czech Republic.



Source: The Czech Statistical Office, Ministry of Finance of the Czech Republic, and the Czech Social Security Administration.

Following retirement, benefits may be increased as a result of parliament action but otherwise remain unchanged in nominal terms by default. The minimum approved increase in nominal pensions is supposed to be at the level of inflation plus one third of increase in real wages. However, this is often not the case; Figure 1 plots the changes in existing nominal retirement benefits, real wages, consumer price index, nominal wages, and a counterfactual scenario in which nominal pensions increase by the minimum suggested amount. We can see that while pension indexing surpassed the benchmark in the 2005-2008 period, it was on a similar rate in the 2009-2012 period and lower than that since then. As a result, the replacement rates further decrease following retirement, compared to what individuals wages would be if they increased according to the real wage changes.

³OECD, Gross pension replacement rates as % of pre-retirement earnings, 2014. As of 4 April 2017: data.oecd.org/pension/gross-pension-replacement-rates.htm.

Notice also that the pension system budget has been in deficit since the Financial crisis and has not substantially improved despite the economic growth and virtually non-existent increase of nominal pensions in the recent years. And given the expected changes in population structure, it is improbable that the situation will improve unless real pensions remain decreasing compared to real wages or social security contributions increase. We will also see later that even the projected increase in retirement age is likely to be only a partial remedy to the problems, exposing future pensioners to constantly increasing gap between pension benefits and pre-retirement earnings.

A detailed description of the Czech Pension system, its estimated development in time, and effect of parametric and structural changes is presented in [Bezděk \(2000\)](#), [Schneider \(2011\)](#), [Cipra \(2012\)](#), or [Marek et al. \(2008\)](#), who uses an OLG model to derive his conclusions. Introduction of a balancing mechanism for the existing PAY-GO system and a funded pillar with particular emphasis on alterations for individuals with children is then briefly analysed by [Hyzl et al. \(2005\)](#).

2.3 The World Bank Pension Framework

The World Bank three pillar system is presented in [Holzmann et al. \(2005\)](#), who build upon the principles established in [Palacios \(1996\)](#) and focus on refining system design so that it adapts the idea of three pillars to varying socio-economic conditions to manage risks in old age. Since the paper describes a general proof of concept, the practical example of such a system used in this study is the frequently discussed Swedish pension system (see e.g. [Brown 2008](#); [Laun and Wallenius 2015](#); or [Kruse 2010](#)). As [Barr \(2013\)](#) concludes, the main strengths of the system are fiscal sustainability built into the strategic design of the system and provision of adequate pensions for most people, i.e. two essential properties of a potential replacement for the existing Czech system.

The pension system is primarily an unfunded scheme with workers contributing 7% of their earnings and the employer contributing 10.21%. The total of 17.21% is 18.5% of the pension base, which excludes the worker's 7% contribution (that is $17.21/0.93=18.5$). Of the total contributions, 16% finances the PAY-GO component (a defined-contribution plan – the income-based pension) and the remaining 2.5% finances a premium pension component. Workers pay contributions up to a ceiling of 8.07 of the price-related base amount ('Prisbasbelopp'), set at SEK 44,500 per year in 2015, i.e. approx. 11.59% of the average annual wage estimated at SEK 384,000 per year ([Swedish Pensions Agency 2015](#)).

The income-based pension (first pillar) is a direct equivalent of the Czech PAY-GO scheme in a sense that it is unfunded, i.e. paid from contributions collected within the same period, yet the calculation of benefits is far less redistributive. Throughout one's life, all contributions, despite being immediately used as transfers for the elderly, are recorded in a personal balance statement and the accumulated virtual funds are then divided by a predetermined annuity divisor upon retirement to determine the regular payments. However, unlike in a standard funded system, the annuity divisor reflects both the remaining life expectancy and an advance interest of 1.6%, which effectively decreases the average life expectancy, leading to higher annuity than in a traditional system. The resulting annuity is recalculated yearly and under standard circumstances increases at the rate of change in nominal wages minus the 1.6%. Due to the resulting high variance of retirement earnings given the annuity calculation, the model assumes that pensions in the first pillar are calculated using the Czech methodology.

The premium pension, the second, funded pillar, is calculated from accumulated savings using a

similar formula (see next section for details). Contributions towards the premium pension are invested in one of more than 800 domestic and foreign pension funds and earn interest at the standard market rate. Finally, in addition to the income-based and premium pension, the guaranteed pension, a means-tested benefit, provides a minimum pension for persons older than 65 with low or no income and at least 40 years of residency in Sweden. It is financed by the government's budget.

An important component of the system is an automatic balancing mechanism, which affects indexing of income-based pension contributions. Under optimal circumstances, rate of indexing exactly reflects changes in nominal wages and a part of contributions is set aside, constituting a buffer fund used during economic downturn. If the pension system liability overweights assets of the system, indexing is lowered proportionally so that the system returns to balance. The mechanism is formally defined in the next section.

2.4 Funded pension schemes

Funded pension schemes are direct counterpoints of the original PAY-GO systems, requiring very little intergenerational solidarity as everyone saves for their own retirement. They are mostly integrated in various multipillar schemes, constituting a minority part in the overall system, but some countries, particularly in Latin America, have implemented nearly fully funded systems in a set of major structural reforms in the past. The pioneering country in this regard was Chile, which transformed its original PAY-GO system into a fully funded one in 1981 and was later followed by Bolivia, Columbia, Costa Rica, Mexico, Panama, Peru, or Uruguay. The Chilean pension system is also used as a specific example used in this study.

In Chile, every affiliate working with labour contract is obliged to contribute to the system since their very first job, creating a personal account at a privately owned and managed pension fund that invests the resources into financial assets of contributor's choice.⁴ The monthly contributions are set at 10% of pre-tax earnings up to a given upper bound on contributions. Besides the main second tier, there is also a form of safety net (a zero tier) financed from the general taxes aiming to alleviate poverty for the poorest and those that did not manage to put aside satisfactory amount of funds for retirement.

Pensioners in Chile can choose from four options of account balance withdrawal: lifetime annuity, programmed withdrawal, temporary income with deferred lifetime annuity, and immediate annuity plus programmed withdrawals. The principle – receipt of pre-calculated monthly transfers adjusted for inflation – is equal in all of them, the difference is in their amount, legal claim on the remaining funds, and risk sharing. Only the standard annuity equivalent to pension benefit calculation in Swedish premium pension is modelled.

3 The Model

The model developed for this study is a dynamic OLG model with exogenous labour supply and heterogeneous agents who leave bequests to their children. The model framework builds on the seminal work of [Auerbach and Kotlikoff \(1987\)](#) and is inspired by [Börsch-Supan et al. \(2006\)](#), [Heer and Maussner \(2009\)](#), and [Zodrow et al. \(2013\)](#). The approach to its estimation is outlined in

⁴Chilean Pension Supervisor (Superintendencia de Pensiones, www.safp.cl).

the Appendix. The terms economic agents (inhabitants) and households are used interchangeably throughout the model description.

The setup is as follows: at the beginning of every year, the remainder of the oldest cohort dies and a new generation is born. Size of the newborn generation is normalised so that the total size of all generations is one, but evolves according to the real-world demographic projections in future periods. Households live for maximum of 60 periods (years) and by default spend first $T = 43$ years working and the last $T^R = 17$ years retired. This corresponds to the average life expectancy of approximately 78 years in the Czech Republic⁵ and the current retirement age of 63 years for men. In line with the existing literature, the first 18 years of actual human life are not modelled. Households face positive probability of death each year, given by exogenous unconditional survival function calibrated using the real-world mortality rate projections. Upon death, all household's assets are immediately transferred to its immediate descendants.

Households are assumed to differ in their skills – and therefore productivity and earnings – both within and across cohorts. To capture the intragenerational wealth inequality, each generation is divided into $Z = 12$ different types of individuals, classified by lifetime income. Following [Altig et al. \(2001\)](#), $z = 1$ and $z = 12$ represent the bottom and top 2% of the population cohort a in terms of lifetime income, respectively, $z = 2$ represents the next bottom 8% (and analogously for $z = 11$ for the high income households), with the remaining 8 income classes representing the other eight deciles. Throughout their lives, households may move between income classes as a result of idiosyncratic productivity shocks following AR(1) process given by

$$z_t = \rho z_{t-1} + \epsilon_t, \quad (3)$$

where $\epsilon_t \sim N(0, \sigma_\epsilon)$; the next-period categorisation thus depends on its past realizations. This essentially represents the process of promotion or job losses. Following [Huggett \(1996\)](#), the initial distribution of households follows a log-normal distribution and is calibrated so that the wealth Gini coefficient in the simulated economy corresponds to the actual value in the Czech Republic.

In addition, household's income evolves over time representing human capital accumulation and has the characteristic humped-back profile with wages peaking at 31 years of household's age (approx. 50 years of actual age). The overall labour-endowment process is given by $e(z, s) = e^{z_s + \bar{y}_s}$, where \bar{y}_s is the mean log-normal income of households of age s . The total annual income of household aged s in income class z in year t is thus

$$I_{s,z,t} = (1 - \tau_{z,t}) e(z, s) l w_t, \quad (4)$$

where $\tau_{z,t}$ and w_t are the effective tax rate and equilibrium wage in the economy, respectively, and l denotes the exogenous labour supply – the average share of time spent working per workday. The effective tax rate is calculated using marginal tax rates for different income levels $\tau_{z,t}^i$ and further contains social security contribution rate τ_t^r , assumed to be flat across all income groups.

