LISBON
SCHOOL OF
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UNIVERSIDADE DE LISBOA

MASTER

MASTER'S IN ACTUARIAL SCIENCE

MASTER´S FINAL WORK

DISSERTATION

ASSESSING THE SUSTAINABILITY OF A PUBLIC PENSION SYSTEM: THE CASE OF BRAZIL

FILIPE DE OLIVEIRA BELLO

NOVEMBER - 2020

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SUPERVISION:
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Abstract

Brazil has experienced an increase of nearly seven points in the Old-Age Dependency Ratio, from 7.0 in 1990 to 13.8 in 2020. Projections estimate it will rise to 36.2 in 2050, which means that there will be approximately 36 individuals aged 65 and over per 100 individuals of working age.

In 2018, the combined deficit in the pension system was close to 6% of the GDP and the deficit of the RPPS (state level) was quite disproportionate. Moreover, in 2019, the condition of the Brazilian public finance was very serious and for the sixth year in a row it was in deficit. The imbalance was mainly caused by the social security deficit. Doubts about the sustainability of the pension system are very pertinent nowadays and a reform was approved and started to be implemented in 2019.

Considering all these elements, the purpose of the work is to provide new insights on the subsistence of the Brazilian public pension system. The goal is to project the revenue and the benefits until 2100, under alternative parametric pension changes and also under a systematic reform, namely the shift to a DC system. Transition costs and other expenses, and the costs related to the minimum guaranteed pension, are also accounted for.

The findings proved that the reform started in 2019 improves the balance and allows the huge deficit in RGPS to decrease for the next ten years, but an increase will be observed from that time on - although of a much less amount than it what would be in a pre-2019 reform scenario. Therefore, it is very likely that the discussion about the sustainability of the system will be again the order of the day in a few years. Further actions must be put into practice.

Exploring the proposed alternatives, results show that the most effective options seem to be to increase the retirement age by linking it to longevity and the switch to a DC scheme. In particular, switch to NDC scheme, seems to solve the problem in the long run.

Keywords: Pension system; Sustainability; Projection; Parametric reform; Systematic reform; PAYGO; FDC; NDC.

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Resumo

O Brasil experimentou um aumento de cerca de sete pontos percentuais no Índice de Dependência de Idosos, de 7,0 em 1990 para 13,8 em 2020. As projeções estimam que este indicador aumentará para 36,2 em 2050, o que significa que haverá aproximadamente 36 indivíduos com 65 ou mais anos por 100 indivíduos em idade ativa.

Em 2018, o défice combinado do sistema de pensões do país era próximo a 6% do PIB, verificando-se ainda ser o desequilíbrio do RPPS (nível estadual) particularmente desproporcionado. As finanças públicas brasileiras encontram-se atualmente numa situação grave e em 2019 registou-se um défice pelo sexto ano consecutivo. O desequilíbrio foi causado principalmente pelo déficit previdenciário. As dúvidas sobre a sustentabilidade do sistema estão na ordem do dia, tendo inclusivamente sido aprovada uma reforma em 2019, cuja implementação foi já iniciada.

Considerando todos estes elementos, o objetivo do presente trabalho é fornecer um contributo que dê algumas indicações sobre o futuro do sistema público de previdência brasileira. Isso passa pela projeção das receitas e dos benefícios até 2100, tendo como base propostas sobre diferentes cenários de alteração nas regras atualmente vigentes e, até, propostas sobre cenários de uma reforma sistemática, nomeadamente a passagem para um sistema CD. Os custos de transição e outras despesas e os custos relacionados com a pensão mínima garantida, também são contabilizados.

Os resultados comprovaram que a reforma iniciada em 2019 melhora o equilíbrio, e permite que o enorme déficit do RGPS diminua nos próximos dez anos, mas um aumento será observado a partir de então - embora em valor bem menor do que o que se teria num cenário pré reforma de 2019. Portanto, é possível que a discussão sobre a sustentabilidade do sistema volte a estar acesa dentro de alguns anos, se nada mais for feito. Outras ações devem ser postas em prática.

Explorando as alternativas propostas, os resultados mostram que as opções mais eficazes parecem ser aumentar a idade de aposentadoria vinculando-a à longevidade e a mudança para um esquema de CD. Em particular, mudar para o esquema NDC, parece resolver o problema no longo prazo.

Palavras-chave: Sistema de pensões; Sustentabilidade; Projeção; Reforma paramétrica; Reforma sistemática; PAYGO; FDC; NDC.

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List of Abbreviations

CAP	*Caixas de Aposentadorias e Pensões*
CF	Cash Flow
COFOG	Classification of the Functions of Government
DB	Defined Benefit
DC	Defined Contribution
DTM	Demographic Transition Model
FDC	Funded Defined Contribution
FUNRURAL	*Fundo de Assistência ao Trabalhador Rural*
IAP	*Institutos de Aposentadorias e Pensões*
IAPAS	*Instituto de Administração Financeira da Previdência e Assistência Social*
IATS	Individual Accounts Total Stock
ILO	International Labour Organization
IMF	International Monetary Fund
IMR	Infant mortality rate
INAMPS	*Instituto Nacional de Assistência Médica da Previdência Social*
INPS	*Instituto Nacional de Previdência Social*
INSS	*Instituto Nacional do Seguro Social*
LOPS	*Lei Orgânica de Previdência Social*
MGP	Minimum Guaranteed Policy
NDC	Notional Defined Contribution
NPV	Net Present Value
NRA	Normal Retirement Age
OECD	Organisation for Economic Co-operation and Development
PAYGO	Pay-As-You-Go
RGPS	Regime Geral de Previdência Social
RPPS	Regime Próprio de Previdência Social
UN	United Nations
WB	World Bank

Chapter I – Introduction

1.1. Overview

The existing public pension system in Brazil is characterized as a Defined Benefit (DB) Pay-As-You-Go (PAYGO) system. Currently, this is the type of pension arrangement that prevails in most developed countries, particularly in Latin America. Despite being the most widespread pension system in the region, this type of pension system is the most exposed to potential demographic disequilibrium's, which has led to concerns regarding its sustainability (Holzmann, Palmer, & Robalino, 2013). One of the main issues results from the fact that last decades have been characterized by declining fertility and increasing longevity, which inherently led to an ageing of the total population.

Brazil has experienced an increase of roughly seven points in the Old-Age Dependency Ratio (ratio of individuals aged 65 years and over to the working population), from 7.0 in 1990 to 13.8 in 2020, according to United Nations (UN) data (OECD, 2019). Additionally, recent projections from the same source show an expected increase in the Old-Age Dependency Ratio to 36.2 in 2050. Overall, this means that there would be approximately 36 individuals aged 65 and over per 100 individuals of working age. Still in line with the same source, life expectancy at birth in the country is 76.6 years, and 22.7 at the age of 60.

Recently[1] the official normal retirement age was set at 62 (women) and 65 (men), in the case of urban workers, and 55 (women) and 60 (men), in the case of rural workers. Transition rules have been produced for a number of existing situations. Because the pension system is under a transition phase, the Organisation for Economic Co-operation and Development (OECD, 2019) estimates that the average retirement age for a person who entered the labor force at age 22 is in fact 52 (women) and 57 (men).

Life expectancy at birth is one of the considerations in evaluating the sustainability of social security systems. Life expectancies at birth and at the retirement age tend to converge in several countries, see for instance (United Nations, 2019 a). With respect to Brazil, the current difference is 6.1 years, that is, life expectancy at birth is 76.6 years and a retiree expects to survive till the age of 82.7. The same source estimates that by the end of this century the difference will decline to 1.9 years, the life expectancy at birth being 87.7 years and 89.6 years old at retirement. Common

[1] For more details, http://www.brasil.gov.br/novaprevidencia/#novas-regras (retrieved October 2020)

significant reasons for this phenomenon are the economic progress and the technology advances in the health system, which have decreased mortality, in particular child mortality, and at the same time have boosted life expectancy at all ages.

The share of old-age individuals in the population and longevity, in agreement with (United Nations, 2019 a), are on a firm growth line: in 2010, 2020 and 2030, respectively, roughly 13.3 million, 20.4 million and 30.4 million people are aged over 65, and the life expectancy at birth is 74.3, 76.6 and 78.5. Additionally, the life expectancy at retirement age (62 for women and 65 for men) is 22.7 for women and 17.1 for men based on the most recent mortality table in Brazil (Instituto Brasileiro de Geografia e Estatística, 2018).

Along with mortality, fertility is an element of population growth, reflecting both the causes and effects of economic and social developments. Following (OECD, 2019) the motives for the accent deterioration in birth rates during the past few decades, see ***Table 1***, include postponed family formation and child-bearing and a decrease in desired family sizes.

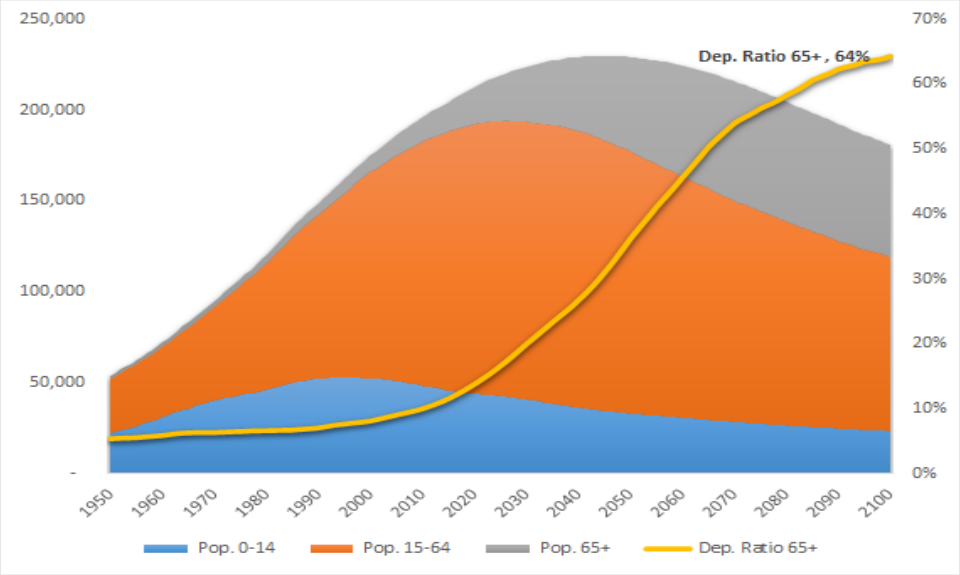
Table 1- Brazilian demographic indicators 1990-2050

	1990	2000	2010	2020	2030	2040	2050
Population (10^6)	149.0	174.8	195.7	212.6	223.9	229.1	229.0
Fertility rate (%)	2.7	2.1	1.8	1.7	1.6	1.6	1.6
Young age pop. (≤ 15yo 10^6)	52.4	52.3	48.6	44.0	40.9	36.4	33.1
Young age pop. (≤ 15yo %)	35.2	29.9	24.8	20.7	18.3	15.9	14.5
Working age pop. (15 to 64yo 10^6)	90.3	113.3	133.8	148.2	152.6	152.1	143.8
Working age pop. (15 to 64yo %)	60.6	64.8	68.4	69.7	68.2	66.4	62.8
Old age pop. (≥ 65yo 10^6)	6.4	9.2	13.3	20.4	30.4	40.6	52.0
Old age pop. (≥ 65yo %)	4.3	5.2	6.8	9.6	13.6	17.7	22.7
Dep. Ratio (old / working age %)	7.0	8.1	10.0	13.8	19.9	26.7	36.2
Dep. Ratio (old / young age %)	12.1	17.5	27.5	46.3	74.4	111.6	157.0
Life expectancy at birth (total)	67.3	71.0	74.3	76.6	78.5	80.3	82.1
Life expectancy at 60 (total)	18.0	19.8	21.4	22.7	23.7	24.7	25.8

Source: Author, based on UN (United Nations, 2019 a) data.

