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Pension Reforms and Adverse Demographics: Options for the Czech Republic

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Abstract

This paper estimates changes in pensions and long-term financial sustainability of the Czech pension system in the light of population ageing, market imperfections or a potential economic downturn, and assesses feasibility of various parametric and structural reforms. To do so, it develops a bespoke OLG model with heterogeneous agents, bequests, productivity shocks, market imperfections, and realistic representation of three distinct types of pension systems calibrated using real-world data. Numerical results are obtained through computer simulations. The estimates show that a well-designed multi-pillar pension scheme provides good results in a number of performance indicators without leading to excessive costs of transition, whereas maintaining the current PAY-GO scheme would lead to a gradual decrease in real pensions, lower pension-to-wage ratios, higher budget deficits, or any combination thereof, unless the statutory retirement age increases beyond 67 years by 2050.

1.Introduction

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 individuals – 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. In this situation, financial sustainability of pension systems has been a particularly discussed topic among both academics and policymakers, especially following the financial crisis of 2007–2008, which has put public finances under an unprecedented pressure. Indeed, many developed and developing countries 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 financial sustainability of a pension systems in countries like Greece or Japan is impossible without substantial reforms (see e.g. OECD, 2015; Finke and Sabatini, 2016), it is far from clear what the optimal solution for each country is. Several authors (e.g. Holzmann et al., 2005; Kaganovich and Zilcha, 2012; Kotlikoff et al., 1999) argue that a structural change, 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 be more beneficial in the long-term than simple parametric changes aimed e.g. at increasing retirement age.

The argument follows from vulnerability of PAY-GO systems to adverse demographical changes and eco- nomic downturn due to reliance on intragenerational solidarity and social security tax revenues (Oksanen, 2009; Cipriani, 2018). At the same time, PAY-GO systems are generally immune to the direct effects of volatility of financial market returns. This is contrary to specifics of funded schemes, which are more resistant to demographic and potentially also political changes – as retirement benefits depend on individual's savings rather than government decisions – but may depend heavily on financial markets (Burtless, 2010s; Casey, 2011; Miles and Černý, 2006). A structural change towards a funded pension system would also be extremely costly as either the current or future generations would need to essentially double their contributions to the pension system. Finally, there may be other potential long-term downsides of their financing structure (see e.g. Barr 2002 or Brooks, 2000).

This study focuses on the case of the Czech Republic, an exemplary country with ageing population and majority of pensioners wholly dependent on contributions from younger generations. It aims to complement results from the previous literature on performance and financial sustainability of pension systems (e.g. Aglietta et al., 2007; Alonso-García et al., 2018; Fehr, 2009; Makarski et al., 2017) and fill the gap in analytical evidence to determine whether there is a well-rounded optimal pension scheme that would provide future Czech pensioners with a decent income in retirement without putting an excessive burden on the younger generations through accumulation of external debt or raising social security tax rate. This is done through comparison of various scenarios with parametric and structural reforms using large-scale simulations of a bespoke overlapping generations (OLG) model with heterogeneous agents, bequests, productivity shocks and market imperfections. In order to provide real-world alternatives to the existing scheme, the structural pension reforms use detailed representations of the existing pension systems from Sweden (a multi-pillar scheme) and Chile (a fully funded scheme).

2. Existing Research

This study is broadly in line with the recent literature on comparative assessments of pension systems in selected countries. For instance, Olivera (2016) evaluates the potential effects of a multi-pillar pension system on pension inequality in Peru; Laun and Wallenius (2015) develop a life cycle labour supply model to forecast labour supply implications of a Swedish pension reform; Blank et al. (2016) compare the Austrian and German pension systems; De La Fuente and Domenech (2013), Patxot et al. (2017) and Vidal-Melia (2014) analyse the financial impact, adequacy of pension benefits and actuarial fairness of the 2011 reform in Spain; and Fredriksen et al. (2019) analyse fiscal effects of the Norwegian pension reform.

Many studies aiming to estimate the future costs and benefits of pension system reforms are based on a series of explicit scenarios determining some of the main factors in the economy. Opposite to this approach, computable general equilibrium (CGE) models assume the economy to fit a predefined, appropriately calibrated theoretical framework and determine future outcomes through simulations of interactions within the economy. Some of the first studies using computer simulations in the area of pension systems were Arrau (1993), Cifuentes and Valdés-Prieto (1999), Cifuentes and Valdes-Prieto (1997) and Kotlikoff et al. (1999). More recent literature analysing pension systems using (stochastic) computer simulations focuses on broad spectrum of topics ranging from adequacy, efficiency, fairness and sustainability of pension systems to estimation of an optimal portfolio allocation in a mix between unfunded and funded schemes (see e.g. Auerbach and Lee, 2011; Bielecki et al., 2015; Devolder and Melis, 2015; Draper and Armstrong, 2007; Godínez-Olivares et al., 2016a; Makarski et al., 2017). For instance, Godínez-Olivares et al. (2016b) design an optimal automatic balancing mechanism to keep the required level of liquidity in pay-as-you-go pension systems by changing the contribution rate, retirement age and/or pension indexation, using population forecasts from Japan and Spain to validate their model. In another study, Alonso-García et al. (2018) construct a computable OLG model to show how a well-designed risk-sharing mechanism may help to restore sustainability of both defined benefit and defined contribution PAY-GO pension schemes using the Belgian population as an example.

The baseline OLG model used in this study was developed by Samuelson (1958) and Diamond (1965), and was recently used in a similar context e.g. by Giammarioli and Annicchiarico (2004), Michel et al. (2010), Verbič (2008) and Tyrowicz et al. (2018), 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. In another study, 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 using an OLG model e.g. in Miles and Černý (2006); Oksanen (2009).

3. Characteristics of the Selected Pension Systems

3.1 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. According to the current legislation, the statutory retirement age will increase by two months per additional year of birth from the current 63 years for men and 62 for women up to 65 years for both men and women by 2030 (MLSA, 2018). However, the model developed in this study also considers a scenario with a further increase in retirement age up to 67 years by 2042 as per the previous legislation (MLSA, 2017). The existing social security taxation financing retirement benefits is set to 6.5% paid by employees and 21.5% paid by employers.

Pension transfers consist of a flat minimum benefit calculated as 9% of the average wage (CZK 2,440 and 27,006 in 2016, respectively) 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 δ_t. This is then multiplied by an income base, calculated using the average reported income while paying social security contributions, proportionally reduced for higher income (where income from previous years is multiplied by a predefined coefficient to reflect inflation). The income base cannot be lower than 25% of the average wage. Formally:

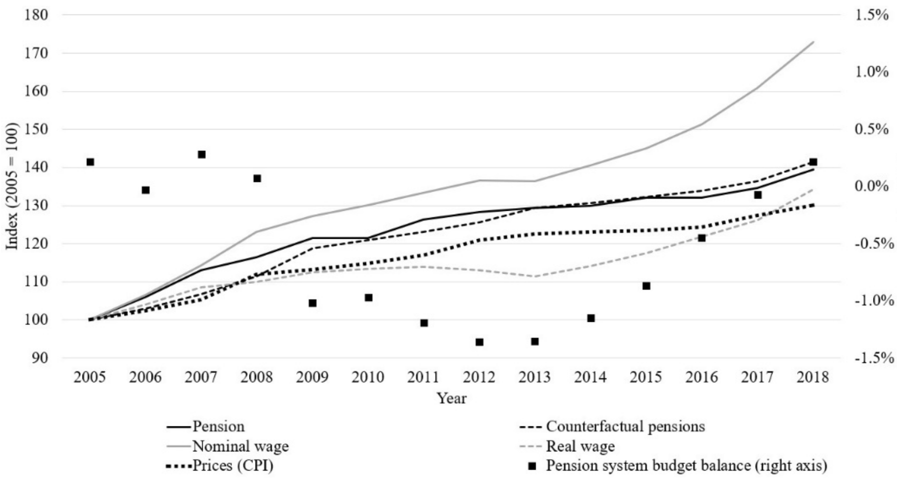
$$B_i = \frac{1}{T}\sum_{t=1}^{T} \delta_t \max(0.25 \times a_t, i_{i,t}) \qquad (1)$$

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

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 monthly wage in year t, $I_{i,t}$ is the total reported monthly income, and c^1 and c^2 are regularly updated cut-offs set at CZK 12,423 and 112,928 in 2016, respectively.

According to the formula, there is an implicit upper bound on pension benefits 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 replacement rates (pensions to pre-retirement net wages) for the lowest income groups at nearly 100% and less than 25% for individuals with income at or above quadruple of the average income. The average reported replacement rates are at 54.3%.

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 increase as a result of parliamentary action but otherwise remain unchanged in nominal terms. Historically, nominal pensions were supposed to increase at the level of inflation plus one third of increase in real wages. Figure 1 plots changes in nominal retirement benefits, real wages, consumer price index, nominal wages, and a counterfactual scenario in which nominal pensions increase by the suggested amount. We can see that pension indexation surpassed the benchmark in the 2005-2007 period but otherwise indeed remained broadly at the level of inflation plus one third of changes in real wages. The level of indexation in 2019 (not shown) decreased slightly to 3.4% from 3.5% in 2018. Due to less than full nominal wage indexation, replacement rates have been decreasing down to approx.