Agents have children at the age of $T^P = 30$ and bequests, given at the time of death, are assumed to be given out of 'joy of giving' ([Kopczuk and Lupton 2007](#)), providing agents with utility directly from the making of bequests.

⁵The World Bank, www.data.worldbank.org.

3.1 Household and firm optimisation

Agents are assumed to be rational and to optimise over their life cycle using a standard utility function common to all households:

$$U(s, z) = \frac{1}{1 - 1/\sigma_u} \left[\sum_{i=s}^{T+T^R} \pi_{s,i,t} \frac{c(i, z)^{(1-1/\sigma_u)}}{(1 + \rho^{i-s})} + \alpha_z \frac{b(z)}{(1 + \rho^{T+T^R-s})} \right], \quad (5)$$

where $b(z)$ denotes bequest planned to be made at the end of life by a representative household in income class z , α_z is the utility function weight placed on bequests as a result of the joy of giving motive, $c(i, z)$ is consumption at age i , and $\pi_{s,i,t}$ represents the probability of surviving additional year at age s , which effectively acts as additional discounting factor in addition to the pure time preference discounting ρ . The survival probability rate depends both on the probability of death at age s , $q_{s,t}$, and the probability of surviving up to that age:

$$\pi_{s,i,t} = \prod_{j=s}^{i+1} (1 - q_{j,t}) \quad (6)$$

Agents maximise lifetime utility subject to a dynamic lifetime budget constraint consisting of labour income (if working) $I_{s,z,t}$, pension transfers (if retired) $p_{s,z,t}$, interest payments from asset holdings, and bequests from their parents. Assets can be either standard taxable assets $A_{s,z}^{tax}$ with yield equivalent to the equilibrium interest rate r or tax-preferred retirement savings assets $A_{s,z}^{ret}$ that accumulate at interest rate r_r , which depends on the particular simulation scenario. Voluntary savings for retirement are not modelled since they work the same way in all pension schemes and implementations and may therefore be disregarded without a change in outcomes of the analysis. Tax-preferred retirement savings $A_{s,z}^{ret}$ thus exist only in the multipillar and enter the budget constraint only once as all funded pensions are assumed to be given out through annuity (i.e. retirement benefits $p_{s,z,t}$) upon retirement. The budget constraint is therefore given by

$$A_{s+1,z,t+1}^{tax} = A_{s,z,t}^{tax} (1 + r_{t+1}) + b(s, z) + I_{s,z,t} + p_{s,z,t} - c(i, z) - A_{s,z,t}^{ret} \quad (7)$$

The production sector consists of a representative firm producing output Y_t using effective labour N_t and capital K_t as inputs in a standard Cobb-Douglas production function given by

$$Y_t = F(\Omega, K_t, N_t) = \Omega K_t^\alpha N_t^{1-\alpha}, \quad (8)$$

where Ω denotes a scaling constant representing technological advancement and α is the output share of capital in the production.

We can derive the equilibrium wage w_t and interest rate r_t using the firm's maximisation problem as prices of capital and labour equal to their marginal product, respectively. For simplicity, the model does not assume firms to pay any taxes on profit but, following discussion from the previous section, they are required to contribute to the social security system. Specifically, the cost of each unit of effective labour is $w \times (1 + \tau^N)$, where τ^N is the social security contribution paid by firm. That is, assuming a depreciation rate δ :

$$w_t = \frac{(1 - \alpha)}{1 + \tau^N} \Omega K_t^\alpha N_t^{-\alpha} \quad (9)$$

$$r_t = \alpha \Omega K_t^{\alpha-1} N_t^{1-\alpha} - \delta \quad (10)$$

3.2 Pension System

The initial pension system specification exactly follows the actual implementation in the Czech Republic. Specifically, pension transfers are determined by income history of new pensioners (adjusted for changes in real wage) and exogenously given replacement rates $rr_{z,t}$. As discussed in the previous section, the replacement rates are in form of marginal rates and decrease with income. An effective replacement rate, $rr_{z,t}^e$ can be calculated for each level of income using the income thresholds translated into the model as percentage of the average wage and the PAY-GO pension transfers are then determined as

$$p_{s,z,t}^{PG} = rr_{z,t}^e \sum_{i=1}^T \frac{I_{i,z,t-T+i}}{T} \quad (11)$$

All agents aged of age T are assumed to retire at the end of the period, with pension benefits determined at that time. Pensions may or may not be indexed afterwards, depending on the particular scenario. Depending on the mechanism of pension budget balancing (if any), pensions may be proportionally lowered across all income classes or the contribution rate τ_t^r may be increased in case the outflow of funds would exceed social security tax revenues. The pension system is modelled to be in deficit of -0.5% GDP as in reality using the pension budget identity:

$$\sum_{s=1}^T \sum_{z \in Z} \tau_t^r I_{s,z,t} \mu_{s,z,t} \leq \sum_{s=T}^{T+T^R} \sum_{z \in Z} p_{s,z,t}^{PG} \mu_{s,z,t} \kappa, \quad (12)$$

where $\mu_{s,z,t}$ is the measure of generation s in income class z in year t and κ is the scaling parameter reflecting the differences between the old-age dependency ratio in the model and in reality caused by the implicit assumption of every household of working age being employed. The scaling parameter is calculated endogenously within the model with resulting value of approx. 1.9. Note that the model assumes zero inflation and pensions are therefore implicitly adjusted for inflation with any further indexation reflecting changes in real wage only.

The premium pension and pensions in the fully funded scheme are determined through contributions to a designated pension funds made by individuals throughout their lives. When agents retire, the funds are transformed into annuity paid regularly for the rest of their lives. Formally, annuities are determined by dividing funds accumulated at the personal pension account by an appropriate annuity divisor D_x . Calculation of annuity divisors differs for the income-based pension and for premium pension, but it is the same for premium pension and the fully funded scheme. Both formulas then follow the Swedish pension system methodology ([Swedish Pensions Agency 2015](#)), where the income-based pension is given by:

$$p_{s,z,t}^{FF} = \frac{1}{D_i} \left[\sum_{s=1}^T (1 + r_t^{T-s}) s_{s,z,t} \right] \quad (13)$$

$$D_i = \sum_{k=T+1}^{T+T^R} (L_k + (L_{k+1} - L_k)) (1.016)^{-(k-i)} \quad (14)$$

Where D_i is the annuity divisor for age group i and L_i is the number of survivors in age group i per 100,000 born. The premium pension is given by:

$$p_{s,z,t}^{FF} = \frac{1}{D_x} \left[\sum_{s=1}^T (1 + r_t^{T-s}) (1 - c^A) s_{s,z,t} \right] \times (1 - c^I) \quad (15)$$

$$D_x = \int_0^\infty e^{-\delta t} \frac{l(x+t)}{l(x)} dt \quad (16)$$

$$\delta = \ln(1 + r) \quad (17)$$

$$l(x) = e^{-\int_0^x q(t) dt} \quad (18)$$

where the first expression in brackets represents the total accumulated wealth in pension funds, c^A represents administrative fees on assets, c^I represents reduction in pension transfers due to imperfect annuity markets, and $q(t)$ is probability of death within one year aged t . Hence, the model does not assume market imperfections to affect the income-based pension. The formulas are essentially equivalent when a single life is insured.

In addition, the fully funded scheme includes a safety net financed by social security contributions p_t that tops up pension transfers for low income classes up to a certain amount, set to the minimum pension obtained in the baseline PAY-GO system. This is financed through the general taxation and thus appears only as increase in government indebtedness in the revenue side of the model.

The guarantee pension in the multipillar scheme decreases with income-based pension and is calculated as follows:

$$g_{s,z,t} = 2.13 \vartheta_t - p_{s,z,t}^{PG} \quad \text{if } p_{s,z,t}^{PG} \leq 1.26 \vartheta_t \quad (19)$$

$$g_{s,z,t} = 0.87 \vartheta_t - 0.48 (p_{s,z,t}^{PG} - 1.26 \vartheta_t) \quad \text{if } p_{s,z,t}^{PG} > 1.26 \vartheta_t \quad (20)$$

where $g_{s,z,t}$ is the calculated pension amount, ϑ_t is the price-related base amount, and $p_{s,z,t}^{PG}$ represent the PAY-GO and/or income-based pension, respectively.⁶ We can see that the amount received is flat up to a point, then increases with income from the income-based pension, and no guarantee pension is provided for people with income-based pension income above a given threshold. ϑ_t is set at 11.59% of average gross income following the Swedish example.

Finally, the income-based pension is calculated using Equation 11 and the indexing of contributions is defined as

$$\frac{\xi_{s,z,t}^*}{\xi_{s,z,t}} = \psi_t \frac{I_t}{I_{t-1}} \quad (21)$$

⁶That is, both the original PAY-GO and the new source of income (excluding premium pension) are considered in the calculation in case of a structural change to a multipillar scheme.

where $\xi_t = \tau_t^r I_{s,z,t}$ is the original contribution made to the system and $\xi_{s,z,t}^*$ is the indexed contribution, with ψ_t being the balancing ratio defined as a ratio of pension system revenues to expenses.