As the population is evidently aging, (United Nations, 2019 a) estimates that the number of people over 65 will be close to 61 million by 2050, which would represent about 27% of the whole population. Overall, it might be concluded that if such demographic development persists, the Brazilian social security scheme might be under serious pressure in the upcoming decades. Questions about the equilibrium of the pension system and whether the health system can handle with the new reality are more relevant. ***Figure 1*** shows that there are reasons for these concerns.

Figure 1- The evolution of Brazilian population



Source: Author, based on UN (United Nations, 2019 a) data.

1.2. The problem

In 2019, the condition of Brazilian public finance was very serious and for the sixth year in a row it was in deficit (Tribunal de Contas da União, 2019). The imbalance was mainly caused by the social security deficit, which has increased considerably in recent years. In fact, the large deficits in social security have taken away resources from social policies and public investments (Tribunal de Contas da União, 2019). ***Table 2*** shows expenditure in key government areas in 2019. It is important to point out that it only accounts for federal expenses, state and local levels have not been included.

Table 2- Main expenditures in Brazil in 2019

	Value (BRL 10^9)	GDP (%)
Health system	126.0	1.74
Public investment	42.5	0.59
Security	11.3	0.16
Education	114.0	1.57
Public debt	285.2	3.93
Social security	767.8	10.58

Source: Author, based on (Tribunal de Contas da União, 2019).

Pension reform in Brazil is necessary (World Bank, 2017), as the system is already in a critical stage. First, because the weight of the expenses in the public budget is so high, that it has a particularly important role to play in the ongoing fiscal adjustment effort. Social security amounts to around one third of total government spending, with a disproportionately large portion attributable to one of the regimes (*Regime Próprio de Previdência Social* - RPPS - for civil servants), which alone accounted for 4.5% of GDP in 2018, and covers only 1.5% of the population. Second, a postponement in or an

flexibilization of the planned pension reform could be costly. Still in line with World Bank, the history of RPPS demonstrates the difficulty of reducing pension deficits if reform is delayed or introduced too timidly.

The time for the percentage of population over age 60 to double, from 10% to 20%, is 2035 (World Bank, 2017). The same source estimates that, with no reform, the deficit of other large regime in the country (*Regime Geral de Previdência Social* – RGPS – that covers the private sector workforce) will reach 16% of the GDP, by 2066. If Brazil wants to avoid a rapid increase in the RGPS deficit, without changing the value of pension benefits, it would have to roughly double the contribution rate of workers by 2035, to around 60% of gross wages. By 2065, when there will be two pensioners per contributor, the same source (World Bank, 2017) estimates the contribution rate would have to double again to 120%.

1.3. Objectives of the study

Considering all the elements described before, this study aims to project the revenue and the expenses for the RGPS until 2100. Particular attention will be given to the pensions system sustainability and parametric and systematic scenarios will be presented in order to quantify the distributive aspects.

For this purpose, a simple integrated methodology to project public pension cash flows over the long term was developed. Particular attention is given to the items where public spending pressures are expected to increase significantly, due to demographic trends. The goal is to simulate alternative pension reforms, including the transition from a PAYGO to a Notional Defined Contribution (NDC) or a Funded Defined Contribution (FDC) system, and the minimum guaranteed pension cost under the latter. In spite of its unpretentiousness, the methodology produces projections that performs in comparison with other works. It therefore offers a good benchmark for assessing alternative reform scenarios.

The thesis is divided into five chapters, including this ***introduction***. ***Chapter 2*** contains an in-depth analysis of the existing literature, exploring what has already been done in terms of research in this particular field, and brings out the great relevance of the theme. ***Chapter 3*** and ***Chapter 4*** correspond to the empirical component, with the methodological approach to the problem in hand, in order to obtain the answers to the research questions: ***Chapter 3*** exhibits the choice of method with a deep and carefully understanding of all inputs used and explains the methods used for measuring the variables and data used in the research process; ***Chapter 4*** reports and analysis the results. ***Chapter 5*** concludes.

Chapter II – Literature Review

In this chapter, it starts by reviewing some general contributions about pension systems worldwide. Then it presents the legal framework that has accompanied the efforts made in Brazil with regard to social protection, as this is the first step to understand the present situation in the country. It closes the chapter discussing some of the more recent contributions about the Brazilian old age pensions system.

2.1. A worldwide overview

(OECD, 2018) report remind the readers that pensions are intended to offer people this security once they can no longer earn their living themselves. They could be financed by the State from general revenues, or through the payroll taxes, on a PAYGO, or they could be fully funded through individual contributions and accumulated assets. Roughly, the amounts of the benefit can be defined according to a formula, case called DB, or they may depend on the amount of assets accumulated, which is called defined contribution (DC). The report explains that, in practice, national systems usually combine PAYGO and funded, DB and DC, and public and private elements. Public pensions have typically been DB in nature and financed on a PAYGO basis, but the increased longevity, along with the declining ratio of actively employed contributors to retired beneficiaries, are real threats to their sustainability.

(Williamson, 2001) elucidates that currently many public old-age pension schemes are still based on the PAYGO model. DC schemes have been in place for many decades, but for a long time they were only found in private and occupational pension plans. In 1981, Chile became the first nation to shift from a PAYGO scheme to a funded DC scheme. During the 1990s a number of other nations, including seven in Latin America, reformed their models and shifted from PAYGO to fully funded DC schemes, or to a mixed model that included a funded DC component in combination with a PAYGO system.

Since 2015, the pace of reforms in OECD countries has slowed and changes have been less widespread (OECD, 2017). Some countries have altered tax incentives, contributions, retirement ages or benefits.

Stress remains to preserve economically and satisfactory supportable levels of pensions as population ageing is a speeding up in most OECD countries (OECD, 2019). There were two people older than 65 years for every ten people of working age in the OECD in 1980. By the end of 2020 this number is expected to be slightly greater than three, and almost six by 2060. The working age

population, calculated using fixed age thresholds, is expected to have reduced by more than one-third in 2060 in several countries. Since 2017, contribution rates were changed in Hungary, Iceland and Lithuania; old-age safety nets and minimum pensions increased in Austria, France, Italy, Mexico and Slovenia, as well as benefits for low earners in Germany. Exclusively Estonia has elevated the retirement age, nonetheless, Slovakia, Netherlands, Italy has restricted previously disclosed increases in the retirement age or extended early-retirement options.

There is an obvious consensus (Acosta-Ormaechea, Espinosa-Vega, & Wachs, 2017) about the demographic evolution having a very negative impact on the PAYGO systems, as expenditure grows and revenue declines. It is necessary to prevent expenses from being too burdensome for future generations. For instance, Spain (Díaz-Giménez & Díaz-Saavedra, 2016) and Greece (Symeonidis, 2017), which presented severe fiscal imbalances, made more radical reforms in their pension systems.

A pension reform involves a complex set of elements that must be analyzed together. (Chybalski & Marcinkiewicz, 2015) advocate that pension systems should be analyzed in a multidimensional way. More specifically, the performance of these systems (Pallares-Miralles, Romero, & Whitehouse, 2012) comprises multiple elements that lead to the calculation of several indicators of established use in the literature.

A contributive old age pension system is traditionally classified using three main criteria: funding, actuarial fairness and risk sharing. Hence, it might be found funded versus unfunded (DB-PAYGO) systems, actuarial versus non actuarial systems, and DB versus DC systems (Lindbeck & Persson, 2002). These three dimensions make it easier to analyses each particular system.

2.2. Brazil: the legal background

2.2.1. First law and the following decades (1920-1960)

According to the Ministry of Finance there has been some kind of social protection scheme in Brazil since the time of the Empire. However, it was only in 1923, with the approval of Law no. 4682 (Eloy Chaves Law), that the country acquired a legal framework for the social protection, which at that time was composed of the *Caixas de Aposentadorias e Pensões* (CAPs). The Eloy Chaves Law specifically dealt with the CAPs of railway companies, as their unions were much more organized and had greater political pressure. The initial objective was to support these workers during the period of inactivity.

This situation changed throughout the 1930s. The growth of the urban population and the expansion of unionism led to a tendency towards social security organization by professional

category, which strengthened the social security institutions, which were taken over by the State, and then the *Institutos de Aposentadorias e Pensões* (IAPs).

The institutions that represented higher income categories quickly became politically strong, as they had more financial and political resources. Distortion came up with this fact as there was a clear privilege for some institutions. Thus, the need for a single social security system was evident.

2.2.2. Unifying the system (1960-1988)

Still in line with Ministry of Finance1, originally all the IAPs operated under a full capitalization regime with a tripartite costing scheme (employer, employee and State). However, very soon two facts became clear: (1) the State would never fulfill its commitment; (2) reserves were often mismanaged. Therefore, in 1960, the whole system shifted to a pure pay-as-you-go defined benefit scheme, due to law no. 3807 (*Lei Orgânica de Previdência Social* - LOPS). LOPS created the *Instituto Nacional de Previdência Social* (INPS), unifying all existing institutions in a new one.
INPS replaced the old IAPs and incorporated their revenues and expenditures, as well as the assets and liabilities. In theory, most of the urban workers, including the employers and self-employed were covered by the system. Coverage was under 50% for the employees, and not above than 10% for employers and self-employed workers in practice (Oliveira & Beltrão, 2000).