50.6% for individuals with the average wage. The pension system budget was balanced until the economic downturn in 2008, followed by deficits in the 2009-2016 period and recovery into surplus in 2018.

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), Cipra (2012), Marek (2008) and Schneider (2011). An introduction of a balancing mechanism for the existing PAY-GO system is then briefly analysed by Hyzl et al. (2005).

3.2 Pension Systems in Sweden and Chile

The following section briefly describes the two alternative pension schemes used in the analysis: The World Bank three-pillar system presented in Holzmann et al. (2005), with Swedish pension system being its real-world representative, and a fully funded system with Chilean scheme as its representative. The Swedish pension system is described and analysed in detail e.g. in Brown (2008), Laun and Wallenius (2015), Könberg et al. (2006), Kruse (2010), Palmer et al. (2000), Settergren (2003) and Settergren (2012). The pension system is primarily an unfunded scheme with workers contributing 7% of their earnings and employers contributing 10.21%; 86% of the total contributions finance a PAY-GO component (a defined contribution plan – the income-based pension) and the remaining 14% finance a premium pension component (Swedish Pensions Agency, 2017).

The income-based pension (first pillar) is an unfunded scheme where all contributions are recorded in a personal account and the accumulated virtual funds are then divided by a predetermined annuity divisor upon retirement to determine the regular payments. The premium pension (second pillar) is calculated from accumulated savings using a similar formula (see next section for details). Finally, in addition to the income- based and premium pension, a guaranteed pension, a means-tested benefit, provides minimum pension for individuals older than 65 with low or no income and at least 40 years of residency in Sweden. It is financed from 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 liabilities overweight assets, indexing is lowered proportionally so that the system returns to balance. The mechanism is formally defined in the next section.

In Chile, everyone working with a labour contract is obliged to contribute to the pension 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 (SAFP, 2017). The monthly contributions are set at 10% of pre-tax earnings up to a given upper bound. Besides the funded tier, there is also a form of a safety net (a zero-tier) financed from 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 forms of account balance withdrawal:

a lifetime annuity, programmed withdrawal, temporary income with deferred lifetime annuity, and immediate annuity plus programmed withdrawals. The principle – pre-calculated monthly income adjusted for inflation – is equal in all of them; the difference is in the amount, legal claim on remaining funds, and risk sharing. Only the standard annuity equivalent of the pension benefit calculation in the Swedish premium pension is modelled in this study.

4. 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 Mauner (2009), Zodrow et al. (2013), Ihori (1996), Deger (2008) and others. Additional model details and approach to its estimation are described in the Appendix. The terms economic agents (inhabitants) and households are used interchangeably throughout the model description. The computer script is broadly based on Heer and Mauner (2009) and further developed by the author. Note, that while the model uses the standard general equilibrium modelling framework, some of the scenarios (see Section 4.3) assume specific parameters, such as interest rate on retirement assets, to be exogenous rather than endogenous. This is in line with e.g. Annabi et al. (2011), Beetsma et al. (2003), Miles and Černý (2006) and Rausch et al. (2011), who use OLG models with explicit exogenous parametrisation in a variety of policy-oriented studies. The simulations were done in MATLAB R2016b.

The setup is as follows: at the beginning of each period (year), the remainder of the oldest cohort dies, and a new generation is born. Size of the first new born generation ($t = 1$) is normalised to one, while size of the subsequent generations ($t = 2, ..$) evolves according to the real-world demographic projections. Agents live for maximum of 60 periods and spend the first $T = 43$ years working and the last $T^R = 17$ years retired. The split was selected to broadly correspond to the current standard statutory minimum retirement age of 62-64 years and the average life expectancy of 78 years in the Czech Republic (World Bank, 2018). In line with the existing literature, the first 18 years of actual life are not modelled. Agents 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, subject to an inheritance tax.

Agents are assumed to differ in their education, skills or health status – and therefore productivity and earnings – both within and across cohorts (Heijdra and Reijnders, 2018). To capture intragenerational wealth inequality, each generation is divided into $Z = \{1..12\}$ different income groups. Following Altig et al. (2001), $z = 1$ and $z = 12$ represent the bottom and top 2% of the population cohort s in terms of income, respectively, $z = 2$ and $z = 11$ represent the next bottom/top 8%, with the remaining 8 income classes representing the other eight deciles. Following Heer and Mauner (2009) and Huggett (1996), agents may move between the income groups as a result of idiosyncratic productivity shocks following a Markov process given by:

$$z_t = \zeta z_{t-1} + \epsilon_t, \tag{3}$$

where $\epsilon_t \sim N(0, \sigma_\epsilon)$; the next-period categorisation thus depends on its past realizations. Following Huggett (1996), distribution of agents' initial income follows a log-normal distribution calibrated so that, while the overall wealth distribution is simplified and does not correspond to reality, the resulting wealth Gini coefficient is close to that of the Czech Republic.

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

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

where $\tau_{z,t}$ and w_t are the effective tax rate and equilibrium wage in the economy, respectively, and l denotes 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 as in the Czech Republic.

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 (see the Appendix for further details).

4.1 Household and Firm Optimisation

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

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

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, $c(j,z_j)$ is consumption at age j, conditional on being in income group z_j at that age, σ_u is the intertemporal elasticity of substitution, and $\pi_{j,t}$ represents probability of surviving additional year at age j, 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:

$$\pi_{s,j,t} = \prod_{k=s}^{j+1} (1 - q_{k,t}). \tag{6}$$

Agents maximise lifetime utility subject to a dynamic lifetime budget constraint consisting of labour income $I_{s,z,t}$ (if working), pension transfers $p_{s,z,t}$ (if retired), 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 (only available in the alternative pension schemes), which depends on the particular simulation scenario. In order to narrow down the impacts of a pension reform on retirement income, retirement savings $A_{s,z}^{ret}$ are not considered to raise domestic capital but rather to be invested abroad, i.e. the overall capital levels are always broadly consistent with the PAY-GO scenario. In reality, the additional accumulated capital would likely be partially invested domestically, further accelerating economic growth.

Voluntary savings for retirement – and therefore also their possible transfer to mandatory savings – are not modelled since they work the same way in all pension schemes and implementations and may therefore be disregarded without a change in the outcomes. $A_{s,z}^{ret}$ are assumed to be inaccessible throughout one's work life and thus enter the budget constraint as a liability while working and as pension benefit once retired. The budget constraints are therefore given by:

$$A_{s+1,z,t+1}^{tax} = A_{s,z,t}^{tax}\,(1 + r_{t+1}) + b_{s,z} + I_{s,z,t} - c(s,z) - A_{s,z,t}^{ret} \tag{7}$$

for workers and

$$A_{s+1,z,t+1}^{tax} = A_{s,z,t}^{tax}\,(1 + r_{t+1}) + p_{s,z,t} - c(s,z) \tag{8}$$

for pensioners. Additionally, $A_{s+1,z,t+1}^{tax} = b(z)$ for $s = T + T^R$, i.e. households do not plan any future savings other than bequests for their children in the last period of their lives. Note, that since labour income is inelastic, a shift in agent's consumption-saving pattern is the only way of responding to changes in the budget constraint.

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

$$Y_t = F(\Omega, K_t, N_t) = \Omega K_t^{\alpha} N_t^{1-\alpha}, \tag{9}$$

where Ω denotes a scaling constant representing technological advancement and $\alpha \in (0,1)$ 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. 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:

$$w_t = \frac{(1-\alpha)}{1+\tau^N}\,\Omega K_t^{\alpha}\,N_t^{-\alpha} \tag{10}$$

$$r_t = \alpha\,\Omega K_t^{\alpha-1}\,N_t^{1-\alpha} - \delta \tag{11}$$

4.2 Pension System

The initial pension system specification follows exactly the actual implementation in the Czech Republic, Sweden and Chile. Specifically, pension transfers are determined by income history of new pensioners 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, $rr^e_{z,t}$ can be calculated for each level of income using the income thresholds translated into the model as percentage of the average wage; PAY-GO pension transfers for a person from income group z retiring at age s in year t are then determined as:

$$p^{PG}_{s,z,t} = rr^e_t \sum_{j=1}^{T} \frac{I_{j,z,t-T+j}}{T} \tag{12}$$

Note, that z in $I_{j,z,t-T+j}$ represents income group at age $s = j$ and it may be that $z_j \neq z_T$, i.e. agent's previous income class differs from that at the retirement age. As in reality, pension calculation is based on agent's historical income record and the effective replacement rate rr^e_t is calculated using agent's overall pension base accumulated over time. All agents aged 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 simulation 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^r_t may be increased if pension system liabilities exceed its assets. The pension system is modelled to be in deficit of 0.5% GDP, as in the Czech Republic in 2016, using the pension budget balance equation:

$$\sum_{s=1}^{T} \sum_{z \in Z} (\tau^r_t + \tau^e_t) I_{s,z,t}\, \mu_{s,z,t} \lesseqgtr \sum_{s=T}^{T+T^R} \sum_{z \in Z} \kappa\, p^{PG}_{s,z,t}\, \mu_{s,z,t}, \tag{13}$$

where $\mu_{s,z,t}$ is the measure of generation s in income class z and year t, τ^e_t is the social security contribution paid by employers, and κ is a scaling parameter reflecting the discrepancy between the old-age dependency ratio in the model and in reality, caused by difference in life expectancy vs retirement age and the implicit assumption that every household of working age is employed in the model, as opposed to positive unemployment rates in reality. The scaling parameter is calculated endogenously within the model. There is no inflation assumed in the model.