An adjustment must be introduced in computation of pensions in funded schemes in $t = 1$, scaling down earlier contributions to reflect changes in real wage not captured in the computation. In particular, the economy is assumed to be in a steady state prior to the first modelled period with the only dynamic effect being growth in multifactor productivity Ω , which can thus be used to approximate the change in real wage. Further, the model does not reflect savings made in funded pension schemes in the total accumulated capital for better comparison with the PAY-GO scheme and to mirror the fact that pension funds are generally allowed to invest in any assets worldwide. Hence, output levels in these schemes are likely to be understated.

Pension savings in the model are not assumed to increase capital accumulation in the economy to reflect that the funds may be invested anywhere, i.e. not necessarily in the country of origin. However, this may potentially lead to underestimation of economic growth in funded systems as suggested by e.g. the historical evidence from Chile, which experienced a substantial boost to its economic performance following the pension reform.

3.3 Calibration

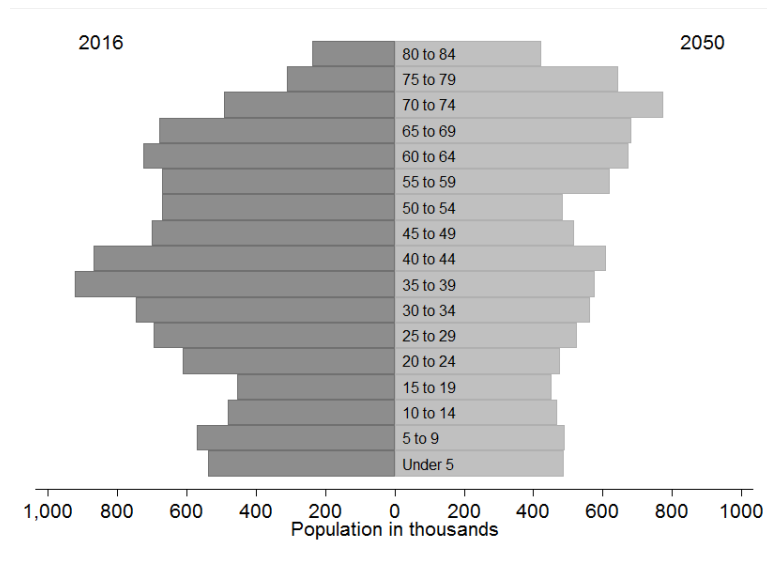
The economy is characterised by labour supply calibrated using data on average annual hours worked from the OECD; productivity distribution calibrated so that the overall distribution of wealth corresponds to the Gini coefficient estimated by the World Bank; intertemporal elasticity of substitution data obtained from [Havranek et al. \(2014\)](#); depreciation and productivity growth rate from the Penn World Tables; income and social security tax rates; and population predictions from the United Nations. For simplicity, the model assumes that the productivity growth rate will remain at the historical 2005-2015 average, although some scenarios assume this to be lower/higher in order to depict the magnitude of induced change in other parameters.

Following [Zodrow et al. \(2013\)](#), the rate of time preference ρ is set equal to 0.011, the variance of earnings for newborn generation is set as $\sigma_{y1} = 0.38$ as in [Huggett \(1996\)](#), and the utility function weight placed on bequests is set so that the bequest/income ratios resemble those identified by [Fullerton and Rogers \(1993\)](#). As in reality, the baseline tax rate is set at 15% of 1.34 times the gross personal income, and income above quadruple of the average wage is taxed by additional 7%. Each individual can deduct CZK 2,070 per month from their taxes (approx. 7.7% of the gross average wage). There is no inheritance tax in the Czech Republic and interest income is taxed as any other source of income at 15%.

Population predictions are based on the total population, mortality, and fertility indicators from [United Nations \(2015\)](#) for years 1996-2050. Following the model specification, I use fertility rates from year $t - 18$ to reflect that $s = 1$ corresponds to the real life age of 19. The initial mortality rates are set according to the UN data for 2016. From the second period onwards, size of the newborn generation evolves according to the ratio of fertility rates compared to the initial period, mortality rates evolve according to the UN data, and the population structure is defined endogenously within the model. The maximum age does not change.

The current and projected population structure is depicted in [Figure 2](#). It highlights three separate trends – decrease in fertility, increase in mortality, and shift in population structure with

Figure 2: Czech population structure in 2016 and 2050 as predicted by [United Nations \(2015\)](#).



large cohorts reaching retirement age in the next decades. In particular, not only is the amount of new pensioners going to remain stable in the upcoming years; a large generation of people now in their forties will reach retirement age in less than thirty years and is unlikely to be replaced by another large cohort of working-age individuals. As a result, the old-age dependency ratio, the number of workers to pensioners, is predicted to decrease from the current 4.04 to just 3.11 in 2050 in the model despite the projected increase in retirement age.⁷

The income and social contribution tax rates are assumed to remain constant regardless of the pension system implemented in order to maintain their comparability. For the multipillar scheme, the distribution of contributions into the income-based and premium pensions follows the Swedish example where 86.5% of all contributions are used to finance the unfunded scheme. For the fully funded pension scheme, the whole amount of contributions from both the employer and the employee are put in the pension funds. The calibration parameters are shown in Table 1.

3.4 Scenarios

In what follows, performance of the existing Czech pension system is compared across multitude of variables, ranging from time and population dimensions to existence of market imperfections and sluggish economic growth. The comparisons are principally aimed at showing the extent of potential changes rather than aiming to pinpoint a particular most probable variant. To this end, each variable of interest is presented in several distinct scenarios that are then combined to create a set of snapshots of the overall system. Only one of the following variables changes in each of the presented scenarios in order to clearly determine sensitivity of the overall model to the studied dimension.

In all scenarios, the existing PAY-GO scheme in its current specification is in place at time $t = 1$ and any structural changes (pension reforms) will only happen in $t = 2$. The system is parametrised using the scaling parameter κ so that its budget balance initially corresponds to the 2015 deficit of

⁷Note that this is still substantially higher than the actual old-age dependency ratio reported by the Czech Social Security Administration of approx. 2.32, which counts only individuals contributing to the social security system as workers, whereas all individuals in a working age are supposed to be employed in the model at the baseline. This discrepancy is adjusted for using the scaling parameter κ .

Table 1: Calibration parameters

Symbol	Description	Source	Value
ρ	Rate of time preference	Zodrow et al. (2013)	0.0110
σ_e	Variance of idiosyncratic shocks	World Bank ^a	0.0129
σ_{y_1}	Variance of earnings for $s = 1$	Huggett (1996)	0.3800
σ_u	Intertemporal elasticity of substitution	Havranek et al. (2014)	0.5000
α_z	Utility function weight placed on bequests	Fullerton and Rogers (1993) ^b	Various
α	Output share of capital in production	Börsch-Supan et al. (2006)	0.35
δ	Depreciation rate	Penn World Tables (v9)	0.0446
τ	Marginal taxation	OECD Tax Database	1.9%-35%
τ_I	Inheritance tax	EY Global Tax Guide	0%
τ_C	Tax on interest income	OECD Tax Database	17.1%
Ω	Baseline productivity growth rate ^c	OECD	1.0208
ϕ	Population scaling parameter	Czech Social security Administration	1.9051

^a Calibrated so that the distribution of wealth, measured by the Gini coefficient, is corresponds to the World Bank data for each country.

^b Calibrated for each income group so that the average bequest-annual income ratios correspond to Fullerton and Rogers (1993).

^c Proxied by GDP per hour worked in constant prices.

the Czech pension system of approximately 0.5% GDP. From $t = 2$ onwards, budget balance depends on the selected scenario.

Pension reforms

Two alternative schemes – the multipillar and fully funded schemes – are assumed as potential substitutes for the existing pension system in order to analyse the main hypothesis of this study: whether any of the three presented systems is strictly better than the other two. The multipillar scheme is represented by the Swedish pension system and the fully funded scheme by the Chilean pension system. In both of these, a second pillar consisting of mandatory contributions into pension funds is established and the importance of the first pillar is proportionally diminished. The old PAY-GO pensions remain to be paid out during the transition period, yet their amount decreases proportionally to the number of years that the new pensioners contributed to the social security system. The old pensions thus decrease to approx. 50% in $t = 24$ after correcting for changes in the real wage. Analogously, pensions from the new system are paid out immediately but are very low at first and increase over time.

Note that because all social security contributions from $t = 2$ onwards go towards the new pension scheme at first and only subsequently are used to cover the former PAY-GO liabilities, any remaining deficit must be covered by the state. Similarly, the guarantee pension and the safety net are financed from the general government budget.

Pension budget

From $t = 2$ onwards the pension budget may remain balanced or not, with pension transfers being financed by increasing indebtedness in case of an unbalanced budget, and by changes in either the social security tax rate or pension transfers in case of a balanced budget. Specifically, if the pension budget is balanced and taxes serve as the balancing mechanism, pension transfers are kept at their initial level indexed (or not) according to one of the indexing scenarios (see below) while taxes change accordingly. Analogously, if pensions adjust, tax rates are kept at their initial level and pensions for

all income groups change to keep the budget balanced. In case of unbalanced budget, both taxes and pensions remain at their initial level, with pensions being indexed each year.

Productivity growth

Continuous economic growth as a result of increasing productivity is one of a few elements that may alleviate the adverse effects of population changes in the long-run without having any clear negative impacts elsewhere. In the baseline scenario, productivity growth is assumed to remain constant over time at the 2005-2015 average level of growth of 2.08%. In two pessimistic scenarios, the growth is assumed to be at 50% and 75% of this rate while in the optimistic scenario at 125% and 150%.