Contributions were set at 8% both for employer and employee, with a maximum contributory salary equivalent to ten minimum wages. The government should transfer revenues from the general taxes in order to cover administrative costs and any deficits.

According to (Oliveira & Beltrão, 2000), despite various attempts during the 60's to include the rural population in the program, only in 1974 an effective coverage was achieved. A flat benefit equal to half of a minimum wage salary was granted to rural workers at the age of 65, or to the disabled at any age, with no requirement of a qualifying period. Medical assistance was also supplied, mostly through contracts with private and philanthropic hospitals. The cost of the program was financed by a contribution of 2.5% imposed on first selling of rural products plus a special contribution of 2.4% on the urban payroll and the *Fundo de Assistência ao Trabalhador Rural* (FUNRURAL) was created to manage the new program by the law number 4,214 in1963.

During the 70's, a means-tested allowance was also created to cover needy people over the age of 70 and disabled people, both urban and rural, without other sources of income. This social assistance cash benefit was equivalent to half of a minimum wage. In 1974 the Social Insurance and Social Assistance Ministry was designed.

The institutional setup was of practical core competency from 1978 to 1988. INPS was in charge of benefit payments and professional development for both urban and rural insured, as well as of paying cash social assistance benefits. The *Instituto Nacional de Assistência Médica da Previdência Social* (INAMPS), which was created in 1977 by Law no. 6439, was responsible to take care of health services for urban and rural insured. Finally, the *Instituto de Administração Financeira da Previdência e Assistência Social* (IAPAS), also created by Law no. 6439, was responsible for the collecting contributions and managing assets.

2.2.3. A new Constitution (1988) and following reforms

Still in accordance with the same source, after almost 20 years of military rule, the 1988 Constitution was promulgated. This new important law reproduced the increasing social apprehensions. It was the most important step to make social protection universal in Brazil.
An important fact happened in 1990 with the creation of Instituto Nacional do Seguro Social (INSS), which incorporated the INPS and IAPAS.

After several years of discussion, a major reform was approved in 1998, already with the sustainability of the system in view. A decision was made to retain the PAYGO system, since the cost of transition to a fully funded capitalization scheme was considered unaffordable (Bravo & Uthoff, 1999), but a few measures were taken. One of the most controversial was the introduction of the *Fator Previdenciário*, a coefficient depending on the number of contributing years, the age at retirement and the life expectation at retirement; with the purpose of reducing the amounts of pensions when the contributing periods are too short or the pensioners are too young.

Year 2003 was marked by a reform to remove some discrepancies between the civil servants regime (historically more generous) and the other regimes, in terms of the contribution rate, pensions amounts and age to retire. Another reform in 2003 reduced benefits for low-wage participants and participants classified as domestic workers.

In 2015, the formula to calculate the disability benefits replaced the last wage with the career average earnings, the compulsory age for retirement in public work increased from 70 to 75 and an alternative to *Fator Previdenciário* was proposed (known as 85/95 formula, as it corresponds to the sum of age at retirement and the period of contributions for women and men, respectively).

In agreement with (OECD, 2017), the 1998 and 2003 reforms reduced implicit pension liabilities, but the transition rules were so generous that there is a large cohort still in active service that will last

to privilege. As a result of a growth in pension spending as this cohort retires is projected to worsen the fiscal deficits of many levels of governments.

2.2.4. Constitutional amendment (2019)

Since previous reforms were ineffective to guarantee the sustainability of the system, in November 2019 Brazil's government enacted a constitutional amendment (Brazil Const. amend. 103, 2019) that reforms old-age pensions by introducing a minimum retirement age, changing contribution rates and eligibility requirements, and modifying benefit calculations. The reform affects the general pension program that covers most employed and self-employed and the special pension program that covers certain public-sector employees. It is intended to curb public spending on pensions, which is among the highest in the world on a relative basis, see (Social Security Administration, 2019). Following Ministry of Finance, the key changes consist of:

Minimum retirement age: There is now a minimum retirement age to qualify for a pension: 65 for men and 60 for women that will gradually rise to age 62 by 2023 (previously, a man would be entitled after 35 years of contributions and a woman after 30 years). Under the old rules, the average retirement age was 57 for men and 52 for women (OECD, 2019).

Contribution requirements: Men who enter the workforce are now required to have at least 20 years of contributions to qualify for an old-age pension. The minimum contribution condition for other insured participant will last to be 15 years.

Contribution rates: The employee contribution rate, which varies depending on an employee's monthly earnings, will become more progressive.

Benefit calculations: The new formula is now less generous (essentially the monthly pension is now 60% of the insured's average monthly earnings, previously it was 70%)[1].

Government is confident that these new rules will help to uphold the system.

2.3. A few studies on the Brazilian case

The long-term sustainability of the Brazilian pension system and the need to reform it has been a recurrent topic of dispute in the Brazilian public sphere and in the academia. At present the debate is heated and there are a few important contributions, discussed below.

The most recent study (Afonso & Carvalho, 2019) was based on the proposal of reform initially presented by the government in 2019. Although the Congress has later altered many aspects of the text, the study remains quite interesting. The authors implemented a non-behavioral actuarial

microsimulation model, and the results show that the proposal was in the right direction to reduce inequalities and the RGPS deficit, even if it was not very efficient from a fiscal perspective. In fact, the aggregate results suggest that the RGPS deficit will stay relatively constant over the next 15 years (the transition rules are mild) and will start increasing from that point on, but at a much lower rates those without reform. (Afonso & Carvalho, 2019) also conclude that the reform does not eliminate the deficit but makes it less unsustainable and will create better general conditions for the government to equate the imbalance in public accounts.

(LIMRA, 2019) show that in Brazil, like in the other countries covered by the study, there is a strong preference for saving products (with retirement in view) with conservative characteristics, in particular, those that guarantee predictable returns and help preserve capital. That is to say, these consumers demonstrate a desire for guaranteed lifetime income, principal protected investment and fixed returns. Banks are the preferred channel for buying retirement income products. Still in line with the research, despite recent government reforms, the majority of the population is not yet covered by comprehensive pensions that provide an adequate level of income.

Another very important study (World Bank, 2017) highlighted that there are two main issues related to the pension reform in Brazil that the current rules do not fully address. The first issue is how to deal with the large RPPS deficits resulting from the pre-2003 cohort of civil servants. These deficits are huge that honoring current pension liabilities might not be economically feasible in some of Brazil's states, even if the states set up their own reform of the RPPS following federal parameters. In this case, a solution would be to minimize the possibility to collect multiple pensions; to reform military pensions and to shorten the transition period. The second issue concerns the interaction between the old age pension rules and some non-contributory social transfers. A possible solution would be to raise the age to access these transfers, which would create incentives for workers to continue contributing.

Analyzing (OECD, 2017), it is possible to conclude that Brazil's pension system was an exception when compared to OECD countries, in the sense that there was effectively no minimum retirement age in the country at that time. The study pointed out that the low average retirement ages of 56 years for men and 53 years for women were one of the main drivers for the deficit of the system, combined with the rising life expectancy, so it was urgent to implement a minimum retirement age indexed to the life expectancy at retirement. These suggestions were partially considered in the 2019 reform. Another important finding in the document is the fact that in the OECD an average-wage worker entering the labor market at age 20, will be entitled to a full pension at the age of 65.5, receiving 53%

of pre-retirement earnings in net terms, but in Brazil a man would receive 70% of pre-retirement earnings at age 55 and a woman would receive 53% at age 50. A third aspect highlighted by the study is the indexation mechanism for minimum pension benefits in force in Brazil (the Constitution states that the minimum pension cannot be lower than the minimum wage), which also contributes significantly to the deficit. Over the last ten years the minimum pension increased almost 90%. Currently two-thirds of pensioners receive this minimum benefit.

Regarding RGPS, (Zviniene, 2019) shows that minimum benefits and social transfers are not efficiently targeted to the poorest, since it is possible to estimate that nearly half of spending is not designed to prevent poverty, but to reward socially valued occupations or correct labor market failings. The author also concludes that moving to a "pure" multi-pillar model, would involve finding financing sources for the costs with the aging population and for the transition costs and would also include the reduction of the largest benefits. (Zviniene, 2019) concludes emphasizing that the low productivity workers will not be able to self-finance long and comfortable retirement, financial and labor market volatility and demographic changes will produce privileges, disadvantages and a "pure" system is improbable to continue without political intervention.

Chapter III – Model and Methodology

3.1. Social security in Brazil: a system in disequilibrium

To start this chapter, which contains the model and the methods used in the analysis, a more comprehensive view of the current situation is required.

Brazil has a very complex pensions system, comprising more than 2,000 different rules (Secretaria de Previdência, 2018), which makes the Brazilian case a special case and maybe one of the most intricate arrangements in the world.

The system is divided into few sections[2] and sub-sections: a general compulsory scheme for private workers, multiple special compulsory scheme for civil servants at different levels of government, and a voluntary complementary scheme, available to all workers (see ***Table 3*** for a summary).

Table 3- A summary of Brazilian pensions

	RGPS	RPPS	State-level schemes	Complementary system
Coverage	Private sector	Civil servants	Civil servants	All workers
Nature	Mandatory	Mandatory	Mandatory	Optional
Scope	National	Federal, state or local	Federal or state	Open or closed
Management	Public	Public	Mixed	Private or independent
Funding	PAYGO	PAYGO	Pre-funding	Fully funded

Source: Author, based on Ministry of Finance (https://www.gov.br/previdencia/pt-br).

The *Regime Geral de Previdência Social* (RGPS) covers the private works. It is supported through payroll taxes, shared by the employer and the employee. It is composed of the urban subsystem and the rural subsystem, where the first is contributory and the second is only partially contributory.

The *Regime Próprio de Previdência Social* (RPPS) for civil servants exists at different levels of government. Reforms of these schemes have been very insignificance, even though they are expressively more benevolent than the RGPS (Bonturi, 2002). Some degree of pre-funding has been introduced at state level, as a few states have reformed the pension schemes for their public employees. These incipient schemes provide at best short-term fiscal relief to state governments (Bonturi, 2002).

[2]For more details, https://www.gov.br/previdencia/pt-br (retrieved October 2020).

The complementary system is available to all workers as an option, being privately managed and fully funded. This system consists of either occupational or personal plans and has grown rapidly in the past few years (Bonturi, 2002).