The premium pension in the multi-pillar scheme and pensions in the fully funded scheme are determined through contributions to designated pension funds. When agents retire, the funds are transformed into an annuity paid regularly for the rest of their lives. Formally, annuities are determined by dividing the funds accumulated by an appropriate annuity divisor D_x. For comparison purposes, calculation of annuity divisors in both the fully funded and the multi-pillar scheme follows the Swedish formula (Swedish Pensions Agency, 2017):

$$p_{s,z,t}^{FF} = \frac{1}{D_x}\left[\sum_{s=1}^{T} (1+r_t)^{T-s}(1-c^A)\, a_{s,z,t}\right] \times (1-c^I) \tag{14}$$

$$D_x = \sum_{j=1}^{T} \frac{1}{(1+r)^j}\frac{L_{j+1}}{L_j} \tag{15}$$

where the first expression in brackets represents the total accumulated wealth – c^A represents administrative fees on assets, c^I represents reduction in pension transfers due to imperfect annuity markets and $a_{s,z,t}$ are savings – and L_j is the number of survivors in age group j per 100,000 born.

Since the formula for calculation of the income-based pension in the Swedish pension scheme results in a substantially higher dispersion of pension benefits within a cohort than in the Czech pension system, it has been replaced by that used in the PAY-GO scheme. At the same time, this unfunded pillar in the multi-pillar scheme is indexed using an automatic balancing mechanism as in the Swedish pension system:

$$\frac{\xi_{s,z,t}^{*}}{\xi_{s,z,t}} = \psi_t \frac{I_t}{I_{t-1}} \tag{16}$$

where $\xi_{s,z,t} = \tau_t^r\, I_{s,z,t}$ 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.

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

$$g_{s,z,t} = 2.13\,\vartheta_t - p_{s,z,t}^{PG} - p_{s,z,t}^{IB} \quad if\;\; p_{s,z,t}^{PG} + p_{s,z,t}^{IB} \leq 1.26\,\vartheta_t \tag{17}$$

$$g_{s,z,t} = 0.87\,\vartheta_t - 0.48\left(p_{s,z,t}^{PG} + p_{s,z,t}^{IB} - 1.26\,\vartheta_t\right)\; if\;\; p_{s,z,t}^{PG} + p_{s,z,t}^{IB} > 1.26\,\vartheta_t \tag{18}$$

where $g_{s,z,t}$ is the calculated pension amount, ϑ_t is a price-related base amount set at 11.59% of average gross income following the Swedish example, and $p_{s,z,t}^{PG}$ and $p_{s,z,t}^{IB}$ represent the PAY-GO and income-based pension. In words, pensioners' benefits are topped up to at least $2.13 \times 11.59\% = 24.7\%$ of the average gross income. This is also shown in Figure 7. Note, that both the original PAY-GO pension and the new source of income (excluding premium pension) are considered in the calculation in case of a structural change to a multi-pillar scheme. The fully funded scheme also includes a safety net p_t^s that tops up pensions 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.

4.3 Calibration

The economy is characterised by labour supply calibrated using data on average annual hours worked from the OECD; intertemporal elasticity of substitution data obtained from Havranek et al. (2015); depreciation and productivity growth rate from the Penn World Tables (Feenstra et al., 2015); income and social security tax rates; and population predictions from the United Nations. The parameter values are presented in Table 1. For simplicity, the model assumes that the baseline productivity growth rate will remain at its historical 2005-2015 average.

Following Zodrow et al. (2013), rate of time preference ρ is set equal to 0.011; variance of earnings for a new born generation is set as $\sigma_{y1} = 0.38$ and the path dependency parameter ζ from Equation 3 is set to 0.96 as in Huggett (1996); variance of idiosyncratic productivity shocks σ_e is set to 0.129 so that the overall wealth distribution in the economy can be characterised by Gini coefficient of 25.9 as in the Czech Republic (World Bank, 2018); 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%.

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. (2015)	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	Feenstra et al. (2015)	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

Notes: [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.

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 population predictions highlight three separate trends – decrease in fertility, increase in mortality, and shift in population structure with large cohorts reaching retirement age in the next decades.

The income and social contribution tax rates are assumed to remain constant regardless of the pension system implemented in order to maintain comparability of the results. In the multi-pillar scheme, 86.5% of all contributions are used to finance the unfunded scheme as per above. In the fully funded pension scheme, the whole amount of contributions from both the employer and the employee are put in the pension funds.

4.4 Scenarios

In what follows, performance of the baseline pension system is compared across multitude of variables, ranging from time and population dimensions to existence of market imperfections and sluggish economic growth. The counterfactuals are principally meant to show the extent of potential changes rather than 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 variable is assumed to change in each scenario. In all scenarios, the existing PAY-GO scheme in its current specification is in place at time $t = 1$ and any structural reforms will take place in $t = 2$.

Starting with pension reforms, two alternative schemes – the multi-pillar and fully funded schemes – are assumed as potential substitutes. 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 initial PAY-GO pensions are still paid during the transition period, yet their amount decreases proportionally to the number of years that the new pensioners contributed to the original 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 low at first and increase over time with contributions made.

From $t = 2$, pension system budget may or may not be forcedly balanced through changes in either the social security tax rate or pension benefits. Specifically, if the pension budget must be balanced and taxes serve as the balancing mechanism, pensions remain unchanged and taxes change accordingly. Analogously, if pensions adjust, tax rates are kept at their original level and pensions for all income groups change proportionally.

Other parameter changes include economic growth, changing as a result of increasing productivity, indexation, changes in retirement age, and asset returns. 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 rate is assumed to be at 50% and 75% of this, while in two optimistic scenarios, it is set to 125% and 150% of the baseline rate. As discussed in Section 3.1, pensions in the Czech Republic in the last 10 years have been indexed at approx. the level of inflation plus one third of increase in real wages. This is used as the baseline scenario; in the alternative scenarios, pensions are not indexed at all or indexed to the full extent of changes in real wages.

Following the discussion from Section 3.1 the baseline scenario assumes that retirement age increases to 64 years in 2023 and to 65 years in 2030 as per the existing legislation in the Czech Republic. In an alternative scenario, retirement age increases further to 66 in 2036 and 67 in 2042. The return on retirement assets is set to 3.5% in the baseline scenario and at 1% and 6% in the pessimistic and optimistic scenarios, respectively, broadly in line with real world pension funds' performance (OECD, 2016). Accumulated government debt is assumed to yield return of 1% pa.

Finally, annuities are assumed to be actuarially fair (i.e. c^A and c^I in Equation (14) are both set to zero) in the baseline scenario. In alternative scenarios, three distinct types of market imperfections are modelled: a financial market crash, administrative costs of running pension funds, and actuarially unfair annuity markets. In the baseline scenario, there are no 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; Sluchynsky, 2015) lower the eventual pension benefits. In a second alternative scenario, these costs 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.

5. Simulation Results

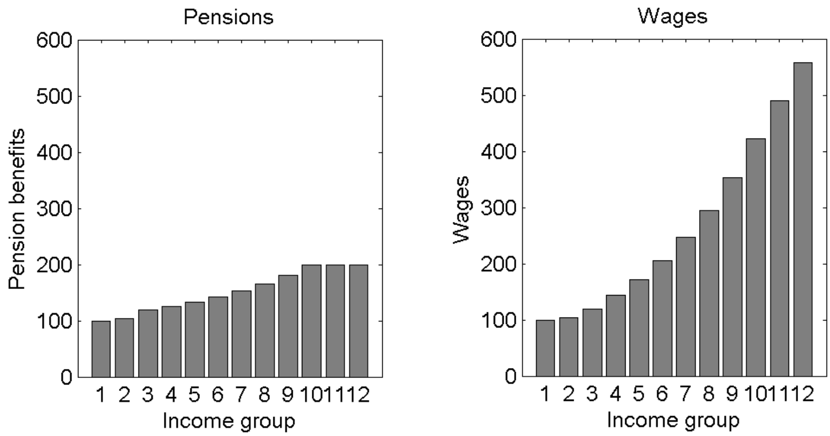
This section first presents the estimated future development of the baseline Czech pension system in the light of the assumed adverse population changes and potential parametric adjustments, followed by a comparison of all three pension schemes in a variety of scenarios. There are five main variables of interest, all of them expressed in real terms in absence of inflation in the model: pensions, degree of intra-generational wealth distribution among pensioners, social security tax rates, pension system indebtedness, and economic growth. The results are presented in several steps, each representing comparison along a different dimension. Throughout this section, period $t = 0$ corresponds to year 2016.