Indexation, changes in retirement age, and asset returns

As discussed earlier, indexation of pensions in the Czech Republic has been all but consistent in the recent years, even though an explicit rule of minimum indexation equal to inflation plus one third of increase in real wages has been introduced recently. In the baseline scenario, all pension benefits are indexed at this rate. In two alternative scenarios, pensions are either not indexed at all or indexed to full extent of changes in real wages in order to reflect the extent of potential adverse effect of changes in the population structure.

Following the proposed changes to the current legislation, the baseline scenario assumes that the retirement age increases to 64 years in 2023 and to 65 years in 2030. In an alternative scenario, the legislation remains unchanged and the retirement age increases further to 66 in 2036 and 67 in 2042.

Finally, the return on pension savings is set at 3.5% at the baseline, a conservative assumption based on [OECD \(2015b\)](#), and at 1% and 6% in the pessimistic and optimistic scenarios, respectively. Indeed, the historical performance of pension funds analysed in the OECD report suggests that even the 6% returns may underestimate the actual performance.

Market imperfections

In the baseline scenario, annuities are actuarially fair (i.e. c^A and c^I in Equation (18) are both set to zero) and pension transfers continuously increase as the leftover funds remain invested through the pension fund. However, in alternative scenarios these assumptions are challenged according to findings presented earlier. In particular, any adverse movements on financial markets decreasing asset prices ultimately lower pension transfers for all affected individuals forever, often creating substantial gaps in retirement income between any two otherwise comparable individuals retiring just a few weeks from each other.⁸

Three distinct types of market imperfections are modelled: crash on financial markets, administrative costs of running pension funds, and actuarially unfair annuity markets. These may only be effective in scenarios with structural changes to the pension system.

In the baseline scenario, there is no crash on financial markets or other market imperfections. In an alternative scenario, a 1.5% annual administrative fee on assets similar to those in the UK or Mexico ([OECD 2013](#)) and 10% reduction in pension benefits due to imperfect annuity markets ([Murthi et al. 2001](#)) lower the eventual pension benefits. In a second alternative scenario, these costs

⁸In Chile, the average individual account balances across all pension funds differing by their riskiness has dropped by more than 35% following the crash on financial markets in 2008, effectively lowering the average pension transfers of individuals retiring in 2009 by a third compared to those who retired in 2007 (Superintendencia de Pensiones, the Chilean Pension Supervisor (www.safp.cl)).

are further complemented by a drop in the market value of pension funds' assets by 40% as a result of a massive crash in $t = 10$, which broadly reflects the average drop in individual account balances across all pension funds in Chile in 2008.

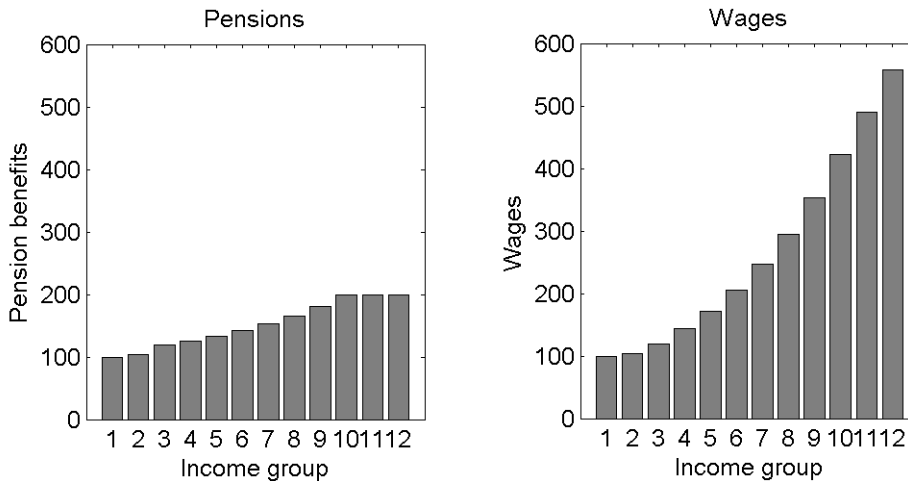
4 Simulation Results

This section presents the main results, first outlining the principal characteristics of the baseline pension system results and its estimated development given the population predictions, and subsequently comparing the status quo to the two alternative schemes. There are five main variables of interest, all of them expressed in real terms in absence of inflation in the model: level of pension benefits, degree of intra-generational wealth distribution among pensioners, social security tax rates, pension system indebtedness, and economic growth. In order to illustrate the full extent of direct and indirect effects, the results are presented in several steps, each representing comparison along different dimension.

4.1 Baseline comparison

Let us first inspect the distribution of pensions in the model as depicted in Figure 3. Clearly, the current scheme benefits lower income classes at the expense of individuals with higher income, as the wealthiest individuals have nearly six times higher gross wages than the bottom 10% of the population but only two times higher pensions. As we will see later, this contribution to intragenerational income equality is one of the main factors distinguishing the Czech PAY-GO scheme from the funded schemes.

Figure 3: Pension and income distribution in the baseline pension system, 2016.

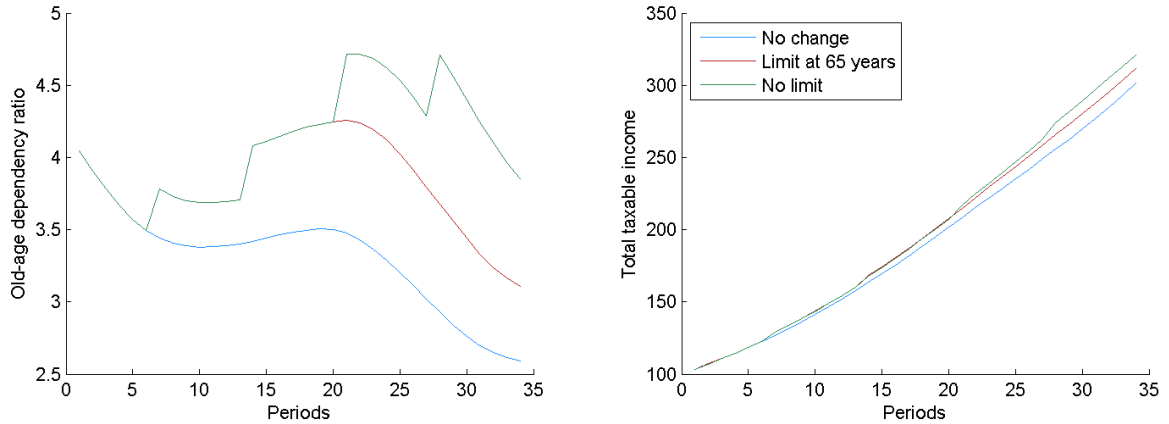


Notes: The values represent multiples of the lowest income class value, standardised to 100.

To better understand the adverse population changes, consider the shifts in old-age dependency ratio – the number of workers to pensioners – and total taxable income over time. These are depicted in Figure 4. We can see that without any adjustments in retirement age the old-age dependency ratio decreases by nearly 40% over the 35 years. If the current legislation remains in place and retirement age increases to 67 years in 2042, the share of pensioners in the population will remain virtually unchanged, suggesting that the rate of increase is appropriate in terms of keeping the pension budget

close to balance. While postponing retirement age principally affects the expenditure side of the pension budget as the change in the number of pensioners is greater than for workers, we can see from the explicit (b) that the series of changes also increases the taxable income in the economy and thus helps the revenue side as well.

Figure 4: Population changes. (a) Old-age dependency ratio, (b) Total taxable income as ratio compared to the $t = 1$ level.



Notes: Scenarios represent changes to retirement age. 'No limit' scenario represents the current legislation where retirement age increases regularly without an upper bound set to it.

As a first step in the comparative analysis, let us analyse the estimated changes in output, pensions, and pension budget (as percentage of GDP) in case of no parametric changes to the existing PAY-GO system, depicted in Table 2. The table presents fifteen distinct scenarios with the same starting point, differing in the rate of pension adjustment (none – indexation only at the level of inflation; 1/3 of changes in real wages, i.e. the minimum suggested by the current government; and full real wage indexation) and productivity growth rate (see previous section). All of the scenarios assume the retirement age to increase to 65 years for both genders by 2030.

Starting with output, defined as product of capital, labour, and productivity growth, it is unsurprising that there are substantial differences across the productivity growth scenarios and intra-indexation scenario variation is meaningless. However, we can see that the level of output is negatively correlated with level of indexation. This is a result of the consumption smoothing; households are rational and aware of facing large drop in income in scenarios with low or no indexation, choosing to save more during their working age in order to increase consumption in retirement.

Pensions are reported twice: once in absolute terms and once relative to real wages in the economy. By definition, absolute value of pensions does not change in the scenario with no indexation and the pension-wage ratio remains constant in the full indexation scenario. If pensions remain at their current levels, the pension budget is estimated to be in large surplus already in 2030 and even more so in 2050, yet only at the cost of drop in the pension-wage ratio – the higher economic growth the higher the surplus and the drop. Even in the very low productivity scenario, pensions are projected to decrease by 46% compared to real wages over the next four decades, resulting in enormous inequality between workers and pensioners. The inequality gap is marginally better in scenarios with partial indexation, yet even there pensions are estimated to decrease to less than half of their current level compared to the real wages. While this may leave pensioners with sufficient income to survive as pensions would still cover inflation, the situation would likely be all but acceptable by the public.