In the case of the military, expenses with inactive military are not included in the social security system; only survival benefits are - and there is a specific contribution to fund them.

In 2018, the combined deficit in the pension system was close to 6% of GDP (see ***Table 4***). The deficit of RPPS in the state level was quite disproportionate, 1.4% of GDP. Taking the total expenditures on civil servants' pension schemes into consideration, more than a half was incurred by sub-national governments.

Table 4- Financial results of the pension system in % of GDP in 2018

	Participants (10^6)	Active Workers (10^6)	Contributions	Expenditure	Balance
RGPS	80.0	51.1	5.7	8.6	-2.9
RPPS	8.8	5.2	2.2	4.5	-2.4
Federal	1.4	0.7	0.5	1.3	-0.8
State	4.0	2.0	1.1	2.5	-1.4
Local	3.4	2.5	0.6	0.7	-0.1
Military	0.8	0.5	0.0	0.7	-0.6
TOTAL	**98.7**	**62.0**	**7.9**	**13.8**	**-5.9**

Source: Author, based on Ministry of Finance (Secretaria de Previdência, 2019; Secretaria de Previdência, 2018)

Table 5 shows the deficit per participant and per worker. There is an enormous disequilibrium in the RPPS state level and in the military case, with deficits per worker of BRL 81,326 and BRL 94,648 respectively. In other words, each worker should pay this value to make face to all expenditures and consequently make the pension system financially balanced.

Table 5- Financial results of the pension system per capita in 2018 and number of systems

	Per participant	Per worker	#Systems
RGPS	2,440	3,817	1
RPPS	18,129	31,095	2,160
Federal	39,178	81,326	1
State	24,112	49,013	27
Local	2,399	3,279	2,132
Military	56,976	94,648	1
TOTAL	**3,982**	**6,462**	

Source: Author based on Ministry of Finance (Secretaria de Previdência, 2019; Secretaria de Previdência, 2018).

Figure 2 shows the financial result in the RGPS (urban, rural and total) from 2010 to 2018. Historically, the result of the rural area has never been positive since 2003 and the deficit has steadily increased in size. In 2019, it contributed to 57% of the RGPS deficit, even though having a much smaller number of beneficiaries. Moreover, ***Figure 2.b*** shows that the rural result has never been in

equilibrium, mainly because it seems to be more like a welfare program than a pension system. Remark that there is no minimum requirement of contributions for a rural worker to retire.

Figure 2 – Results *(10^9)*: (a) Urban, (b) Rural & (c) RGPS

Figure 2.a - Urban

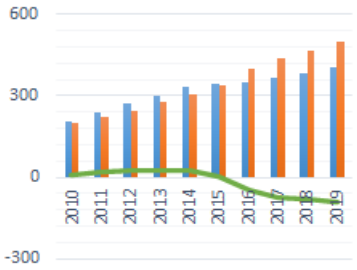


Figure 2.b – Rural

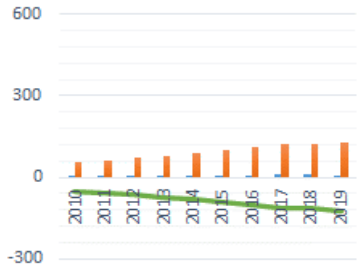


Figure 2.c - RGPS

Source: Author, based on Ministry of Finance (Secretaria de Previdência, 2019)

Public spending is often classified using different methodologies, making international comparisons quite challenging[3]. In this case it is possible to perform these comparisons accurately, due to the Classification by Functions of Government (COFOG) methodology, used by OECD and UN, which makes the data on expenditure by function of the central government comparable with those of others countries (OECD, 2011, p. 194)

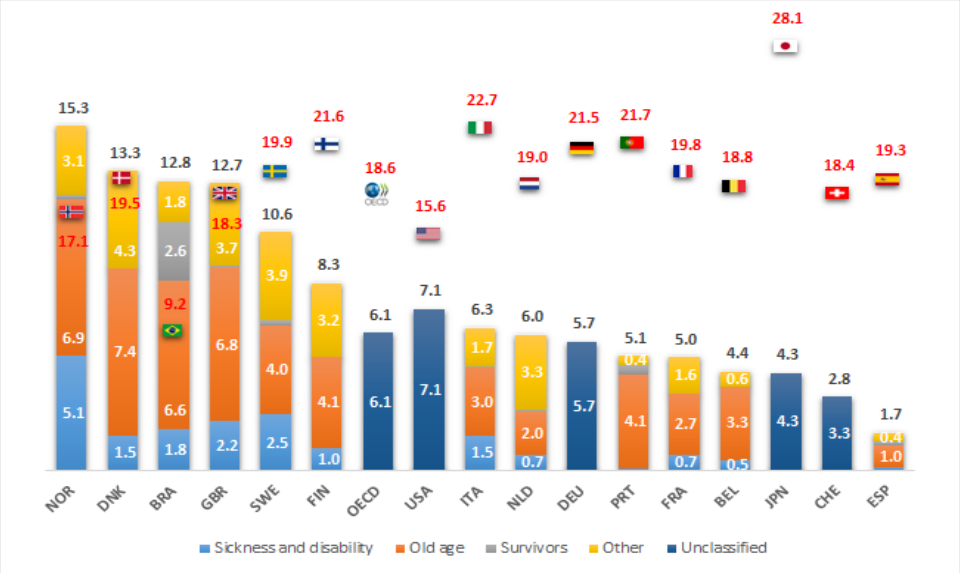
Taking into consideration the expenditure in social protection of the central government, Brazil's public pension expenditure is about 13% of GDP, above the OECD average and close to some Nordic countries, as Norway and Denmark. From this total, 1.9% goes to sickness and disability benefits, 6.6% is used to pay old-age benefits, 2.6% is for survivor benefits, 2.0% is for other expenses. Although only 9.2% of the Brazilian population is over 65, a very low percentage in comparison to other countries, the expenditure with old age benefits is high, see ***Figure 3***.

According to (Tesouro Nacional, 2020), General Expenses and Social Protection represent together more than 25% in terms of GDP and 77% of total expenditures in 2017. This value is above the international average, that is around 15% of GDP in a sample of 54 countries. The same source states that there is a gap between the composition of the public spending on social protection and the demographic structure. Observing he fast process of ageing in the country, this tendency is expected to become worse. The reform of the pension system is a priority.

[3] For more details, https://www.gov.br/tesouronacional/pt-br/importacao-arquivos/cofog-message.pdf (retrieved October 2020).

Figure 3 relates social protection expenses of central government in OECD countries, in percentage of GDP, and population above 65 years old, in 2018.

Figure 3- Social protection (% GDP) vs 65+ old-age (% pop) in 2018



Source: Author, based on (Tesouro Nacional, 2020; OECD, 2019).

From 2018 to 2019, the Social Protection share increased 6.3%, representing now 39.3% of the total expenditure, and the main items are Old Age (52%), Survivors (20%) and Sickness and Disability (14%). The General Expenses decreased 6.7%, the main item being Public Debt Transactions (59%). ***Table 6*** shows a comparison between 2018 and 2019 of the expenditures of the central government by COFOG category. Expenditure with Social Protection became the category with the largest share in total spending, a dynamic that reflects the growth in spending under the RGPS, along with the policy of linking benefits to the minimum wage and the increasing number of beneficiaries (Tesouro Nacional, 2019).

Table 6 - Expenditures by COFOG category of the central government

	Value (BRL 10^9)		% of Expenditure		% of GDP	
	2018	2019	2018	2019	2018	2019
General public services	936.1	873.7	40.0	36.6	13.6	12.0
Defence	49.8	51.4	2.1	2.2	0.7	0.7
Public order and safety	77.0	82.6	3.3	3.5	1.1	1.1
Economic affairs	77.3	99.3	3.3	4.2	1.1	1.4
Environmental protection	5.1	6.7	0.2	0.3	0.1	0.1
Housing and community amenities	5.3	9.1	0.2	0.4	0.1	0.1
Health	144.7	153.3	6.2	6.4	2.1	2.1
Recreation, culture and religion	3.8	4.0	0.2	0.2	0.1	0.1
Education	160.3	166.2	6.9	7.0	2.3	2.3
Social protection	882.3	938.2	37.7	39.4	12.8	12.9
TOTAL	**2,341.7**	**2,384.5**	**100.0**	**100.0**	**34.0**	**32.9**

Source: Author, based on Ministry of Finance (Tesouro Nacional, 2020).

Table 6 shows a comparison between 2018 and 2019 of the expenditures of the central government by COFOG category. According to the Ministry of Finance (Tesouro Nacional, 2020), the two most representative categories throughout the series (see ***Table 6***) are General public services and Social protection, which together summed up 25% of GDP in 2019 and 76% of total central government public spending. The Social protection was the category with the largest share in total spending in 2019 and this dynamic reflects the growth in spending under the RGPS, along with the policy of linking the benefits to the minimum wage and the expanding of beneficiaries.

Having described the system, the next section contains the model used to deal with the disequilibrium problem.

3.2. Modelling a PAYGO DB pensions system

The International Monetary Fund (Acosta-Ormaechea, Espinosa-Vega, & Wachs, 2017) created a consistent method to analyze the pension's inflows and outflows. This methodology will be adopted in this work through Microsoft Excel (Microsoft 365 MSO), using the most recent information available for Brazil. The purpose is to estimate the implications of alternative reforms, in order to mitigate/eliminate the financial disequilibrium of the system. It is important to point out that the focus is on the long-term projection, which explains the variables, assumptions and relationships included in the model (Goldstein & Gigerenzer, 2009; Miller & Castanheira, 2013).

3.2.1. Number of pensioners

There are three population groups receiving pension benefits from the public system in the formal sector: retirees, survivors and permanently disabled. There is also a fourth group, of non-contributory

pensioners. Thus, the number of pensioners receiving government benefits in a certain year t is estimated as follows

$$Bnfp_t = PenPop_t \times lp \times fs + Bnfs_t + Bnfpd_t + Bnfnc_t, \quad \textit{Eq. 1}$$

where $Bnfp_t$ is the total number of pensioners, $PenPop_t$ is the population with ages equal to or higher than the average retirement age, lp is the labor force participation rate, fs is the size of the formal sector, $Bnfs_t$ is the number of survival pensioners, $Bnfpd_t$ is the number of permanently disabled pensioners and $Bnfnc_t$ is the number of non-contributory pensioners.