5.1 Baseline Comparison

Let us first inspect distribution of pensions in the baseline model as depicted in Figure 2. 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 intra-generational income equality is one of the main factors distinguishing the Czech PAY-GO scheme from the funded schemes.

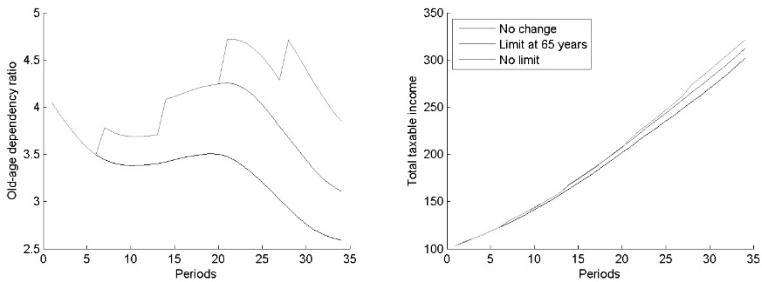
To fully appreciate the adverse population changes, consider the shifts in old-age dependency ratio and total taxable income over time as depicted in Figure 3. Without any adjustments in retirement age, the old-age dependency ratio decreases by nearly 40% over the span of 35 years. Increasing retirement age to 67 years by 2042 would keep share of pensioners in the population virtually unchanged, suggesting an appropriate rate of adjustment. In addition, while postponing retirement age affects principally the expenditure side of the pension budget by reducing the number of pensioners in the economy, we can see from the explicit (b) that the additional workers would help the revenue side as well.

Figure 2 Pension and Income Distribution in the Baseline Pension System, 2016



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

Figure 3 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 balance (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; and *full* real wage indexation) and productivity growth rate. All scenarios assume retirement age to increase to 65 years for both genders by 2030. Changes in the equilibrium wage are not reported as it increases effectively at the same rate as output (see Equation 10).

Starting with output Y_t (column Y in Table 2), it is negatively correlated with pension indexation and there are substantial differences across the productivity growth scenarios. This is a result of the consumption smoothing; households respond to the prospect of a large drop in income when retired in scenarios with low or no indexation, choosing to save more during their working age in order to increase consumption in retirement, which, in turn, leads to a higher output.

Table 2 Baseline Simulation Results – Unbalanced Pension Budgets, No Structural Changes. Assumptions: Limited Retirement Age Increase

				2016					2030					2050		
PGR	***Pen. adj.***	***P***	***P/W***	***Y***	***B***	***CB***	***P***	***P/W***	***Y***	***B***	***CB***	***P***	***P/W***	***Y***	***B***	***CB***
Very low		100%	100%	100%	-0.5%	0.0%	127%	100%	127%	-0.4%	-26%	179%	100%	169%	-5.1%	-62%
Low		100%	100%	100%	-0.5%	0.0%	142%	100%	142%	-0.4%	-26%	234%	100%	221%	-5.1%	-62%
Baseline	Full	100%	100%	100%	-0.5%	0.0%	159%	100%	159%	-0.4%	-26%	306%	100%	288%	-5.1%	-62%
High		100%	100%	100%	-0.5%	0.0%	177%	100%	177%	-0.4%	-26%	399%	100%	376%	-5.1%	-62%
Very high		100%	100%	100%	-0.5%	0.0%	198%	100%	198%	-0.4%	-26%	519%	100%	490%	-5.1%	-62%
Very low		100%	100%	100%	-0.5%	0.0%	109%	85%	128%	2.0%	-5%	122%	67%	173%	1.5%	54%
Low		100%	100%	100%	-0.5%	0.0%	113%	79%	144%	2.9%	4%	134%	56%	228%	3.7%	98%
Baseline	1/3	100%	100%	100%	-0.5%	0.0%	117%	73%	162%	3.8%	12%	147%	46%	300%	5.6%	137%
High		100%	100%	100%	-0.5%	0.0%	122%	68%	181%	4.6%	20%	162%	39%	394%	7.1%	171%
Very high		100%	100%	100%	-0.5%	0.0%	127%	63%	203%	5.4%	27%	177%	32%	515%	8.4%	201%
Very low		100%	100%	100%	-0.5%	0.0%	100%	78%	129%	3.0%	5%	100%	54%	175%	4.0%	104%
Low		100%	100%	100%	-0.5%	0.0%	100%	69%	145%	4.4%	18%	100%	41%	231%	6.7%	161%
Baseline	None	100%	100%	100%	-0.5%	0.0%	100%	62%	163%	5.5%	29%	100%	31%	305%	8.6%	209%
High		100%	100%	100%	-0.5%	0.0%	100%	55%	183%	6.6%	40%	100%	24%	399%	10.1%	248%
Very high		100%	100%	100%	-0.5%	0.0%	100%	49%	205%	7.5%	49%	100%	18%	521%	11.2%	282%

Notes: PGR = Productivity Growth Rate, Adj. = Pension adjustment, Y = aggregate output, P = average pension, P/W = ratio of average pensions to equilibrium wage, B and CB = pension (cumulative) budget balance. Pension and output values standardised using 2016 values. Equilibrium interest rate varies between 3% and 5%. See text for scenario description.

Pensions are reported twice: once in absolute terms and once relative to real wages in the economy (columns P and P/W in Table 2, respectively). By definition, the 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. Similarly, to other variables, the pension-wage ratio is set to 100% in 2016 and higher/lower values in the future correspond to higher/lower pension-wage ratio than in the initial period. Recall from Section 3.1, that replacement rates in the Czech Republic for individuals with an average wage were approx. 50.6% in 2018 (that is, their income decreased by nearly a half once retired); a decrease to 46% in 2050 as in the scenario with the baseline productivity growth and indexation at one third of growth in real wages (row 8, column 2050 P/W in Table 2), which broadly represents the average indexation in the last ten years, therefore corresponds to a real-world replacement rate of 23.3%, which is even lower than the existing social security tax rate of 28%.

Indeed, in scenarios with pensions indexed at one third of real wages (rows 6-10), pension budget ends in a substantial surplus (columns B and CB in Table 2, representing the annual and cumulative pension budget balance, respectively) at the cost of relatively poorer pensioners. This contrast is even starker in the scenarios with indexation only at the level of inflation (rows 11-15), where the pension-wage ratio decreases to just 31% in the scenario with baseline productivity growth, corresponding to real-world replacement rates of 15.7%. The replacement rates remain unchanged only in the scenarios with indexation at the level of growth in real wages, resulting in an accumulated debt of 62% GDP in 2050.

Finally, even though pensioners would maintain their existing relative income levels in the scenario with full pension indexation, this would be only at the cost of enormous indebtedness or cuts in other public policy areas, as all scenarios are estimated to lead to over 5% GDP deficit each year by 2050. Note that the projected indebtedness is equivalent in all scenarios as any changes in tax revenues due to economic growth are exactly matched by increase in pensions. To conclude, there will always be a trade-off between maintaining a balanced pension budget and disparity between income of workers and pensioners, regardless of the level of economic growth.

5.2 Parametric Changes

If one cannot maintain sustainable long-term pension system financing and appropriate replacement rates at the same time regardless of economic growth, can other parametric changes to the current system help? According to Equation 13, in addition to adjusting the pension system's expenditure (pensions) as above, one may also adjust the revenue side (taxes) or their proportions (retirement age). Table 3 presents the 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), all of which assume the baseline aggregate productivity growth. Note, that rows 2, 5 and 8 in Table 3 are equivalent to rows 3, 8 and 13 in Table 2 in their assumptions and results.

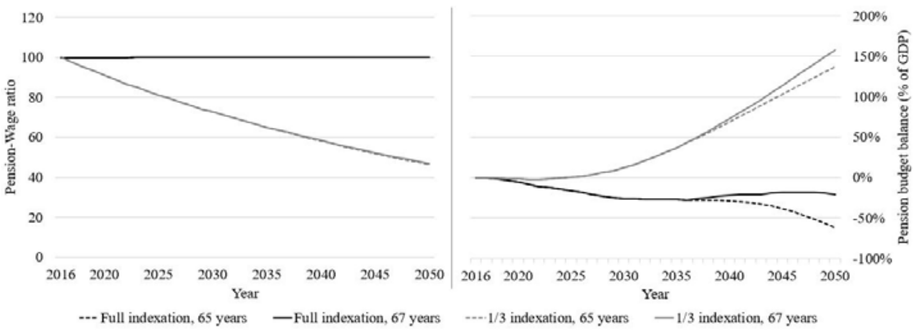
Table 3 Simulation Results of a Parametric Change to the Existing Pension System, Differing by Assumed Retirement Age Increase. Assumptions: Baseline Productivity Growth