Table 2: Baseline simulation results – unbalanced pension budgets, no structural changes. Assumptions: limited retirement age increase.

PGR	Adj.	2016				2030				2050			
		Pension	Output	Deficit	P/W	Pension	Output	Deficit	P/W	Pension	Output	Deficit	P/W
Very low	Full	100%	100%	0.5%	100%	127%	127%	0.4%	100%	179%	169%	5.1%	100%
Low		100%	100%	0.5%	100%	142%	142%	0.4%	100%	234%	221%	5.1%	100%
Baseline		100%	100%	0.5%	100%	159%	159%	0.4%	100%	306%	288%	5.1%	100%
High		100%	100%	0.5%	100%	177%	177%	0.4%	100%	399%	376%	5.1%	100%
Very high		100%	100%	0.5%	100%	198%	198%	0.4%	100%	519%	490%	5.1%	100%
Very low	1/3	100%	100%	0.5%	100%	109%	128%	-2.0%	85%	122%	173%	-1.5%	67%
Low		100%	100%	0.5%	100%	113%	144%	-2.9%	79%	134%	228%	-3.7%	56%
Baseline		100%	100%	0.5%	100%	117%	162%	-3.8%	73%	147%	300%	-5.6%	46%
High		100%	100%	0.5%	100%	122%	181%	-4.6%	68%	162%	394%	-7.1%	39%
Very high		100%	100%	0.5%	100%	127%	203%	-5.4%	63%	177%	515%	-8.4%	32%
Very low	None	100%	100%	0.5%	100%	100%	129%	-3.0%	78%	100%	175%	-4.0%	54%
Low		100%	100%	0.5%	100%	100%	145%	-4.4%	69%	100%	231%	-6.7%	41%
Baseline		100%	100%	0.5%	100%	100%	163%	-5.5%	62%	100%	305%	-8.6%	31%
High		100%	100%	0.5%	100%	100%	183%	-6.6%	55%	100%	399%	-10.1%	24%
Very high		100%	100%	0.5%	100%	100%	205%	-7.5%	49%	100%	521%	-11.2%	18%

Notes: PGR = Productivity Growth Rate, Adj. = Pension adjustment, P/W = ratio of average pensions to wage, Deficit = Pension budget deficit in the given year. Pension and output values standardised using 2016 values. See text for scenario description.

Finally, even though pensioners would maintain their current relative wealth levels in the full indexation, this would be only at the cost of enormous indebtedness or cuts in other public policy areas as all of the scenarios are estimated to lead to over 5% GDP deficit each year by 2050. Note that the projected indebtedness is the same in all scenarios as any changes in tax revenues due to economic growth are exactly equilibrated by increase in pension system liabilities. The bottom line is thus that higher economic growth may significantly alleviate the negative impact of demographic changes, yet the benefits decrease with level of indexation.

4.2 Parametric changes

Given the long-term unsustainability of pension system finances and appropriate replacement ratios at the same time, what are the possibilities in terms of parametric changes to the current system? According to Equation 12, one may change the revenue side (taxes), expenditure side (pensions), or their proportions (retirement age). Table 3 presents projected performance indicators of the existing PAY-GO system in nine scenarios differing in indexation (as above) and retirement age (no change, up to 65 years, unlimited; see the previous section for details), all of them assuming baseline growth in productivity.

Table 3: Simulation results of a structural change to the existing pension system, differing by assumed retirement age increase. Assumptions: baseline productivity growth.

R. age	Adj.	2016				2030				2050			
		Pension	Output	Deficit	P/W	Pension	Output	Deficit	P/W	Pension	Output	Deficit	P/W
No change	Full	100%	100%	0.5%	100%	160%	154%	3.4%	100%	308%	277%	9.1%	100%
Up to 65		100%	100%	0.5%	100%	159%	159%	0.4%	100%	306%	288%	5.1%	100%
Up to 67		100%	100%	0.5%	100%	159%	159%	0.4%	100%	303%	300%	1.3%	100%
No change	1/3	100%	100%	0.5%	100%	118%	157%	-1.7%	72%	148%	291%	-3.9%	46%
Up to 65		100%	100%	0.5%	100%	117%	162%	-3.8%	73%	147%	300%	-5.6%	46%
Up to 67		100%	100%	0.5%	100%	117%	162%	-3.8%	73%	147%	310%	-7.3%	47%
No change	None	100%	100%	0.5%	100%	100%	159%	-3.9%	61%	100%	296%	-7.5%	30%
Up to 65		100%	100%	0.5%	100%	100%	163%	-5.5%	62%	100%	305%	-8.6%	31%
Up to 67		100%	100%	0.5%	100%	100%	163%	-5.5%	62%	100%	314%	-9.7%	32%

Notes: R. age = Retirement age, Adj. = Pension adjustment, P/W = ratio of average pensions to wage, Deficit = Pension pension budget deficit in the given year. Pension and output values standardised using 2016 values. See text for scenario description.

Analogously to results shown in Table 2, lower pensions result in higher relative output due to

increased capital accumulation. Outcomes of partial and unlimited retirement age adjustment are equal in 2030 as both of these result in retirement age of 65 at that time. We can see that the retirement age increase results in virtually no change in the old-age dependency ratio in 2030 as suggested by 4, which in turn leaves pension budget nearly in balance even in the full indexation scenario and in surplus should pensions be indexed at lower rates.

Similarly, increasing retirement age to 67 years by 2042 is estimated to allow pension indexation at the level of changes in real wages with a minor effect on pension budget, while maintaining retirement age at 65 years would result in substantially higher deficits. The rate of change in pension budget bottom line increases with indexation, i.e. with total liabilities.

Although the results generally suggest that increasing retirement age may nearly balance out the adverse demographic changes while maintaining consistent replacement rates, there are three additional points to be made. Firstly, the model slightly overstates the positive impact of retirement age change due to the assumption of arbitrary maximum age, as the average life expectancy is projected to increase over time, resulting in comparatively greater decrease in the old-age dependency ratio. Second, going back to Figure 2 the decrease in the old-age dependency ratio is projected to continue also after 2050 – retirement age would therefore need to keep constantly increasing beyond 67 years in the future. Lastly, such changes to retirement age may simply not be feasible in reality without appropriate changes to work arrangements of older people.

The alternative ways of keeping financed under control are depicted in Table 4, which shows outcomes across three dimensions: retirement age, pension benefit adjustment (only partial and full), and balancing mechanism (taxes or pensions). Taxes are represented by the total social security taxation paid employees and employers. All scenarios again assume baseline productivity growth rate.

Table 4: Simulation results of alternative pension budget balancing mechanisms. Assumptions: baseline productivity growth.

R. Age	Adj.	BM	2016				2030				2050			
			Pension	Tax	Deficit	P/W	Pension	Tax	Deficit	P/W	Pension	Tax	Deficit	P/W
No change	Full	TA	100%	28%	0.5%	100%	156%	34%	0.0%	100%	289%	45%	0.0%	100%
Up to 65			100%	28%	0.5%	100%	158%	29%	0.0%	100%	296%	38%	0.0%	100%
Up to 67			100%	28%	0.5%	100%	158%	29%	0.0%	100%	301%	30%	0.0%	100%
No change	1/3	TA	100%	28%	0.5%	100%	118%	25%	0.0%	72%	149%	20%	0.0%	45%
Up to 65			100%	28%	0.5%	100%	118%	21%	0.0%	72%	149%	17%	0.0%	45%
Up to 67			100%	28%	0.5%	100%	118%	21%	0.0%	72%	149%	14%	0.0%	45%
No change	-	PA	100%	28%	0.5%	100%	132%	28%	0.0%	82%	197%	28%	0.0%	62%
Up to 65			100%	28%	0.5%	100%	155%	28%	0.0%	98%	231%	28%	0.0%	74%
Up to 67			100%	28%	0.5%	100%	155%	28%	0.0%	98%	280%	28%	0.0%	92%

Notes: R. age = Retirement age, Adj. = Pension adjustment, P/W = ratio of average pensions to wage, BM = Balancing mechanism, TA = taxes adjust, PA = pensions adjust, Deficit = Pension pension budget deficit deficit in the given year. Pension and output values standardised using 2016 values. See text for scenario description.

We can see that the tax changes required to maintain balanced budget vary substantially, in a similar way to the level of deficit in the previous analysis. In particular, the estimates suggest that taxes could be lowered to half by 2050 if pensions were indexed only at one third of growth in real wages and retirement age increased to 67 years. On the contrary, they would need to be increased by more than 17 percentage points in the scenario with full pension indexation and no changes in retirement age. Notice that the output levels are slightly lower in the full indexation scenarios compared to results in Table 3. This is due to the assumption that increasing external debt has no immediate negative impacts on the economy, whereas excessive taxation lowers both consumption and savings and thus decreases the generated output.

Finally, pensions would decrease by just 8% by 2050 if they served as balancing mechanism and retirement age increased without limits, and by 26% and 38% in scenarios with limited and no changes in retirement age, respectively, keeping the current social security tax rates unchanged. Note that this is a simplified scenario in which all pensions paid in a given period are reduced proportionally in order to keep pension budget balanced, as opposed to the automatic balancing mechanism in the multipillar scheme, which lowers the indexing rate of contributions and pensions but the indexation can never be negative.