3.2.2. Pension Payments

A series of calculations must be performed to compute aggregate values for pension expenditure. To begin with, it might be determined the average monthly pension per person for new beneficiaries in the year of their retirement,

$$AvPendbnb_t = rr\frac{AvWage_t}{12}, \quad \textit{Eq. 2}$$

where rr is the replacement rate[4] for new retirees and $AvWage_t$ is the average wage, calculated as

$$AvWage_t \begin{cases} \dfrac{GDP_{n_t} * ws}{Empl_t}, & t < 2020 \\ Av_{wage_{t-1}}(1 + g_{n_t}), & t \geq 2020 \end{cases}. \quad \textit{Eq. 3}$$

For $t < 2020$, GDP_{n_t} is nominal GDP, ws is the share of compensation of employees and $Empl_t$ is total employment, calculated as follows:

$$Empl_t = (1 - u)lp \times WorkPop_t, \quad \textit{Eq. 4}$$

where u is unemployment rate and $WorkPop_t$ is the working-age population, then defined to be from 20 to 60 years old (men) and from 20 to 55 (women).

For $t \geq 2020$, the assumption is that the average monthly wage grows each year according to the nominal GDP growth rate,

$$gn_t = (1 + gpc_t)\left(1 + g_{pop_t}\right)(1 + \pi_t) - 1, \quad \textit{Eq. 5}$$

[4] The value of a pension as a proportion of a worker's wage during a base period, such as last year or three years or fifteen or entire lifetime average wage. It also denotes, as another definition, the average pension of a group of pensioners as a proportion of the average wage of the group (Bogomolova, Impavido, & Pallares-Miralles, 2007).

where gpc_t is the real per capita GDP growth, g_{pop_t} is the population growth rate and π_t is the inflation rate.

The average pension for current beneficiaries, $AvPenCbdb_t$, is computed by 5-year cohorts and by indexing the previous year average pension to the inflation rate.

$$AvPenCbdb_t = AvPenCbdb_{t-1}(1 + \pi_t). \quad \textit{Eq. 6}$$

The need to use 5-year cohorts results from the fact that the existing projections (United Nations, 2019 a) present data in this way. It is important to point out that, even though pension benefits are indexed to inflation, these cannot be below the minimum wage[5] (Cuevas, Karpowicz, Mulas-Granados, & Soto, 2017). Nevertheless, mostly because often the minimum wage also increases with inflation, and according to the parsimony principle and the need to keep calculations simpler, the thesis will use the last equation. To be straight to the rule, an assumption about income distribution by cohorts of pensioners would have been required, which is not achievable.

The average pension for all beneficiaries, $AvPendb_t$ is monthly computed as the weighted average of the current and new pensions, and their weights are established by the number of beneficiaries in each cohort as shown below.

$$AvPendb_t = \sum_{t=1}^{\infty} AvPenCbdb_t \frac{cb_t}{Bnfp_t} + AvPenNbdb_t \frac{nb_t}{Bnfp_t}, \quad \textit{Eq. 7}$$

where $\frac{cb_t}{Bnfp_t}$ is the proportion of current beneficiaries and $\frac{nb_t}{Bnfp_t}$ is the proportion of new beneficiaries to the total number of beneficiaries.

Finally, $TotBenefdb_t$ denotes the total benefits and is given by

$$TotBenefdb_t = AvPendb_t \times Bnfdb_t \times 12, \quad \textit{Eq. 8}$$

where $Bnfdb_t$ is the total number of pensioners under the scheme in year t. Additionally, $TotBenefdb_t$ will denote the share of total beneficiaries, proportionally to the total number of beneficiaries.

3.2.3. Contributions

$Contrdb_t$ denotes the number of workers who make contributions to the system and is equal to

$$Contrdb_t = WorkPop_t \times lp \times fs, \quad \textit{Eq. 9}$$

[5] See more details at article number 201 at the Brazilian Federal Constitution.

where $WorkPop_t$ is the working-age population, now defined to be from 20 to 65 years old (men) and from 20 to 62 (women).

$AvContrdb_t$ denotes the average monthly contribution per person and it might be computed as:

$$AvContrdb_t = crdb_t \frac{AvWage_t}{12}, \quad \textit{Eq. 10}$$

where $crdb_t$ is the total contribution rate and equals the sum of three rates: the employee's, the employer's and the government's, denoted $crdb_{ee}, crdb_{er}$ *and* $crdb_g$, respectively. Then,

$$crdb_t = crdb_{ee} + crdb_{er} + crdb_g. \quad \textit{Eq. 11}$$

Therefore, the total contributions, denoted by $TotContrdb_t$, are equal:

$$TotContrdb_t = AvContrdb_t \times Contrdb_t \times 12. \quad \textit{Eq. 12}$$

3.2.4. Net cash flow

Using ***Eq. 12*** and ***Eq. 8***, the net cash flow is

$$Ncfdb_t = TotContrdb_t - TotBenefdb_t. \quad \textit{Eq. 13}$$

3.2.5. Transition rules

The aim of this section is to define the transition rules to the new reform (Brazil Const. amend. 103, 2019). There are six different transition rules[6] that basically combine age and length of contributions. Nevertheless, mostly because the material impact comes from the establishment of a new minimum entitlement age, and according to the parsimony principle and the need to keep calculations manageable, this thesis will work only with this transition rule. To be straight to the rule, an assumption about the distribution of the length of the contributions period, by age and cohorts of pensioners, would have been required, which is not achievable.

The transition rule describes a constant increase of six months in the retirement age until reaching the age of 65 for men and 62 for women, starting from 61 and 56 respectively. Effects are over the proportions of old age pensioners and the working age population, by impacting when the population of a certain age moves from contributors to beneficiaries of the system.

[6] For more details, http://www.brasil.gov.br/novaprevidencia/#novas-regras (retrieved October 2020).

3.3. Alternative reform scenarios

The aim of this section is to define a few scenarios that may shed a light on possible ways to reform the system, in order to achieve its future sustainability and actuarial-financial equilibrium. Each scenario may be considered as a stand-alone or combined or any of the other.

3.3.1. Scenario 1: Pre-2019 reform

This scenario (Scn1) aims to replicate the pension system before the reform (Brazil Const. amend. 103, 2019) that incremented the retirement age was implemented. In accordance with the transition rules (see ***Transition rule***), it will keep the retirement age to 60 for men and 55 for women. ***Eq. 1*** will be replaced with ***Eq. 14*** and $WorkPop_t$ in ***Eq. 9*** will be replaced with ***Eq. 15***:

$$PenPopdb_t^{Scn1} = PenPopdb_t + RefAge_t \frac{varScn1_t}{5}, \quad \textit{Eq. 14}$$

$$WorkPop_t^{Scn1} = WorkPop_t - RefAge_t \frac{varScn1_t}{5}. \quad \textit{Eq. 15}$$

where $PenPopdb_t^{Scn1}$ denotes the pension-age population in Scn1, $WorkPopdb_t^{sc1}$ denotes the working-age population in Scn1, $RefAge_t$ is the cohort of the population that is affected by the reform; $varscn_1$ is

$$varScn_1 = ra_t - ra^{Scn1}, \quad \textit{Eq. 16}$$

where ra_t is the retirement age and ra^{Scn1} is the retirement age before reform.

3.3.2. Scenario 2: Increase in the retirement age by linking to longevity

This scenario (Scn2) aims to increment the retirement age by linking it to the increments in the average age of the whole Brazilian population, according to projections. This scenario is assumed to occur only when the transition rules (see ***Transition rule)*** end up, which means in 2028 (men) and 2032 (women). The increase in retirement age equals the increment in the average age of the population. Again, ***Eq. 1*** will be replaced with ***Eq. 17*** and $WorkPop_t$ in ***Eq. 9*** will be replaced with ***Eq. 18***:

$$PenPopdb_t^{Scn2} = PenPopdb_t - RefAge_t \frac{varScn2_t}{5} \quad \textit{Eq. 17}$$

$$WorkPopdb_t^{Scn2} = WorkPopdb_t + RefAge_t \frac{varScn2_t}{5}, \quad \textit{Eq. 18}$$

where now

$$varScn2_t = ap_t - ap_{2028(2032)}, \quad \text{Eq. 19}$$

$ra_t = 65(62), ap_t$ equal to the average age of the whole population in year t.

3.3.3. Scenario 3: Decrease in the replacement rate by a constant

This scenario (Scn3) aims to decrease the replacement rate of the new pensioners by $varScn3_t$, defined as 0.5%, every year throughout the time horizon, which is assumed to be equal to 10 years. Naturally, the legal minimum pension has to be guaranteed.

Expressing the average benefit amount for new old-age pensioners in the year of retirement as the product of the average wage by the replacement rate, the constant rr (see ***Eq. 2***) will be now replaced with ***Eq. 20***. Therefore, in the years of 2021-2030 the replacement rate equals

$$rr_t = \begin{cases} rr_{t-1} - varScn3_t & t = 2021, \dots, 2030 \\ rr_{2030} & t > 2030 \end{cases}, \quad \text{Eq. 20}$$

where now

$$varScn3_t = 0.005(t - 2020). \quad \text{Eq. 21}$$

3.3.4. Scenario 4: Decrease in the indexation of pension benefits by a factor

This scenario (Scn4) aims to decrease the indexation of pension benefits. Under Scn4, the benefit will be indexed by the ratio $varScn4_t$, defined as 75% of the CPI, instead of 100%. This change will be applied to both new and existing pensions. ***Eq. 6*** will be replaced with ***Eq. 22,***

$$AvPenCbdb_{t_c}^{Scn4} = AvPenCbdb_{t-1_c}^{SC4}(1 + \pi_t \times varScn4_t), \quad \text{Eq. 22}$$

where now

$$varScn4_t = 0.75. \quad \text{Eq. 23}$$

The reform starts immediately in 2021 and impacts only existing pensioners because new pensioners are expected to receive benefits in according with a replacement rate and the average wage.

3.3.5. Scenario 5: Increase in the contribution rate by a constant percentage

This scenario (Scn5) aims to increase the total (employers and employees) contribution rate by $varScn5_t$, defined as 10% of the current percentage. ***Eq. 11*** will be replaced with ***Eq. 24.***

$$crdb_t^{Scn5} = crdb_t(1 + varscn_5), varScn5_t = 0.1. \quad \text{Eq. 24}$$

3.3.6. Scenario 6: Increase in the contribution rate by a self-correction

This scenario (Scn6) aims to increase the contribution rate by $varScn6_t$, in a way that the pensions system will be in equilibrium (no deficit, no surplus,) year after year. It is perhaps an unrealistic scenario that was proposed for Germany and introduced by (Furman, 2007). ***Eq. 11*** will be replaced with ***Eq. 25***

$$crdb_t^{SC6} = crdb_t + varScn6_t \qquad \textit{Eq. 25}$$

where now

$$varScn6_t:\ Ncfdb_t \equiv 0, \qquad \textit{Eq. 26}$$

$Ncfdb_t$ defined in ***Eq. 13***.