		2016					*2030*					*2050*				
Ret. Age	***Adj.***	***P***	***P/W***	***Y***	***B***	***CB***	***P***	***P/W***	***Y***	***B***	***CB***	***P***	***P/W***	***Y***	***B***	***CB***
No change		100%	100%	100%	-0.5%	-0.5%	160%	100%	154%	-3.4%	-40%	308%	100%	277%	-9.1%	-162%
Up to 65	Full	100%	100%	100%	-0.5%	-0.5%	159%	100%	159%	-0.4%	-26%	306%	100%	288%	-5.1%	-62%
Up to 67		100%	100%	100%	-0.5%	-0.5%	159%	100%	159%	-0.4%	-26%	303%	100%	300%	-1.3%	-21%
No change		100%	100%	100%	-0.5%	-0.5%	118%	72%	157%	1.7%	1%	148%	46%	291%	3.9%	79%
Up to 65	1/3	100%	100%	100%	-0.5%	-0.5%	117%	73%	162%	3.8%	12%	147%	46%	300%	5.6%	137%
Up to 67		100%	100%	100%	-0.5%	-0.5%	117%	73%	162%	3.8%	12%	147%	47%	310%	7.3%	157%
No change		100%	100%	100%	-0.5%	-0.5%	100%	61%	159%	3.9%	20%	100%	30%	296%	7.5%	166%
Up to 65	None	100%	100%	100%	-0.5%	-0.5%	100%	62%	163%	5.5%	29%	100%	31%	305%	8.6%	209%
Up to 67		100%	100%	100%	-0.5%	-0.5%	100%	62%	163%	5.5%	29%	100%	32%	314%	9.7%	223%

Notes: R. age = Retirement age, Adj. = Pension adjustment, Y = aggregate output, P = average pension, P/W = ratio of average pensions to equilibrium wage, B and CB = pension (cumulative) budget balance. Pension and output values standardised using 2016 values. Equilibrium interest rate varies between 4% and 5%. See text for scenario description.

Recall, that the proposed linear increase of retirement age up to 67 years of age would keep the old-age dependency ratio virtually constant until 2050 (see Figure 3). As a result, the pension budget would be nearly in balance even in the full-indexation scenario – and in surplus should pensions be indexed at lower rates (see rows 3 and 6, columns B and CB in Table 3).[1] However, increasing retirement age to 65 years and maintaining it at that level thereafter would not be enough beyond 2035 (when the old-age dependency ratio starts to decrease), again resulting in high budget deficits and/or low replacement rates. Equally, old-age dependency ratio is projected to continue decreasing well beyond 2050 – retirement age would therefore need to increase beyond 67 years in the future. One must also consider practical applicability of such changes; increasing retirement age to 67 years may simply not be feasible in reality without appropriate changes to work arrangements for older people. The detailed changes in the pension-wage ratios and pension budget balance over time are depicted in Figure 4, showing the growing disparity in pension budget balance between the two alternative retirement age scenarios from 2035 onwards.

Figure 4 PAY-GO Scheme: Explicit (a) - Pension-Wage Ratios (Left); Explicit (b) - Pension Budget Deficit (Right)



Assumptions: Baseline productivity growth, varying retirement age and pension indexation.

The alternative ways of keeping finances 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 by employees and employers. By definition, pension adjustment is available only in scenarios with taxes serving as a balancing mechanism. All scenarios assume baseline productivity growth rate.

[1] The model slightly overstates the positive impact of a retirement age change due to the assumption of an arbitrary maximum age. In reality, average life expectancy is projected to increase more than in the model due to survival probabilities at ages beyond the maximum age in the model increasing over time, resulting in comparatively greater decrease in the old-age dependency ratio than in the model.

Table 4 Simulation Results of Alternative Pension Budget Balancing Mechanisms. Assumptions: Baseline Productivity Growth

					2016					*2030*					*2050*		
R. Age	***Adj.***	***BM***	***P***	***P/W***	***Tax***	***B***	***CB***	***P***	***P/W***	***Tax***	***B***	***CB***	***P***	***P/W***	***Tax***	***B***	***CB***
No change			100%	100%	28%	-0.5%	-0.5%	156%	100%	34%	0.0%	-0.6%	289%	100%	45%	0.0%	-0.7%
Up to 65	Full	TA	100%	100%	28%	-0.5%	-0.5%	158%	100%	29%	0.0%	-0.6%	296%	100%	38%	0.0%	-0.7%
Up to 67			100%	100%	28%	-0.5%	-0.5%	158%	100%	29%	0.0%	-0.6%	301%	100%	30%	0.0%	-0.7%
No change			100%	100%	28%	-0.5%	-0.5%	118%	72%	25%	0.0%	-0.6%	149%	45%	20%	0.0%	-0.7%
Up to 65	1/3	TA	100%	100%	28%	-0.5%	-0.5%	118%	72%	21%	0.0%	-0.6%	149%	45%	17%	0.0%	-0.7%
Up to 67			100%	100%	28%	-0.5%	-0.5%	118%	72%	21%	0.0%	-0.6%	149%	45%	14%	0.0%	-0.7%
No change			100%	100%	28%	-0.5%	-0.5%	132%	82%	28%	0.0%	-0.6%	197%	62%	28%	0.0%	-0.7%
Up to 65	-	PA	100%	100%	28%	-0.5%	-0.5%	155%	98%	28%	0.0%	-0.6%	231%	74%	28%	0.0%	-0.7%
Up to 67			100%	100%	28%	-0.5%	-0.5%	155%	98%	28%	0.0%	-0.6%	280%	92%	28%	0.0%	-0.7%

Notes: R. age = Retirement age, Adj. = Pension adjustment, BM = Balancing mechanism, TA = taxes adjust, PA = pensions adjust, Tax = social security tax rate, P = average pension, P/W = ratio of average pensions to equilibrium wage, B and CB = pension (cumulative) budget balance. Pension and output values standardised using 2016 values. Equilibrium interest rate varies between 4% and 5%. See text for scenario description.

We can see that the tax changes required to maintain a balanced budget vary substantially across the scenarios (see rows 1-6, column Tax in Table 4), in a similar way to changes in budget deficit in the previous analysis. In particular, the estimates suggest that taxes could be lowered by 50% by 2050 if pensions were indexed only at one third of growth in real wages and retirement age increased to 67 years (row 6). On the contrary, they would need to be increased by more than 17 pp in the scenario with full pension indexation and no changes in retirement age (row 1). Notice, that the output levels are slightly lower in the full indexation scenarios (rows 1-3) compared to results in Table 3. This is due to the assumption that increasing indebtedness has no immediate negative impact on the economy, whereas excessive taxation lowers consumption, savings and equilibrium wage. The difference may be further understated due to the assumption of full employment; in reality, higher taxes may also lead to higher unemployment rates and generally worse macroeconomic performance.

Finally, pensions would decrease by just 8% by 2050 if they served as balancing mechanism and retirement age increased without limits (row 9), and by 26% and 38% in scenarios with limited and no changes in retirement age (rows 7-8), 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 may be reduced proportionally in order to keep the pension budget balanced, as opposed to the automatic balancing mechanism (see Section 5.3), which would lower – or stop – pension indexation, but it would never lead to a decrease in real pensions.

5.3 Pension Reform

The analysis up to this point shows that the only way of maintaining pension-wage replacement rates and pension budget deficits at their current levels in the existing PAY-GO scheme is by increasing the retirement age without limits, keeping the old-age dependency ratio nearly constant over time. This section investigates whether a structural reform – a switch to an alternative pension scheme – would be more beneficial in the long term and what would be the implications in the short term.

In a first set of scenarios, consider a structural change taking place in period t = 2 with no market imperfections, baseline productivity growth, and 3.5% annual return on retirement assets. Table 5 compares the two alternative pension schemes to the baseline PAY-GO scheme (full indexation, unbalanced budget) as above (rows 1-3 in Table 5 are equivalent to rows 1-3 in Table 3).

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

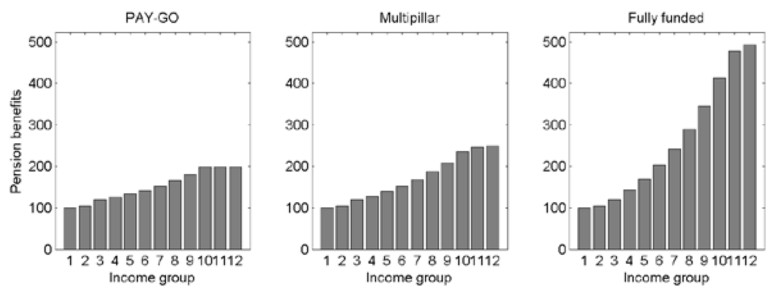
		2016					2030					2050				
PS	**R. Age**	**P**	**P/W**	**Y**	**B**	**CB**	**P**	**P/W**	**Y**	**B**	**CB**	**P**	**P/W**	**Y**	**B**	**CB**
PG	No change	100%	100%	100%	-0.5%	-0.5%	160%	100%	154%	-3.4%	-40%	308%	100%	277%	-9.1%	-162%
	Up to 65	100%	100%	100%	-0.5%	-0.5%	159%	100%	159%	-0.4%	-26%	306%	100%	288%	-5.1%	-62%
	Up to 67	100%	100%	100%	-0.5%	-0.5%	159%	100%	159%	-0.4%	-26%	303%	100%	300%	-1.3%	-21%
M	No change	100%	100%	100%	-0.5%	-0.5%	129%	78%	158%	0.0%	-17%	258%	81%	285%	-2.3%	-37%
	Up to 65	100%	100%	100%	-0.5%	-0.5%	140%	86%	162%	1.3%	-11%	299%	96%	292%	-1.8%	-21%
	Up to 67	100%	100%	100%	-0.5%	-0.5%	140%	86%	162%	1.3%	-11%	355%	116%	301%	-1.3%	-15%
FF	No change	100%	100%	100%	-0.5%	-0.5%	153%	100%	146%	-7.2%	-163%	432%	147%	255%	-1.2%	-277%
	Up to 65	100%	100%	100%	-0.5%	-0.5%	178%	116%	149%	-5.8%	-154%	504%	174%	263%	-1.0%	-251%
	Up to 67	100%	100%	100%	-0.5%	-0.5%	178%	116%	149%	-5.8%	-154%	615%	216%	272%	-0.8%	-246%

Notes: PS = pension scheme (PG = PAY-GO, M = multi-pillar, FF = fully funded), R. age = Retirement age, Y = aggregate output, P = average pension, P/W = ratio of average pensions to equilibrium wage, B and CB = pension (cumulative) budget balance. Pension and output values standardised using 2016 values. Equilibrium interest rate varies between 4% and 6%. See text for scenario description.