4.3 Pension reform

We have seen that the only way the existing PAY-GO scheme provides future pensioners with pensions close to their pre-retirement earnings is if retirement age increases unlimitedly, keeping the old-age dependency ratio nearly constant over time. In this section, I investigate whether a move towards one of the alternative pension schemes would be more beneficial in the long-term, and what would be the implications in the short-term.

As a first step in the analysis, consider a structural change taking place in $t = 2$ with no market imperfections, baseline productivity growth, and 3.5% annual return on savings. Table 5 shows the projected changes in pensions, output, and pension budget deficit for the two alternative pension schemes as in the last section, as well as results of the existing PAY-GO scheme for comparison.

Table 5: Simulation results of a structural change to the existing pension system, differing in assumed change in retirement age. Assumptions: baseline productivity growth and return on retirement savings.

PS	R. age	2016				2030				2050			
		Pension	Output	Deficit	P/W	Pension	Output	Deficit	P/W	Pension	Output	Deficit	P/W
PG	No change	100%	100%	0.5%	100%	160%	154%	3.4%	100%	308%	277%	9.1%	100%
	Up to 65	100%	100%	0.5%	100%	159%	159%	0.4%	100%	306%	288%	5.1%	100%
	Up to 67	100%	100%	0.5%	100%	159%	159%	0.4%	100%	303%	300%	1.3%	100%
M	No change	100%	100%	0.5%	100%	129%	158%	0.0%	78%	258%	285%	2.3%	81%
	Up to 65	100%	100%	0.5%	100%	140%	162%	-1.3%	86%	299%	292%	1.8%	96%
	Up to 67	100%	100%	0.5%	100%	140%	162%	-1.3%	86%	355%	301%	1.3%	116%
FF	No change	100%	100%	0.5%	100%	153%	146%	7.2%	100%	432%	255%	1.2%	147%
	Up to 65	100%	100%	0.5%	100%	178%	149%	5.8%	116%	504%	263%	1.0%	174%
	Up to 67	100%	100%	0.5%	100%	178%	149%	5.8%	116%	615%	272%	0.8%	216%

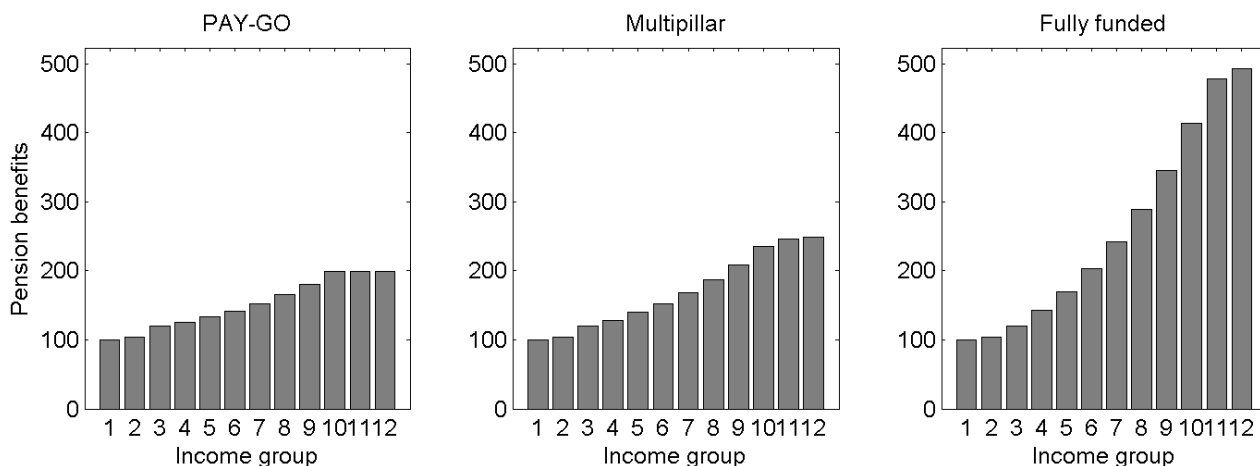
Notes: PS = pension scheme (PG = PAY-GO, M = multipillar, FF = fully funded), R. age = Retirement age, Pension = average pension benefits, Deficit = Pension pension budget deficit in the given year. Pension and output values standardised using 2016 values. See text for scenario description.

Starting with the fully funded scheme, the model suggests vast improvement in pension benefits without a significant effect on the output. Recall that the model does not assume savings into pension funds to increase capital accumulation in the economy and thus likely understates the effects on economic growth, which may in reality be boosted compared to the PAY-GO scheme. The difference in average reported pensions is caused principally by high income classes as the replacement rates become essentially flat across income groups, unlike in the original pension scheme where the rates exponentially decreased with income. This is also depicted in Figure 5; note that since the safety net in the fully funded scheme is set so that the lowest income class cannot be worse off as a result of the transition, virtually everyone in the economy is better off in the new system, albeit at the cost of increasing indebtedness.

Indeed, the transition affects pension budget deficit twice – once due to the necessity to finance PAY-GO pensions for everyone who contributed to the old system and once due to non-existence

of large gap in contributions and benefits of wealthy individuals, putting more equal burden on all income groups. The pension budget deficit is largest in the early years and decreases over time proportionally to decrease in PAY-GO pensions paid out (see also Figure 8). As shown in Table 5, the resulting pension budget deficit would be lower than in the other schemes by 2050 (and at all times after) but substantially higher in the early years, up to more than 10% of GDP.

Figure 5: Intragenerational equality in pensions, 2050.



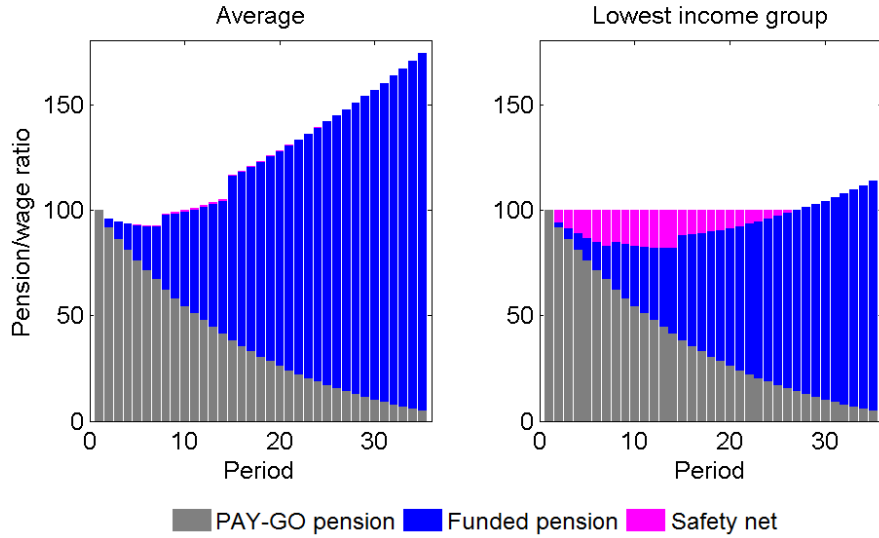
Notes: The values represent multiples of the lowest income class value, standardised to 100. Values are standardised within each pension scheme.

The differences in pension-wage ratios compared to the PAY-GO system reflect changes in replacement rates rather than higher indexation. In fact, the average replacement rates are fairly low in the existing scheme due to the redistribution effects and since annuities in the fully funded scheme are indexed using return on financial assets rather than real wage, virtually any positive interest rate will result in higher average pension-wage ratios.

The transition towards a fully funded scheme in terms of average pensions and pensions received by the lowest income class are then depicted in Figure 6. On average, the total pension-wage ratio is projected to decrease in the first years as a result of decreasing PAY-GO pensions and new savings not being able to accumulate substantive accrued interest, but the funded pensions start to grow more rapidly than the PAY-GO pensions decrease in just about ten years after the transition started. Importantly, assuming constant return on savings and no problems on financial markets, replacement rates become constant once first generation that contributed only to the new system retires, unlike in the existing scheme where retirement age needs to be adjusted constantly to reflect changes in the population structure. Unlike richer households, the lowest income groups would require additional support from the government through the safety net as their savings would be too low at first. However, even they are projected to be better off than in the existing scheme at some point and the total support paid out through the safety net is very low as shown on the left graph.

Going back to results of the multipillar scheme depicted in Table 5, the pension-wage ratios are essentially a linear combination of the other two schemes, proportional to the share of contributions going to the unfunded and funded pillars, respectively, although they further reflect the automatic balancing mechanism introduced in the scheme. In particular, the ratios are lower than in the fully-indexed PAY-GO scenario and in the fully funded scheme, but the pension budget deficit is lower

Figure 6: Composition of total pension benefits, transition towards a fully funded scheme.



Notes: Pensions standardised within each figure. Assumptions: baseline productivity growth, limited retirement age increase, 3.5% return on savings.