3.4. Alternative pension scheme scenarios under a DC system

When considering conversion from the Brazilian PAYGO to FDC (or NDC) schemes, the number of old age pensioners who participate in each of them depends on the transition being mandatory or not.

If the DC scheme is compulsory, it is compulsory for new employees only, existing contributors will have to stay in the PAYGO system. This means that only new cohorts entering the labor market would contribute to the new scheme and the old cohorts would continue in the PAYGO system. Hence, the coexistence of the two schemes in parallel remains during the change and a full conversion to the new scheme happens only after the death of all the participants of the PAYGO scheme.

If the new scheme is not mandatory, the new cohorts are divided between the PAYGO system and the new scheme.

In ***Chapter 4***, four new scenarios (Scn7, Scn8, Scn9 and Scn10) correspond to optional or mandatory transition to FDC (NDC), respectively.

3.4.1. Transition from a PAYGO to a private FDC pension scheme

Basically, the two main points from the perspective of the government to shift from PAYGO DB to private FDC schemes are: (i) the fear that the former will become completely unsustainable because of the economic and demographic trends; (ii) the wish to enhance savings, which might boost investment and eventually economic growth (Calvo, Bertranou, & Bertranou, 2010).

However, this transition comes with challenges, predominantly throughout the shift time. The main question is how to finance the benefits to workers who have already retired or who will retire

in the near future but belong to the old scheme (Schmidt-Hebbel, 1999). Another challenge is related to the fact that, precisely because the benefit is not defined, FDC schemes might provide lower retirement pensions. In such cases, the government may feel forced to step in and introduce a minimum pension guarantee (Bertranou, 2001).

In the following sections, the thesis assumes that a transition from the PAYGO Brazilian system to private FDC pension schemes will take place, starting in 2030. Moreover, it assumes that the transition can be mandatory or not. In the latter case, the new cohorts entering the labor market from 2030 that opt for the DC scheme will receive their pension benefits as an annuity depending on the accumulated account balance and the real rate of return. Contributions will be calculated in the same way in the new DC system and in the old DB system. Next points explain the methodology used in this framework.

3.4.1.1. Individual account balance under a FDC Scheme

In order to calculate the balance of the individual accounts, the working-age population was divided into quintiles according to income level for the MGP calculations basis and to estimate government responsibility, and into age cohorts of five years each. $AvContrdc_{t_q}$ denotes the contribution per capita of quintile q of cohort c in year t and is given by:

$$AvContrdc_{t_q} = is_q \times Av_{wage_t} \times crdc, \qquad \textit{Eq. 27}$$

where is_q is the income share of quintile q and $crdc$ is the contribution rate defined as the same contribution rate from the DB system. ***Eq. 28*** gives below the amount in the account in year t for a worker in quintile q of cohort c ($AccBalfdc_q$):

$$AccBalfdc_{t_q} = AccBalfdc_{t-1_q}(1 + ifdc_t) + AvContrdc_{t_q}\frac{cy}{12}, \qquad \textit{Eq. 28}$$

where $ifdc_t$ is the real rate of return (calculated using the nominal interest rate and inflation), and cy is the average number of contributions to the individual account per year, to include unemployment periods and other events that result in temporary pauses in contributions. The account balance raises up each year until it reaches its maximum level the year before retirement.

At the time of retirement, a whole life annuity is purchased using the balance in the account immediately before. Each annual payment is of amount

$$RetAnnfdc_{t_{c_q}} = \frac{AccBalfdc_{t_{c_q}}}{a_{NRA}^{*(13)}}, \quad \textit{Eq. 29}$$

where $a_{NRA}^{*(13)}$ denotes the expected present value of a whole life annuity in arrears that makes 12 payments throughout the year plus one more on December[7]. Basis: the most recent mortality table in Brazil (Instituto Brasileiro de Geografia e Estatística, 2018) and the interest rate term structure in

$$a_{NRA}^{*(13)} = \frac{N_{NRA+1}}{D_{NRA}} + \frac{(77-h)}{156} \quad \textit{Eq. 30}$$

Table 7- Index of 13 payment

Month[8]	Dec	Nov	Oct	Sep	Aug	Jul	Jun	May	Apr	Mar	Feb	Jan
H	0	1	2	3	4	5	6	7	8	9	10	11

Source: Author, based on (SUSEP, 2013)

where N_x and D_x are the usual commutation functions (Jordan, 1967) and h represents the month of the first payment (set to be June).

3.4.1.2. Social security expenditure under a FDC Scheme

Contributions made to the accounts of low-salary participants may not be enough to purchase a pension (at least) equal to the MGP. The government (through the social security system), although not collecting any contributions from these citizens, is responsible for paying the amount necessary to cover the difference. In order to evaluate this liability, the MGP is compared to the average annual pension of quintile q of cohort c in year t, to check whether it is necessary to cover the difference or not. $GovExpfdc_t$ denotes the total government expenditure in year t and is given by ***Eq. 31***.

$$GovExpfdc_t = \sum_{q=1}^{5} (MGP_t - RetAnnfdc_{t_q}) I_{t_q} \times Bnfpdc_{t_q}, \quad \textit{Eq. 31}$$

where $I_{t_q} = 1$, if $RetAnnfdc_{t_q} < \text{MGP}_t$, and $I_{t_q} = 0$ otherwise; $Bnfpdc_{t_q}$ is the number of beneficiaries of quintile q and cohort c in year t. Thus, total benefits, $TotBeneffdc_t$, and total contributions, $TotContrfdc_t$, are given by:

$$TotBeneffdc_t = GovExpfdc_t, \quad \textit{Eq. 32}$$

$$TotContrfdc_t = 0. \quad \textit{Eq. 33}$$

[7] See more details at law number 4,281 of 1963.
[8] Month of the first payment.

Using ***Eq. 32*** and ***Eq. 33***, the net cash flow is

$$Ncfdc_t = TotContrfdc_t - TotBeneffdc_t. \quad \textit{Eq. 34}$$

As long as the two systems coexist, the total expenditure from both schemes is $TotBenefdbfdc_t$, the total of revenue from both schemes is $TotContrdbfdc_t$ and may be calculated as:

$$TotBenefdbfdc_t = TotBenefdb_t + TotBeneffdc_t, \quad \textit{Eq. 35}$$

$$TotContrdbfdc_t = TotContrdb_t + TotContrfdc_t, \quad \textit{Eq. 36}$$

Using ***Eq. 35*** and ***Eq. 36,*** the net cash flow is

$$Ncfdbfdc_t = TotContrdbfdc_t - TotBenefdbfdc_t. \quad \textit{Eq. 37}$$

3.4.2. Transition from a PAYGO to a public NDC pension scheme

According to the literature (Holzmann, Palmer, & Robalino, Nonfinancial Defined Contribution Pension Schemes in a Changing Pension World, 2013), the NDC may be viewed as a midterm between PAYGO and FDC. According to (Simonovits, 2006) NDC schemes have most of the advantages of the FDC design (for instance, the robust connection among formal market, individual savings and pension benefits) and also present other advantageous features (for instance, they deal with the longevity risk by linking the pension benefits to whole life annuities, and are sometimes a less costly way to move to a DC scheme (Brooks & Weaver, 2005).

Basically, the two main points when shifting from PAYGO DB to NDC are: (i) how to transform rights of workers in the old scheme into rights in the newly introduced NDC scheme; (ii) how to quantify the unfinanced legacy from the old scheme, which should be financed by general revenues (Palmer, 2006).

Additionally, a NDC scheme provides no direct contribution to national saving during the build-up phase to maturity. Unlike in the FDC scheme, where the money in the accounts is invested in market assets and participants earn a market rate of return, in the NDC scheme, by definition, the individual account is a notional DC scheme and participants earn an internal rate of return, determined by economy development (Holzmann & Palmer, 2006). Furthermore, current contributions are used to pay current pensions, as in PAYGO scheme, and individual account values represent only a claim on a future pension (Directorate-General for Economic and Financial Affairs, 2007)

3.4.2.1. Individual notional account balance under a NDC Scheme

This part follows closely Individual account balance under a FDC Scheme, as the main differences regarding the per capita account balance under a NDC scheme are that individual accounts are not funded and the rate of return is based on the average wage growth rather than a market rate of return. Hence, the account value at the end of each year consists of contributions accumulated during the year plus the accumulated value from the previous years, which is indexed by the average rate of growth of earnings per contributor (Directorate-General for Economic and Financial Affairs, 2007).

Therefore, $\mathrm{AccBalndc}_{t_q}$ is the balance in the notional account of quintile q and cohort c in year t and is calculated as follow:

$$AccBalndc_{t_q} = AccBalndc_{t-1_q} * (1 + indc_t) + AvContrdc_{t_q}\frac{cy}{12}, \quad \textit{Eq. 38}$$

where $indc_t$ is the financial rate based on the average wage growth.

Using ***Eq. 28*** and ***Eq. 30***, it follows that

$$RetAnnndc_{t_q} = \frac{AccBalndc_{t_q}}{a_{NRA}^{*(13)}}, \quad \textit{Eq. 39}$$

3.4.2.2. Expenditure, revenue and net cash flow under a public NDC scheme

Unlike in the case of private FDC schemes, where the public pension expenditure is just the necessary to cover the MGP, the public pension expenditure consists of total pensions in the case of a public NDC scheme. Thus, the government collects all the contributions and it is in charge of paying the pension benefits.