In the fully funded scheme, the model suggests substantially higher pensions without a significant effect on budget deficit in 2050 (rows 7-9). This is caused principally by high income classes, as replacement rates become essentially flat across income groups, unlike in the original pension scheme, where they exponentially decrease with income. This is also depicted in Figure 5.[2] Since public expenditure is reduced to payments to individuals caught by the pension safety net, budget deficits caused by adverse demographic changes are no longer a major issue in a fully funded scheme. At the same time, transition to a new pension scheme affects pension budget deficit twice – once due to necessity to finance PAY-GO pensions for all contributors to the old system and once due to inability to benefit from high intra-generational income redistribution as a consequence of low replacement rates of high-earning individuals, who would previously pay nearly the same proportion of their income in exchange for a very limited pension. As the cost of paying out the original PAY-GO pensions is highest in the early years after transition, pension budget deficit is in fact very high initially and decreases over time. Transition to a fully funded scheme thus leads to accumulated debt of more than 250% of GDP by 2050 (see Table 5, rows 7-9, column 2050 CB and Figure 8).

The effects on economic growth may be understated since retirement savings $A_{s,z}^{ret}$ are assumed not to increase domestic capital, but, compared to the PAY-GO scheme, the results indicate that reduction in regular savings as a result of higher pensions would slightly decrease the aggregate economic output (rows 1-3 vs 7-9, column Y).

Figure 5 Intra-Generational 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 gradual changes to structure of the average pensions and pensions received by the lowest income group during a transition to a fully funded scheme are depicted in Figure 6. On average, 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 enough accrued interest, but the funded pensions start to grow more rapidly

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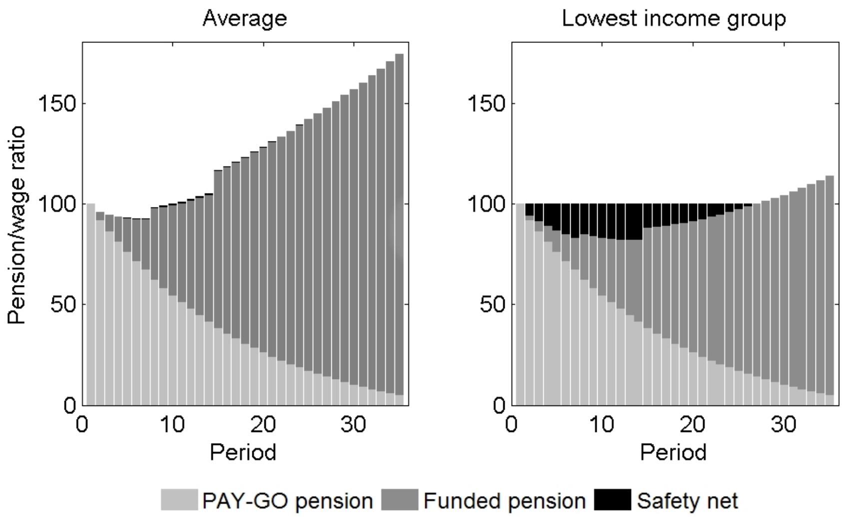
[2] Note, that since the safety net in the fully funded scheme is set so that the lowest income class cannot be worse off in terms of pensions as a result of the transition, virtually everyone in the economy is better off in the new system, although at the cost of increasing indebtedness.

than the PAY-GO pensions decrease in just about ten years after transition, leading to a net increase in pensions. Since replacement rates in a fully funded scheme are constant across generations, retirement age does not need to be adjusted constantly to reflect changes in the population structure as in the PAY-GO scheme. Unlike richer households, the lowest income groups would require additional support from the government through safety net payments as their savings would be too low at first. However, even they are projected to be eventually better off than in the existing scheme.

Figure 6 Composition of Total Pension Benefits, Transition Towards a Fully Funded Scheme



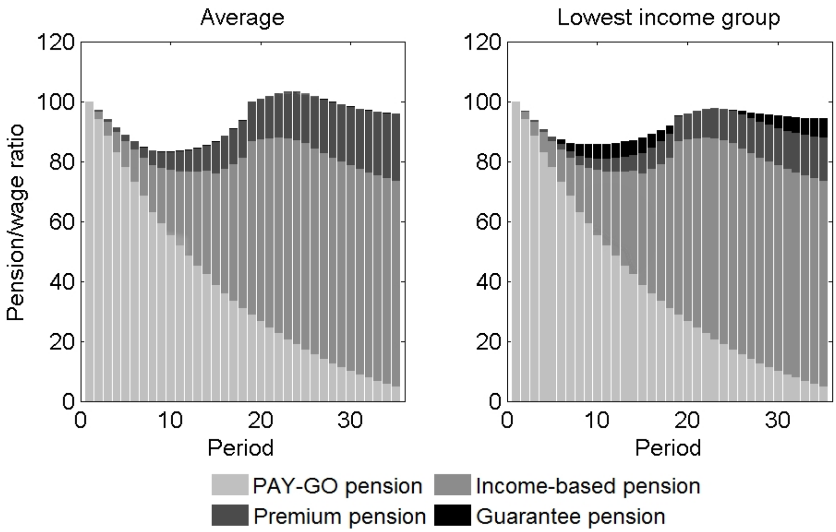
Notes: Pensions standardised within each figure. Assumptions: baseline productivity growth, limited retirement age increase, 3.5% return on savings.

Going back to Table 5, results of the multi-pillar scheme are essentially a convex combination of the other two schemes, proportional to the share of contributions going to the unfunded (86%) and funded (14%) pillars. In particular, the multi-pillar scheme is largely dependent on demographics, yet the automatic balancing mechanism prevents excessive budget deficits. As a result, the pension-wage ratios and budget deficits are generally lower than in the PAY-GO scheme (rows 4-6 vs 1-3, columns B and P/W). The lower pensions also lead to higher savings in standard taxable assets and therefore increased output. At the same time, contributions to the funded pillar accumulate gradually over time and lead to higher pensions than what would be achievable with the same pension budget balance in the PAY-GO scheme, while at a substantially lower cost of transition than the fully funded scheme. Indeed, the pension system accumulates virtually no debt despite the transition while providing higher pensions than the PAY-GO scheme by 2050.

The detailed dynamics of pension transfers are depicted in Figure 7. Similarly to a fully funded scheme, the average pension benefits are projected to drop at first –

in fact more than in the fully funded scheme – due to the guarantee pension set lower than the safety net in the fully funded scheme, pensions of high income classes not able to outweigh the lack of accrued interest, and the balancing mechanism reducing indexation to reflect lower tax revenues and prevent budget deficits. Nevertheless, the pension-wage ratio stabilises within just 8 years, reaches its original level after 20 years and remains fairly constant thereafter using the automatic balancing mechanism. Notice, that since less than a fifth of all contributions goes towards the funded second pillar, the relative pension levels eventually decrease again, following changes in the old-age dependency ratio, yet the share of pensions being financed through the funded pillar increases over time, reducing the system's overall costs to the public.

Figure 7 Composition of Total Pension Benefits, Transition Towards a Multi-Pillar Scheme



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

Pensions of the lowest income group are again topped up; the amount received through the guarantee pension depends only on the income-based pension, as opposed to the safety net in the fully funded system, so the top-up will actually bring pensioners to nearly 100% of the original pension-wage ratio in later stages of the transition. The resulting average replacement rates (Table 5, rows 4-6, column P/W) are thus not a product of high pensions 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. This may further be adjusted through ratio of contributions going towards the funded and unfunded pillars.

Finally, Table 6 shows results of structural changes with various rate of return on retirement assets (rows 1, 3 and 6 are equivalent to rows 2, 5 and 8 in Table 5). There are two facts to highlight. First, notice the high variation in the fully funded pensions (rows 5-7, column P/W) due to accrued interest, depicting strong reliance on performance of financial markets. Second, changes to rate of return on retirement assets have virtually no impact on the pension budget (rows 2-7, columns B and CB) because only a small share of the population is projected to receive additional payments from the government. Indeed, even a low rate of return on savings leads to higher resulting pensions than in the current system and the remaining budget deficit is a consequence of changes in the population structure (multi-pillar scheme) and remaining PAY-GO pensions to be paid (both schemes). On the other hand, the 6% return on savings, which may still be rather low considering the past performance of most state or private owned pension systems in the world (see OECD 2016), provides pensioners with income otherwise unachievable in the PAY-GO scheme.