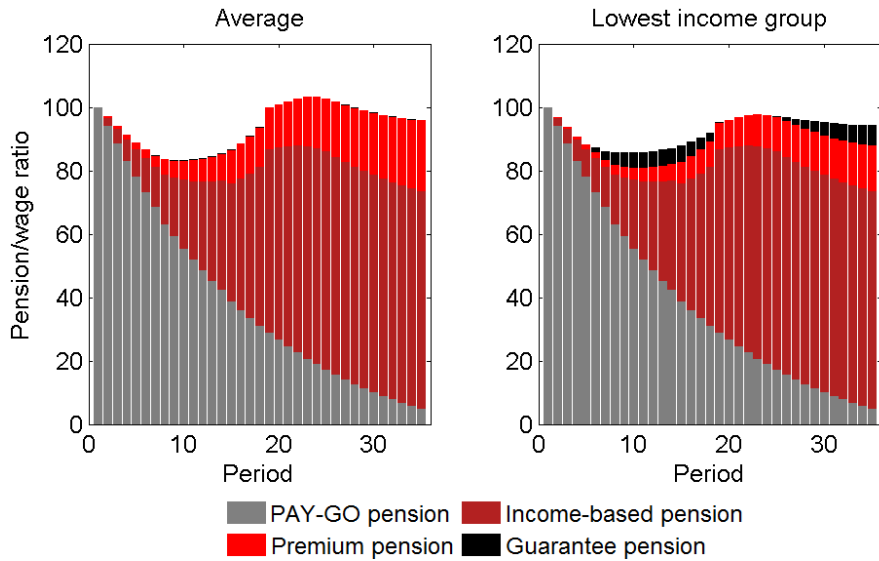
as well, with the annual deficits being disproportionately lower than in the PAY-GO scheme and the accumulated debt disproportionately lower than in the fully funded scheme.

The source of these differences is depicted in Figure 7. Similarly to the fully funded scheme, average pension benefits are projected to drop at first, in fact more than in the previous example as a result of guarantee pension set lower than the safety net in the fully funded scheme, pensions of high income classes are not able to outweigh the lack of accrued interest, and the balancing mechanism further reducing the level of indexation to balance lower tax revenues. Nevertheless, the pension-wage ratio stabilises soon after with the first increase in retirement age and remains fairly constant afterwards thanks to the automatic balancing mechanism. Notice that since less than a fifth of all contributions goes towards the funded second pillar, the relative pensions eventually decrease again, following changes in the old-age dependency ratio, but the contribution of annuities in structure of the total pension benefits increases constantly, constituting greater share of the total pensions than the contributions towards the funded pillar.

Pensions of lowest income group are again topped, this time by the guarantee pension. Notice that since the amount received through guarantee pension depends only on the income-based pension but not on the premium pension, as opposite to the safety net in the fully funded system, the top-up will actually bring pensioners up to nearly 100% of the original pension-wage ratio in later stages of the transition. The resulting relatively high average replacement rates shown in Table 5 are thus not a product of excessively high rates of rich households like in the fully funded system; instead, they reflect a small decrease for the poor and a small increase for the rich. But since the formula for calculation of pension benefits and the share of contributions going towards the funded second pillar may be optimised to a large extent, the change in distribution of wealth may be adjusted in reality.

As a final step in baseline analysis of the alternative pension schemes, consider a change in rate of return on retirement savings, as depicted in Table 6. There are two striking results: firstly, the variation in resulting pensions particularly in the fully funded scheme is enormous and reflects the importance of accrued interest in the eventual accumulated balance; and secondly, the changes in rate

Figure 7: Composition of total pension benefits, transition towards a multipillar scheme.



Notes: Pensions standardised within each figure. Assumptions: baseline productivity growth, limited retirement age increase, 3.5% return on savings.

of return have essentially zero impact on the pension budget. This is because only a very small share of the total population is assumed to receive guarantee pension in the multipillar scheme thanks to the first, unfunded pillar constituting a consistent source of retirement income despite potentially low premium pension. The impact on pension budget is then so low because even the small rate of return on savings actually leads to higher resulting pensions than in the current system. The remaining budget deficit is thus a consequence of changes in the population structure (multipillar scheme) and remaining PAY-GO pensions to be paid (both schemes).

On the other hand, the 6% return on savings, which still may be low considering the past performance of most state or private owned pension systems in the world (see [OECD 2015b](#)), provides pensioners with income that would otherwise never be achievable in the current settings. Note that the various scenarios reflect both potential changes in the overall market returns but also variance in savings decisions within a single cohort. That is, while there may be some predefined investment guidelines set by the government as in the Chilean case, where older workers are required to transfer their savings to funds investing principally in fixed income assets, individuals are in principle able to choose from a wide variety of funds differing in risk and return and the resulting pensions are thus likely to vary to a far greater extent than in the existing PAY-GO scheme.

4.4 Impact of market imperfections

So far we have seen that while unfunded pension schemes as modelled in this study lead to redistribution of wealth and thus help low income households to have decent pensions despite low contributions, they fare relatively poorly when faced with adverse demographic changes. Funded pension schemes, while theoretically not immune to endogenous changes in the economy caused by changing old-age dependency ratio, are more promising in this respect, offering stable growth of pension benefits without extensive public indebtedness, as well as boost to the economy through higher capital accumulation. However, funded pension schemes in reality also introduce new elements in the analysis: uncertainty and market imperfections.

Table 6: Simulation results of a structural change to the existing pension system, differing in assumed return on retirement savings. Assumptions: baseline productivity growth, limited retirement age increase.

PS	IR	2016				2030				2050			
		Pension	Output	Deficit	P/W	Pension	Output	Deficit	P/W	Pension	Output	Deficit	P/W
PG	-	100%	100%	0.5%	100%	159%	159%	0.4%	100%	306%	288%	5.1%	100%
M	1.0%	100%	100%	0.5%	100%	135%	162%	-1.3%	83%	270%	294%	1.8%	86%
	3.5%	100%	100%	0.5%	100%	140%	162%	-1.3%	86%	299%	292%	1.8%	96%
	6.0%	100%	100%	0.5%	100%	147%	162%	-1.3%	90%	355%	289%	1.9%	114%
FF	1.0%	100%	100%	0.5%	100%	146%	151%	5.8%	95%	307%	273%	1.0%	103%
	3.5%	100%	100%	0.5%	100%	178%	149%	5.8%	116%	504%	263%	1.0%	174%
	6.0%	100%	100%	0.5%	100%	223%	147%	5.9%	147%	886%	252%	1.0%	319%

Notes: PS = pension scheme (PG = PAY-GO, M = multipillar, FF = fully funded), IR = Return on savings into pension funds, Pension = average pension benefits, Deficit = Pension pension budget deficit deficit in the given year. Pension and output values standardised using 2016 values. See text for scenario description.

As a last step in the analysis, baseline results of (partially) funded pension schemes from the last section are compared with two alternative scenarios: one in which annuities are not actuarially fair and there is an annual fee on savings made into pension funds, and the second scenario further assuming a stock market crash to occur at time $t = 10$. Together, the three scenarios thus give a better overview of the potential performance variation of pension system. The results are shown in Table 7 and Figure 8, which also highlights the changes in pension budget deficit over time as a result of the structural changes. Similar to discussion in the previous section, market imperfections have very little impact on debt accumulation as pensioners are worse off but mostly not enough for the safety mechanisms to start functioning. Budget balance is thus shown only for the baseline scenario.

Table 7: Simulation results of a structural change to the existing pension system, differing in market imperfection scenarios. Assumptions: baseline productivity growth and return on retirement savings, limited retirement age increase.

PS	Scenario	2016				2030				2050			
		Pensions	Output	Deficit	P/W	Pensions	Output	Deficit	P/W	Pensions	Output	Deficit	P/W
PG	-	100%	100%	0.5%	100%	159%	159%	0.4%	100%	306%	288%	5.1%	100%
M	-	100%	100%	0.5%	100%	140%	162%	-1.3%	86%	299%	292%	1.8%	96%
	AC	100%	100%	0.5%	100%	137%	162%	-1.3%	84%	278%	294%	1.8%	89%
	AC+C	100%	100%	0.5%	100%	130%	163%	-1.3%	80%	269%	295%	1.8%	86%
FF	-	92%	92%	0.5%	100%	178%	149%	5.8%	116%	504%	263%	1.0%	174%
	AC	100%	100%	0.5%	100%	155%	150%	5.8%	101%	361%	270%	1.0%	122%
	AC+C	100%	100%	0.5%	100%	113%	153%	5.7%	74%	301%	273%	1.0%	101%

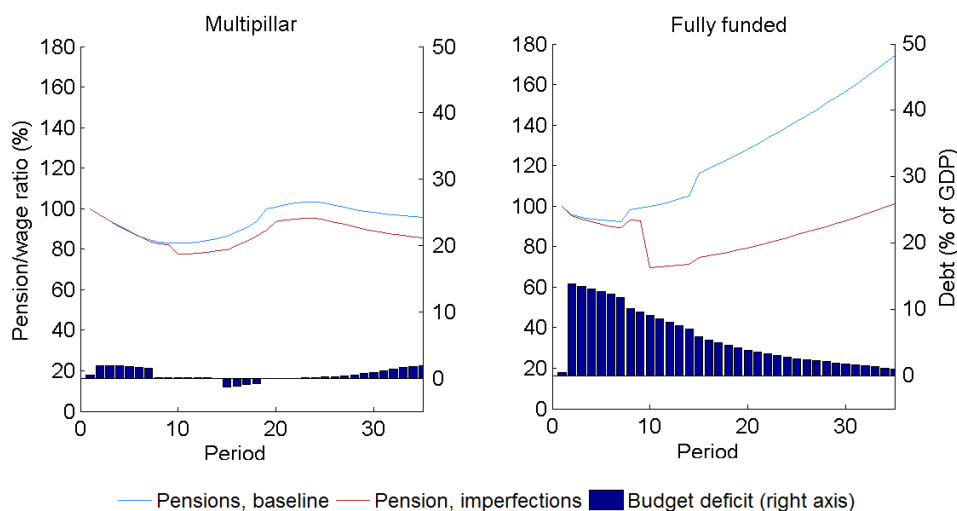
Notes: PS = pension scheme (PG = PAY-GO, M = multipillar, FF = fully funded), AC = Administrative costs, AC+C = Administrative costs and stock market crash, Pension = average pension benefits, Deficit = Pension pension budget deficit deficit in the given year. Pension and output values standardised using 2016 values. See text for scenario description.