Using the same idea of ***Eq. 31***, $GovExpndc_t$ denotes the total government expenditure in year t:

$$GovExpndc_t = \sum_{q=1}^{5}(MGP_t - RetAnnndc_{t_q})I_{t_q} \times Bnfpdc_{t_q}, \quad \textit{Eq. 40}$$

$TotBenefndc_t$ denotes the total benefits, $TotContrndc_t$ denotes the total contributions and are given by:

$$TotBenefndc_t = \sum_{q=1}^{5} RetAnnndc_{t_q} \times Bnfpdc_{t_q} + GovExpndc_t) \quad \textit{Eq. 41}$$

$$TotContrndc_t = \sum_{q=1}^{5} AvContrdc_{t_q} \times WorkPopdb_{t_q}. \quad \textit{Eq. 42}$$

Using ***Eq. 41*** and ***Eq. 42***, the net cash flow is

$$Ncfndc_t = TotContrndc_t - TotBenefndc_t. \quad \textit{Eq. 43}$$

As long as the two systems coexist, the total expenditure and the total contributions are

$$TotBenefdbndc_t = TotBenefdb_t + TotBenefndc_t, \quad \textit{Eq. 44}$$

$$TotContrdbndc_t = TotContrdb_t + TotContrndc_t. \quad \textit{Eq. 45}$$

Using ***Eq. 44*** and ***Eq. 45*** the net cash flow is

$$Ncfdbndc_t = TotContrdbndc_t - TotBenefdbndc_t. \quad \textit{Eq. 46}$$

Chapter IV – Results

This chapter follows the structure in Sections ***3.2***, ***3.3*** and ***3.4***. For each of the scenarios defined in these sections, a projection of contributions and benefits covering the 2020-2100 period will be made, in order to study the sustainability of the public pensions system and also to assess the different measures that are proposed in the several scenarios.

3.5. DB system baseline result

In this section it starts with the projections of contributions and benefits if the current rules, resulting from the 2019 reform, remain unchanged. Using ***Eq. 1*** to ***Eq. 13***, results obtained are displayed in ***Table 8.*** It is important to mention that the evolution in the revenue is mainly due to the changing aspects of the working-age population shown in ***Figure 1.***

Table 8 - Baseline (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	8.4	9.5	9.5	9.0	8.3	7.6	7.0	6.4	6.0
Male	4.4	4.9	4.9	4.7	4.4	4.0	3.7	3.4	3.2
Female	4.0	4.6	4.6	4.3	4.0	3.6	3.3	3.0	2.8
Benef.	14.7	13.5	16.5	20.9	24.2	26.2	26.4	26.0	24.9
Male	6.3	5.9	7.7	10.0	11.9	13.1	13.3	13.3	12.8
Female	8.4	7.6	8.8	10.9	12.4	13.0	13.1	12.8	12.1
Balance	**-6.3**	**-4.0**	**-7.0**	**-11.9**	**-15.9**	**-18.5**	**-19.3**	**-19.6**	**-18.9**
Male	-1.9	-1.0	-2.7	-5.3	-7.5	-9.1	-9.6	-9.8	-9.6
Female	-4.4	-3.0	-4.2	-6.6	-8.4	-9.4	-9.8	-9.7	-9.3

Source: Author.

Table 8 shows that in the 2020-2100 period, after a slight recovery in the next ten years (due to the impact of the transition rule), the disequilibrium of the system always gets worse until 2100, when it starts to recover again. This is explained by the demographic pressure. Furthermore, regarding females, it performs worse than regarding males because of the difference in the retirement age and the fact that women live longer. Nevertheless, there is a steady convergence during the forecast horizon as a result of the new retirement age and the increase in male longevity. One point is clear: the 2019 reform is clearly insufficient and further reforms will be required very soon.

3.6. Alternative reforms under DB system results

The proposals of reform analyzed in Section ***3.3*** focus on parametric reforms, to find the most effective way to keep the deficit of the system under control. This can be done either through extending the entitlement age or trying to smooth the costs with the aging population via changing the way benefits are calculated. However, according to the literature (Koutronas & Yew, 2017), in

many cases, such reforms proved to be not so effective to pension systems with an insufficient linkage among contributions and benefits.

3.6.1. Scenario 1: Pre-2019 reform

This scenario is complementary to the previous one and presents the evolution of the pension system before the 2019 reform, when the retirement age was 60 for men and 55 for women. The intention is to measure the effects of that reform (even if it is already known from the last section that other measures will have to be taken).

As a result of the earlier decrease in the working-age population and the earlier increase in the retired population, there is a quicker reduction in contributions and increment in benefits. The deficit grows at a faster rate than without the reform, as expected.

Table 9 - Scn1 Pre-reform (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	8.4	8.6	8.4	7.8	7.2	6.6	6.0	5.5	5.2
Male	4.4	4.5	4.5	4.2	3.9	3.6	3.3	3.0	2.8
Female	4.0	4.1	3.9	3.6	3.3	3.0	2.7	2.5	2.3
Benef.	14.7	17.6	21.7	26.0	29.1	30.3	30.4	29.5	28.0
Male	6.3	7.8	9.9	12.3	14.2	15.0	15.1	14.8	14.2
Female	8.4	9.8	11.8	13.7	15.0	15.3	15.2	14.7	13.8
Balance	**-6.3**	**-9.0**	**-13.3**	**-18.2**	**-22.0**	**-23.7**	**-24.3**	**-23.9**	**-22.9**
Male	-1.9	-3.3	-5.4	-8.1	-10.3	-11.4	-11.8	-11.8	-11.4
Female	-4.4	-5.7	-7.9	-10.1	-11.7	-12.3	-12.5	-12.1	-11.5

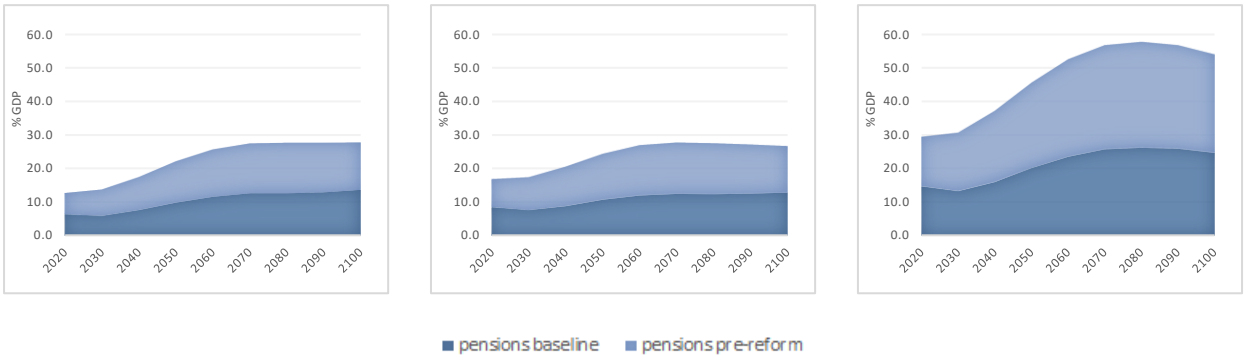
Source: Author.

Table 9 (cf. ***Eq. 1*** to ***Eq. 16***) shows a steady deterioration in the balance in pre-reform scenario, reaching its peak in 2080 as 24.3% of GDP. A difference in terms of balance performance between female and male might be noticed during some decades and the deficit in balance is projected to double it in 2040. Additionally, there is a huge saving of 51% over the next 10 years.

Figure 4 shows a comparison with the benefits pre-reform and the benefits under the baseline scenario (post-reform), throughout the projection. It is clear that expenditure with benefits would be significantly higher if there was no reform (Brazil Const. amend. 103, 2019). Despite not eliminating the deficit, the reform has an obvious importance to the fiscal burden.

Figure 4 - Reform impact on benefits: (a) Male, (b) Female and (c) Total

Figure 4.a – Male **Figure 4.b - Female** **Figure 4.c - Total**



Source: Author.

3.6.2. Scenario 2: Increase in the retirement age by linking to longevity

Increasing the entitlement age is perhaps one of the most popular solutions in the reform of PAYGO systems. A sustainable way to do it is linking retirement age to longevity improvements, since this implicates automatic increases in that age. As people tend to understand the reasoning behind this measure, it is not bad also from a policymaker`s perspective. This scenario affects both sides, increasing the contributions (received longer) and decreasing the benefits (paid for shorter periods) and it affects the numbers of contributors and beneficiaries as working population would stay longer contributing to the system.

Table 10 - Scn2 Ret. age linked to longevity (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	8.4	9.5	10.1	10.2	10.0	9.5	9.0	8.4	7.8
Male	4.4	4.9	5.2	5.3	5.2	5.0	4.7	4.4	4.1
Female	4.0	4.6	4.9	4.9	4.8	4.5	4.3	4.0	3.7
Benef.	14.7	13.2	13.5	14.4	15.4	15.8	15.8	15.2	14.8
Male	6.3	5.6	5.9	6.3	6.8	7.1	7.2	6.9	6.8
Female	8.4	7.6	7.6	8.1	8.5	8.7	8.6	8.3	8.0
Balance	**-6.3**	**-3.7**	**-3.4**	**-4.2**	**-5.4**	**-6.2**	**-6.8**	**-6.8**	**-7.0**
Male	-1.9	-0.7	-0.7	-1.0	-1.6	-2.0	-2.4	-2.5	-2.7
Female	-4.4	-3.0	-2.7	-3.2	-3.8	-4.2	-4.3	-4.3	-4.3

Source: Author.

Table 10 (cf. ***Eq. 1*** to ***Eq. 13*** and ***Eq. 17*** to ***Eq. 19***) shows a great positive impact in the system balance. Indexing the retirement age to longevity after the transition rules end up, which means in 2028 (men) and 2032 (women), showed a possible path to the sustainability of the pension system. Additionally, in 2040 the deficit in balance is projected to be (-3.4%) roughly the half of the one in the baseline setting (-7.0%).

Table 11 displays the average age of the population and the new retirement age by linking it to the average age of the population. $Avg.Age$ denotes the average age of the population and $Ret.Age$

denotes the new retirement age in this scenario. Furthermore, for the whole population was calculated as the weighted average of males and females.

Table 11 - Scn2 Average age and new retirement age

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Avg. Age.	35.0	38.4	41.6	44.4	46.5	48.2	49.1	49.6	49.8
Male	34.0	37.2	40.3	43.0	45.2	46.8	47.9	48.5	48.8
Female	35.9	39.4	42.7	45.5	47.7	49.4	50.4	50.9	51.2
Ret. Age.	58.5	63.2	66.5	69.2	71.5	73.2	74.3	75.0	75.5
Male	61.0	65.6	68.7	71.4	73.6	75.2	76.3	76.9	77.2
Female	56.0	61.0	64.6	67.4	69.7	71.3	72.3	72.8	73.1

Source: Author.

3.6.3. Scenario 3: Decrease in the replacement rate by a constant value

Decreasing the generosity in PAYGO is another way to balance the system. The replacement rate is the key parameter to achieve it. This scenario might be not good from a policymaker`s perspective, as people react badly to such reductions. It affects only the benefits side, the numbers of contributors and beneficiaries is not altered.