Note, that the three scenarios reflect both the potential changes in the overall market returns but also differences in savings decisions. That is, while there may be some predefined investment guidelines set by the government as in Chile, where older workers are required to transfer their savings to funds investing principally in fixed-income assets, individuals may otherwise be able to choose from a wide variety of funds differing in their risk-return profiles and the resulting pensions are thus likely to vary to a far greater extent than in the existing PAY-GO scheme, highlighting the need of a proper regulation and education.

5.4 Impact of Market Imperfections

The analysis thus far shows that while the existing Czech PAY-GO scheme leads to redistribution of wealth and therefore helps low income households to have decent pensions despite low contributions, it fares relatively poorly when faced with adverse demographic changes and requires constant increase in statutory retirement age as a result. The funded and multi-pillar schemes are more promising in this regard, offering higher pensions without extensive public indebtedness (disregarding the cost of transition). In reality, however, funded pension schemes also introduce new elements to the analysis – uncertainty and market imperfections (Krueger and Kubler, 2006; Merton, 1983; Sluchynsky, 2015) – that may greatly affect their resulting performance. Two scenarios depicting this are shown in Table 7 and Figure 8. In the first scenario, there is an annual fee on savings made into pension funds and pension annuities are not actuarially fair, giving, on average, pensioners back less than the optimal amount each year. In the second scenario, in addition to market imperfections, a stock market crash occurs at time $t = 10$, leading to a one-off reduction in value of retirement assets. The baseline results for comparison (rows 1, 2 and 5) are equivalent to rows 2, 5 and 8 in Table 5 and assume 3.5% interest rate on retirement assets, full pension indexation in the PAY-GO scheme and retirement age increasing to 65 years.

Table 6 Simulation Results of a Structural Change totThe Existing Pension System, DifferingiIn Assumed Return on Retirement Savings. Assumptions: Baseline Productivity Growth, Limited Retirement Age Increase

		2016					2030					2050				
PS	***IR***	***P***	***P/W***	***Y***	***B***	***CB***	***P***	***P/W***	***Y***	***B***	***CB***	***P***	***P/W***	***Y***	***B***	***CB***
PG	-	100%	100%	100%	-0.5%	-0.5%	159%	100%	159%	-0.4%	-26%	306%	100%	288%	-5.1%	-62%
M	1.0%	100%	100%	100%	-0.5%	-0.5%	135%	83%	162%	1.3%	-11%	270%	86%	294%	-1.8%	-20%
	3.5%	100%	100%	100%	-0.5%	-0.5%	140%	86%	162%	1.3%	-11%	299%	96%	292%	-1.8%	-21%
	6.0%	100%	100%	100%	-0.5%	-0.5%	147%	90%	162%	1.3%	-11%	355%	114%	289%	-1.9%	-21%
FF	1.0%	100%	100%	100%	-0.5%	-0.5%	146%	95%	151%	-5.8%	-154%	307%	103%	273%	-1.0%	-248%
	3.5%	100%	100%	100%	-0.5%	-0.5%	178%	116%	149%	-5.8%	-154%	504%	174%	263%	-1.0%	-251%
	6.0%	100%	100%	100%	-0.5%	-0.5%	223%	147%	147%	-5.9%	-155%	886%	319%	252%	-1.0%	-253%

Notes: PS = pension scheme (PG = PAY-GO, M = multi-pillar, FF = fully funded), IR = Return on savings into pension funds, Y = aggregate output, P = average pension, P/W = ratio of average pensions to equilibrium wage, B and CB = pension (cumulative) budget balance. Pension and output values standardised using 2016 values. Equilibrium interest rate varies between 4% and 6%. See text for scenario description.

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

				2016					*2030*					*2050*		
PS	***Scenario***	***P***	***P/W***	***Y***	***B***	***CB***	***P***	***P/W***	***Y***	***B***	***CB***	***P***	***P/W***	***Y***	***B***	***CB***
PG	-	100%	100%	100%	-0.5%	-0.5%	159%	100%	159%	-0.4%	-26%	306%	100%	288%	-5.1%	-62%
	-	100%	100%	100%	-0.5%	-0.5%	140%	86%	162%	1.3%	-11%	299%	96%	292%	-1.8%	-21%
M	AC	100%	100%	100%	-0.5%	-0.5%	137%	84%	162%	1.3%	-11%	278%	89%	294%	-1.8%	-21%
	AC+C	100%	100%	100%	-0.5%	-0.5%	130%	80%	163%	1.3%	-11%	269%	86%	295%	-1.8%	-21%
	-	100%	100%	100%	-0.5%	-0.5%	178%	116%	149%	-5.8%	-154%	504%	174%	263%	-1.0%	-251%
FF	AC	100%	100%	100%	-0.5%	-0.5%	155%	101%	150%	-5.8%	-154%	361%	122%	270%	-1.0%	-249%
	AC+C	100%	100%	100%	-0.5%	-0.5%	113%	74%	153%	-5.7%	-153%	301%	101%	273%	-1.0%	-247%

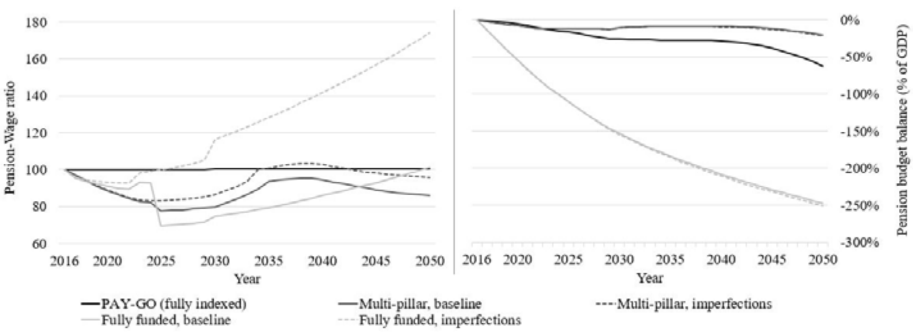
Notes: PS = pension scheme (PG = PAY-GO, M = multi-pillar, FF = fully funded), AC = Administrative costs, AC+C = Administrative costs and stock market crash, PY = aggregate output, P = average pension, P/W = ratio of average pensions to equilibrium wage, B and CB = pension (cumulative) budget balance. Pension and output values standardised using 2016 values. Equilibrium interest rate varies between 4% and 6%. See text for scenario description.

The alternative scenarios have no impact on the pension budget as pensions are generally high enough for most people to not require further support from the government. Pensions, on the other hand, differ substantially in the alternative scenarios. This is particularly true for the fully funded system, where pensions decrease by nearly 30% on average in 2050 compared to the optimal baseline scenario (rows 4-5, column P/W) just due to administrative costs and imperfect annuity markets. The effect of stock market crash is partially hidden in the table as it happens prior to 2030, yet we can clearly see the further difference in the resulting pensions (rows 4 and 7).3

The projected long-term benefits of a transition to a fully funded scheme, offering higher pensions at lower cost to the public, are thus not guaranteed and come only at the cost of an enormous pressure on the public finances during the transition period. There are ways to reduce this cost or distribute it over time; for instance, Chile offered workers a choice between the old PAY-GO pension and the new pension scheme, in which previous contributions would be reflected in the future annuities, in effect maintaining at least some inflow of funds in the system. In the Czech Republic, the cost could also be partially offset by reduction in social security taxation to levels in other countries. Notwithstanding that, the costs would still be extremely high and the pension system challenges would all but shift from adverse demographics to poorly performing financial markets.

The multi-pillar scheme, if properly set up, diversifies the two risks at a considerably lower cost of transition. In particular, Figure 8 shows that the impact of a stock market crash is negligible even in the short-term and that the long-term financial sustainability is still improved compared to the PAY-GO scheme as a result of introduction of a funded pillar. In addition, the automatic balancing mechanism ensures that the budget would return to balance as soon as possible, as opposed to the existing scheme.

Figure 8 Structural Changes: Explicit (a) - Pension-Wage Ratios (Left); Explicit (b) - Pension Budget Deficit (Right)



Assumptions: Baseline productivity growth, retirement age increase up to 65 years, 3.5% return on savings.

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[3] The actual effect of a stock market crash is underestimated in the model as the retirement savings $A_{s,z}^{ret}$ are considered effectively separated from the economy and there is no contagion effect spreading potential crisis across borders assumed in the model.

6. Conclusions

Large post-war generations reaching retirement age and persistent trends of decreasing fertility and mortality are putting pension systems in many countries under an unprecedented pressure and are expected to do so in the next years and decades. The Czech Republic, with its ageing population and an unfunded pension system with vast majority of pensions financed from taxes collected within the same period – and thus heavily reliant on the old-age dependency ratio – is a prime example of the growing challenges. Indeed, it is clear that substantial changes to the existing scheme need to be made in order to avoid an excessive debt burden put on the next generations and that each year passed without a change will make such adjustments more difficult.