Looking at the results, we can see that the alternative scenarios indeed have essentially no impact on the pension budget as the pensions are in principle high enough for most people not to require support in terms of guarantee pension. Pensions, on the other hand, differ substantially in the alternative scenarios. This is particularly true for the fully funded system, where pensions decrease by more than 30% on average just due to administrative costs and imperfect annuity markets compared to the optimal baseline scenario. The effect of stock market crash is partially hidden in the table as happens prior to the first reporting period, yet we can clearly see the further difference in the resulting pensions, which decreases over time as the savings are slowly catching up with the counterfactual scenario. Note also that the effect of a large stock market crash is in fact underestimated in the

model as it does not assume the secondary impacts – particularly an economic downturn that leads to further decrease in savings.

The bottom line is that a structural change towards a fully funded system is projected to be beneficial in the long-run, offering higher pensions at lower cost to the public, but only at the cost of an enormous pressure on the public finances in early years after the transition begins. There are ways to reduce this cost or distribute it differently over time – e.g. Chile used a different transition mechanism where everyone was able to choose to receive the old PAY-GO pension only or to join the new pension scheme with contributions to the old system being reflected in the annuity, rather than maintaining both systems as it is modelled in this study. In case of the Czech Republic, the cost could also be partially offset by reduction in social security taxation to levels in other countries. However, we have seen that the fully pension system, although highly resistant to population changes is highly vulnerable to problems on financial markets.

Figure 8: Pensions and pension budget deficit in case of a structural change.



Notes: Pensions represent average benefits and are standardised within each figure. Assumptions: baseline productivity growth, limited retirement age increase, 3.5% return on savings.

Lastly, the multipillar scheme again serves as a middle ground between the two polarised systems, offering protection against both the adverse demographics and low asset returns to extent given by share of contributions going to the individual pillars. The pensions are thus lower than in the fully funded scheme, yet higher than in the existing PAY-GO scheme at cost lower than in either of the systems. Moreover, the impact of a large stock crash on both pensions and pension system budget is highly limited and the automatic balancing mechanism ensures that the budget will return to balance as soon as possible.

5 Conclusions

The persistent trends of decreasing fertility and mortality rates, as well as large, primary post-war generations reaching retirement age are expected to put increasing pressure on the Czech pension budget in the next years and decades – a scenario that is remarkably similar among virtually all countries in the world. It is clear that substantial changes to the existing pension systems need to be made in order to avoid excessive debt burden put on the next generations and that each year passed

without a change will make these adjustments more difficult due to already mounting budget deficits and constantly decreasing ratio of workers to pensioners.

This study analyses both parametric and structural changes to pension systems with the aim to suggest an optimal way going forward. The results suggest that, conditional on continuous economic growth, a decrease in the old-age dependency ratio may not necessarily lead to lower real pensions in PAY-GO pension schemes in the future, even when keeping pension budget more or less balanced. At the same time, this is only at the cost of growing disparity between pre-retirement earnings and pension benefits. The alternative – indexing pensions to real wages – would either require substantial increase in social security taxation or unlimited increase in retirement age, or it would almost certainly lead to explosive pension budget deficits.

Funded pension schemes may seem an attractive alternative, offering greater protection against adverse demographic changes. However, the account balances transferred to lifetime annuities are inherently dependent on performance of financial markets and, as the analysis in this paper showed, the resulting pension benefits may very well be lower than even unindexed pensions in a PAY-GO scheme in case of imperfect annuity markets or inability to save properly, let alone potential stock market crashes. Achieving desirable savings is also only possible if interest rate on savings is near the growth rate of real wages. Moreover, transition towards a fully funded scheme would be extremely costly and lead to substantially different distribution of wealth in retirement compared to the highly redistributive existing PAY-GO scheme.

The multipillar scheme, modelled according to the existing Swedish pension system, then emerges as an attractive compromise, being vulnerable to both demographic changes and financial market issues, yet to a lesser extent than each of the individual schemes. From practical perspective, transition towards a multipillar scheme also offers greater possibilities for further parametric changes and is far less costly than a transition towards a fully funded scheme.

In the end, it is therefore not possible to say whether there exists an optimal scheme for the Czech Republic because none of the presented schemes are optimal in all factors considered. However, given the current level of redistribution in the existing pension system and difficulty to maintain a balanced budget, the multipillar scheme with high proportion of contributions going towards the unfunded pillar and particularly an automatic balancing mechanism seem to be the best option overall.

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Appendix

Model Dynamics

The economy is assumed to be in a steady state in each period. Formally, steady state is an equilibrium for given government policy and the initial distribution of capital $\{k_{s,0}\}_{s=1}^{T+T^R}$ and is characterized by a set of value functions $V_s(k_{s,t}, K_t, N_t)$, individual policy rules $c_s(k_{s,t}, K_t, N_t)$ and $k_{s+1}(k_{s,t}, K_t, N_t)$, and relative prices of labour and capital w_t, r_t , such that:

1. Individual and aggregate behaviour are consistent:

$$N_t = \sum_{s=1}^T \sum_{z \in Z} e(z, s) l \mu_{s,z,t} \quad (22)$$

$$K_t = \sum_{s=1}^T \sum_{z \in Z} k_t^s \quad (23)$$

2. Households' dynamic programs and firms' optimization problems are solved by satisfying Equations (5)–(10) using the relative prices w_t, r_t , pensions, and the individual policy rules $c_s(\cdot)$ and $k_{s,t+1}(\cdot)$.
3. The goods market clears:

$$\Omega K_t^\alpha N_t^{1-\alpha} = \sum_{s=1}^{T+T^R} \frac{c_{s,t}}{T+T^R} + K_{t+1} - (1-\delta)K_t \quad (24)$$

The algorithm used in this study follows [Nishiyama and Smetters \(2007\)](#) and utilises value function iteration to compute agents' policy functions for respective periods and shocks. Let $v(K)$ be the value function equal to the discounted sum of all instantaneous utility functions $u(c_1), u(c_2), \dots, u(c_{T+T^R})$, where c_1, c_2, \dots denote household's consumption at age $1, 2, \dots, T+T^R$, and K denotes the optimal capital decisions that maximize household's lifetime utility. In other words, given a sequence of capital stocks, $v(K)$ is the maximum discounted level of household's utility.

Assume an optimal sequence of capital stocks from $s=1$ to time $s=q$, that is, $K = k_1, k_2, \dots, k_q$, then the best level of capital K^* in time $s=q+1$ is given by

$$v(K^*) = \max_{0 \leq K' \leq f(K)} u(f(K) - K') + \beta v(K'), \quad (25)$$

where $f(K)$ denotes the production function and $f(K) - K'$ thus denotes consumption in a given period. Given the idiosyncratic shocks presented in the model, there is a unique optimal policy function $g(K)$ that governs the capital accumulation for each possible combination of shocks in agent's life, which in practice prevents direct computation of the optimal capital stock for newly born agents. To overcome this, the optimal capital allocation for each income group is calculated separately for each year of age in a backward induction framework.

Let k_{min} and k_{max} denote the minimum and the maximum capital stock a household could possess at a single point in its life. Choosing a number of grid points n , we may discretize the interval; we can assign a level of capital to each of the equidistant points k_1, k_2, \dots, k_n in the interval, with $k_1 = k_{min}$ and $k_n = k_{max}$. Since no agents can live more than $T+T^R$ years, we can calculate the optimal

saving decision for each level of asset holdings at the beginning of the last year of life and pension transfers so that the utility function $u(c_{T+T^R})$ is maximised. Note that agents will not consume their entire wealth in order to bequeath a part of it for their children. Similarly, in all prior periods $s = 1, \dots, T + T^R - 1$, the instantaneous utility depends on actual consumption, which, in turn, depends on savings and other forms of income. However, here it also depends on the intended level of capital accumulation at time $s + 1$, determined by savings at time t . And as the savings in period $s + 1$ further depend on the projected capital stock in period $s + 2$ in a similar manner, the value function can be expressed in a recursive form, following [Stokey \(1989\)](#):

$$v_s(k_{s,t}, K_t, N_t) = \max_{k_{s+1,t+1}, c_{s,t}} [u(c_{s,t}) + \beta v_{s+1}(k_{s+1,t+1}, K_{s+1}, N_{s+1})]. \quad (26)$$

Clearly, at time s , one can always consider such level of capital k_{s+1} for $s + 1$ so that $k_{s+1} \leq k_s$ as all it takes is to save less than to consume. On the other hand, only some points with higher level of capital are accessible, as it is impossible borrow. The algorithm assesses utility for each point on the asset grid at time s through computation of value functions for all points at $s + 1$. Only accessible levels of capital are then considered and compared. And since the total wealth in each period of life can only be saved further or consumed, the optimal savings decisions implicitly determine the optimal consumption such that it maximises the total discounted lifetime utility. Agents are considered rational but their decisions made are on the basis of available information about institutional arrangement, wages, and interest rates – they do not predict future price evolution and have no information about planned policy changes.

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