As noted by Alonso-García et al. (2018), the challenges to PAY-GO pension systems are threefold: they need to provide an adequate income for pensioners in retirement; pensions need to be in a reasonable proportion to contributions paid; and the pension system needs to be financially sustainable in the long run. While these are conflicting goals, it may be possible to improve in all directions at once by increasing efficiency or changing structure of the system, rather than just its parametrisation.

This study analyses both parametric and structural changes to the Czech pension system with the aim of estimating their long-term impact on pensioners and the system as a whole. The analysis is done through computer simulations of a bespoke OLG model of the Czech pension system, as well as two alternative schemes based on the real-world pension systems in Sweden and Chile. Using the latest projections of population ageing and various assumptions regarding economic growth, returns on retirement assets and pension system parametrisation – minimum retirement age, indexation of pensions, tax vs debt financing – the model indicates how each counterfactual scenario scores in the three conflicting measures above.

The results suggest that, conditional on a continuous economic growth, a decrease in the old-age dependency ratio due to population ageing may not necessarily lead to lower real pensions while keeping pension budget balanced in the existing PAY-GO scheme. At the same time, this is only at the cost of a growing disparity between pre-retirement earnings and pension benefits. Specifically, the real-world average replacement rates are estimated to decrease from 50.6% to just 23.3% in 2050 in a scenario with baseline productivity growth if pensions are indexed at the current level, i.e. inflation plus one third of changes in real wages. To avoid that, indexation must follow nominal wages completely; this would almost certainly lead to explosive pension budget deficits in absence of an increase in social security taxation or retirement age. Importantly, the numerical simulations show that a gradual increase in the statutory retirement age up to 67 by 2042 may indeed almost entirely offset the adverse demographic changes until then, maintaining financially sustainable pension system and constant replacement rates. Nevertheless, retirement age would need to continue increasing even beyond that in the future, raising a question of practicality of such a scenario.

Funded pension schemes may seem as an attractive alternative, offering greater protection against adverse demographic changes and providing a direct link between contributions paid and benefits received, providing improved results in all three dimensions cited by Alonso-García et al. (2018). However, the account balances transformed into lifetime annuities are inherently dependent on performance of financial markets and imperfections of annuity markets, potentially resulting in even lower pensions than in the existing PAY-GO scheme with no pension indexation. What is more, achieving desirable savings is possible only if interest rate on savings is at or above the growth rate of real wages. Transition towards a fully funded scheme would also be extremely costly, accumulating a debt of over 250% GDP by 2050, and lead to substantially different distribution of wealth in retirement compared to the highly redistributive existing PAY-GO scheme, which would likely face a fierce opposition in reality.

The multi-pillar scheme modelled according to the existing Swedish pension system with indexing deter- mined using an automatic balancing mechanism and a guarantee pension paid to the lowest income groups, emerges as perhaps an optimal compromise. It is vulnerable to both adverse demographic changes and financial market downturn, yet to a lesser extent than each of the individual schemes – plus this conflicting dependency may be adjusted by changing the PAY-GO and funded financing. In addition, a transition towards a multi-pillar scheme would be far less costly than to a fully funded one. In fact, the accumulated debt by 2050, including the cost of transition, is estimated to be lower in the multi-pillar scheme than in the existing PAY-GO scheme, although at the cost of lower pensions**.**

APPENDIX

The following text expands on the model description from Section 4 and some of its limitations. Throughout the *Appendix*, $A_{s,z,t}$ represents taxable capital stock consisting of non-retirement assets of an agent of age s in income class z in period t, referred to as $A_{s,z,t}^{tax}$ in Section 4. In each period, new agents are born without wealth, $A_{1,z,t} = 0$, but may start accumulating capital through savings. Analogously, in the last period, agents sell all of their remaining capital stock for consumption and bequests left for their children.

Model Equilibrium

The economy is assumed to be in an equilibrium in each period. The concept of equilibrium uses a recursive representation of the consumer's problem following Heer and Mauner (2009) and is characterised by the following properties:

1. Individual and aggregate behaviour are consistent:

$$N_t = \sum_{s=1}^{T} \sum_{z \in Z} e(s,z)\, l\, \mu_{s,z,t}, \tag{19}$$

$$K_t = \sum_{s=1}^{T+T^R} \sum_{z \in Z} A_{s,z,t}, \tag{20}$$

$$C_t = \sum_{s=1}^{T+T^R} \sum_{z \in Z} c(s,z,t), \tag{21}$$

2. Agents' dynamic programs and firms' optimisation problems are solved by satisfying Equations (5)–(11) using the relative prices w_t, r_t, pensions, and the individual policy rules $c_s(.)$ and $A_{s+1}(.)$.
3. The goods market clears:

$$\Omega K_t^{\alpha} N_t^{1-\alpha} = C_t + K_{t+1} - (1-\delta) K_t. \tag{22}$$

The market equilibrium does not require pension budget to be balanced and therefore pensions to be set at an equilibrium level. On the contrary, various scenarios used in this study explicitly assume unbalanced government budget with exogenously given pension indexation. Equally, the interest rate on retirement assets is set exogenously in some scenarios, rather than equal to the equilibrium interest rate. This does not invalidate the market equilibrium as Equations 19-22 still hold and the exogenously given parameters are part of agents', firm's and government's decision-making processes, affecting consumption or social security tax rates. This is in line with previous studies (see e.g. Annabi et al. 2011; Beetsma et al. 2003; Miles and Černý 2006; Rausch et al. 2011).

Inheritance Process

As described in Section 4, all agents are assumed to have children at age $T^P = 30$, leave bequests at the time of death, and face positive probability of death throughout their lives with a certain death at age $T + T^R$. The computer script does not simulate individual agents but rather the entire cohorts consisting proportionally of the $z = \{1..12\}$ income groups; each cohort aged $\{1..(T + T^R - T^P)\}$ thus receives some bequests each year. For simplicity, the model assumes that bequests received are proportional to own income, i.e. that poor/rich parents have poor/rich children. Assets of agents who die prior to age T^P are taken by the government. The average bequest per agent from income group z received when aged s in period t is thus equal to the total bequests left by agents from the same income group z who died aged $s + 30$ in the same period t, divided by the cohort size $\mu_{s,z,t}$:

$$b_{s,z,t} = \left(1 - \pi_{s+30,t}\right) A_{s+30,z,t} \frac{\mu_{s+30,z,t}}{\mu_{s,z,t}} \tag{23}$$

where $\pi_{T+T^R,t} = 0$.

Solution Method

The simulation algorithm used in this study is based on Heer and Mauner (2009) and Nishiyama and Smetters (2007) and utilises value function iteration to compute agents' policy functions for respective periods and shocks. Specifically, the agent's decision functions are calculated using backward induction, i.e. by analysing the optimal behaviour in the last period of agent's live and, conditional on that, in all preceding periods.

Let $V_s(A_{s,z}, z_s)$ be the value of the objective function of an s-year old agent from income group z with wealth $A_{s,z}$ and idiosyncratic productivity level z_s. $V_s(A_{s,z}, z_s)$ is defined as the solution to the dynamic program:

$$V_s(A_{s,z}, z_s) = \max_{A_{s+1}, c_t} \{U(s,z) + \pi_s \left[V_{s+1}(A_{s+1}, z_{s+1})(1+\rho)^{-1} \mid A_{s,z}, z_s\right]\} \tag{24}$$

That is, subject to the budget constraints, optimal decision rules for consumption and next-period capital stock are functions of wealth and the idiosyncratic productivity shock, and associated with every optimal next period capital stock $A_{s+1}(A_{s,z}, z_s)$ is an optimal consumption policy $c(s,z)$. Note, that the agents implicitly take into consideration any potential inheritance received or given as per Equations 7-8.

Consequently, in each period, all agents can calculate the optimal consumption and saving behaviour in that period given their age, income group, probability of death and moving to another income group in the next period, and the existing market prices w_t and r_t, tax rates, pensions, and interest rate on retirement assets – all of which they are aware of. However, while agents can predict their own behaviour in the future (e.g. when they retire and how much they would consume given the projected income), the model assumes that they are unable to make proper predictions regarding the economy as a whole and assume, given the lack of a better estimate, that the market prices and other parameters would remain at their existing levels (note, that there is no inflation in the model). This includes inability to properly calculate impacts of long-term demographic changes assumed throughout this study or the resulting government's reaction. As a result, the number of possible scenarios to calculate decreases exponentially compared to a model with perfect foresight, making the computational time more manageable.

The main simulation process can thus be characterised as follows:

1. Parametrise the model and compute aggregate employment N_t.
2. Make an initial guess on the equilibrium values of K_t and compute values of w_t, r_t, pensions and other endogenously determined parameters.
3. Compute the household's decision functions by backward induction.
4. Compute the optimal consumption and saving behaviour for each cohort alive in period t.
5. Calculate the aggregate capital stock K_t.
6. Update K_t and repeat the process until convergence.
7. Once a market equilibrium is found, proceed to the next period and repeat the entire process, using K_{t-1} as a best guess for K_t.

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