Table 12 - Scn3 Replacement rate (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	8.4	9.5	9.5	9.0	8.3	7.6	7.0	6.4	6.0
Male	4.4	4.9	4.9	4.7	4.4	4.0	3.7	3.4	3.2
Female	4.0	4.6	4.6	4.3	4.0	3.6	3.3	3.0	2.8
Benef.	14.6	13.0	15.4	19.1	22.1	23.8	24.1	23.7	22.7
Male	6.2	5.7	7.1	9.2	10.9	12.0	12.2	12.2	11.7
Female	8.3	7.3	8.2	9.9	11.2	11.8	11.8	11.6	11.0
Balance	**-6.2**	**-3.5**	**-5.8**	**-10.1**	**-13.8**	**-16.2**	**-17.0**	**-17.3**	**-16.7**
Male	-1.9	-0.8	-2.2	-4.5	-6.5	-8.0	-8.5	-8.7	-8.6
Female	-4.3	-2.7	-3.6	-5.6	-7.2	-8.2	-8.5	-8.5	-8.2

Source: Author.

Table 12 (cf. ***Eq. 1*** to ***Eq. 13***, ***Eq. 20*** and ***Eq. 21***) presents an improvement in balance in comparison with the baseline, although the overall saving in benefits is only 2.2% of GDP in 2100. Given the very insufficient decrease in the deficit, a sensibility analysis to ***Scenario 3*** was run, assuming a decrease of -1%, instead of -0.5%, smoothly throughout 10 years. ***Table 13*** reflects the greater impact: the deficit decreased by 4.5% of GDP in 2100.

Table 13 - Scn3 Replacement rate new (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	8.4	9.5	9.5	9.0	8.3	7.6	7.0	6.4	6.0
Male	4.4	4.9	4.9	4.7	4.4	4.0	3.7	3.4	3.2
Female	4.0	4.6	4.6	4.3	4.0	3.6	3.3	3.0	2.8
Benef.	14.4	12.4	14.2	17.4	20.0	21.5	21.7	21.4	20.5
Male	6.2	5.4	6.6	8.4	9.9	11.0	11.1	11.1	10.7
Female	8.2	7.0	7.6	9.0	10.0	10.6	10.6	10.3	9.8
Balance	**-6.1**	**-3.0**	**-4.7**	**-8.4**	**-11.7**	**-13.9**	**-14.7**	**-15.0**	**-14.5**
Male	-1.8	-0.6	-1.7	-3.7	-5.6	-7.0	-7.4	-7.7	-7.5
Female	-4.3	-2.4	-3.0	-4.7	-6.1	-7.0	-7.3	-7.3	-7.0

Source: Author.

3.6.4. Scenario 4: Decrease in the indexation of pension benefits by a constant value result

Expenditure with benefits can be reduced also through adjustments in the way these are indexed to inflation, a good option regarding effectiveness and from the policymaker`s perspective. This scenario affects benefits only.

Table 14 - Scn4 Indexation (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	8.4	9.5	9.5	9.0	8.3	7.6	7.0	6.4	6.0
Male	4.4	4.9	4.9	4.7	4.4	4.0	3.7	3.4	3.2
Female	4.0	4.6	4.6	4.3	4.0	3.6	3.3	3.0	2.8
Benef.	14.7	12.7	15.1	18.9	21.7	23.2	23.2	22.8	21.7
Male	6.3	5.6	7.1	9.2	10.8	11.8	11.9	11.8	11.3
Female	8.4	7.1	8.0	9.7	10.9	11.4	11.3	11.0	10.4
Balance	**-6.3**	**-3.2**	**-5.6**	**-9.9**	**-13.4**	**-15.5**	**-16.1**	**-16.3**	**-15.7**
Male	-1.9	-0.7	-2.2	-4.5	-6.4	-7.8	-8.1	-8.4	-8.1
Female	-4.4	-2.5	-3.4	-5.4	-7.0	-7.8	-8.0	-8.0	-7.6

Source: Author.

In ***Table 14*** (cf. ***Eq. 1*** to ***Eq. 13***, ***Eq. 22*** and ***Eq. 23***), it might be observed a significant positive impact in the balance, and the overall savings in paid benefits is 3.2% of GDP in 2100. In 2040 the deficit is projected to be -5.6% versus -7.0% in the baseline scenario.

3.6.5. Scenario 5: Increase in the contribution rate by constant value

Another common way to reform a pension system is to increase the contribution rate, however this scenario might be not desirable from a policymaker`s perspective. This scenario impacts contributions only.

Table 15 (cf. ***Eq. 1*** to ***Eq. 13*** and ***Eq. 24***) gives evidence of an almost immaterial impact on the system balance and on the overall savings (0.6% of GDP in 2100).

Table 15 - Scn5 Contribution rate (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	9.2	10.4	10.5	9.9	9.2	8.4	7.7	7.1	6.6
Male	4.8	5.4	5.4	5.2	4.8	4.4	4.1	3.8	3.5
Female	4.4	5.0	5.1	4.8	4.4	4.0	3.6	3.3	3.1
Benef.	14.7	13.5	16.5	20.9	24.2	26.2	26.4	26.0	24.9
Male	6.3	5.9	7.7	10.0	11.9	13.1	13.3	13.3	12.8
Female	8.4	7.6	8.8	10.9	12.4	13.0	13.1	12.8	12.1
Balance	**-5.5**	**-3.1**	**-6.0**	**-10.9**	**-15.1**	**-17.8**	**-18.6**	**-18.9**	**-18.3**
Male	-1.5	-0.6	-2.3	-4.8	-7.1	-8.7	-9.2	-9.5	-9.3
Female	-4.0	-2.5	-3.8	-6.1	-8.0	-9.1	-9.4	-9.4	-9.1

Source: Author.

As ***Scenario 5*** did not show a significant improvement, another sensibility analysis was performed, assuming an increase of 25% of the current percentage, instead of 10%. ***Table 16*** reflects the result: there is a positive effect but still not a large one (1.5% of GDP in 2100).

Table 16 - Scn5 Contribution rate new (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	10.4	11.8	11.9	11.3	10.4	9.5	8.8	8.1	7.5
Male	5.5	6.1	6.1	5.9	5.5	5.0	4.7	4.3	4.0
Female	5.0	5.7	5.8	5.4	4.9	4.5	4.1	3.8	3.5
Benef.	14.7	13.5	16.5	20.9	24.2	26.2	26.4	26.0	24.9
Male	6.3	5.9	7.7	10.0	11.9	13.1	13.3	13.3	12.8
Female	8.4	7.6	8.8	10.9	12.4	13.0	13.1	12.8	12.1
Balance	**-4.3**	**-1.7**	**-4.6**	**-9.6**	**-13.8**	**-16.6**	**-17.6**	**-18.0**	**-17.4**
Male	-0.8	0.2	-1.5	-4.1	-6.4	-8.1	-8.6	-9.0	-8.8
Female	-3.4	-1.9	-3.1	-5.5	-7.4	-8.5	-9.0	-9.0	-8.6

Source: Author.

3.6.6. Scenario 6: Increase in the contribution rate by a self-correction

A hypothetical reform consists in increasing the contribution rate so that there will be no deficit along the period. Naturally, this scenario is impracticable from a policymaker`s perspective. It affects contributions only.

Table 17 - Scn6 Self-correction (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	14.7	13.5	16.5	20.9	24.2	26.2	26.4	26.0	24.9
Male	6.3	5.9	7.7	10.0	11.9	13.1	13.3	13.3	12.8
Female	8.4	7.6	8.8	10.9	12.4	13.0	13.1	12.8	12.1
Benef.	14.7	13.5	16.5	20.9	24.2	26.2	26.4	26.0	24.9
Male	6.3	5.9	7.7	10.0	11.9	13.1	13.3	13.3	12.8
Female	8.4	7.6	8.8	10.9	12.4	13.0	13.1	12.8	12.1
Balance	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Male	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Female	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Author.

Table 17 (cf. ***Eq. 1*** to ***Eq. 13***, ***Eq. 25*** and ***Eq. 26***) shows that the system is balanced (no deficit, no surplus) over the whole projection. Although unrealistic, this scenario might be useful to provide

information about the gap between the current contribution rate and the rate required to balance the accounts (see ***Table 18***).

Table 18 - Scn6 Self-correction contribution rate

	2020	2030	2040	2050	2060	2070	2080	2090	2100
CRate.	50%	42%	51%	66%	82%	96%	105%	113%	116%
Male	40%	34%	44%	60%	76%	91%	100%	108%	113%
Female	59%	49%	56%	72%	88%	101%	111%	118%	121%

Source: Author.

These results are in line with those presented in (World Bank, 2017) and are a consequence of projections, which show that there will be more than one beneficiary per contributor in less than 50 years.

3.7. Alternative pension scheme scenarios under DC system results

The previous scenarios focused on reforms of the current system, addressing demographic issues and unbalanced contributions and benefits, which generally leads to an unfunded liability (Koutronas & Yew, 2017).

A more extreme approach is to gradually replace a public PAYGO with a private FDC scheme, with all the costs involved, including the burden of a minimum guaranteed pension under a DC system. In ***3.4.1.1*** it was proposed that the shift to a DC system would be implemented in 2030, due to the transition rule. From this year, new cohorts entering the labor market would contribute only to the new system, in the full shift option, or 50% would contribute to the new system and the other 50% to the old system, in the partial shift option.

3.7.1. Scenario 7: Transition from a PAYGO to a private FDC pension scheme in partial shift

Under this scenario, new participants can choose the scheme where contributions go to. For instance, it was observed in Peru (1993), Argentina (1994), Colombia (1994) and Uruguay (1995) (Bonasia & Napolitano, 2006).

Using (cf. ***Eq. 1*** to ***Eq. 5*** and ***Eq. 27*** to ***Eq. 37)***, results are as follows (see ***Table 19***).

Table 19 – Scn7 pension CFs projections (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	8.4	9.4	8.4	7.0	5.5	4.1	3.5	3.2	3.0
Male	4.4	4.8	4.3	3.7	2.9	2.2	1.9	1.7	1.6
Female	4.0	4.5	4.1	3.3	2.6	1.9	1.7	1.5	1.4
Benef.	14.7	13.5	16.5	20.9	24.2	26.0	22.3	17.6	14.0
Male	6.3	5.9	7.7	10.0	11.9	13.1	11.4	8.9	7.1
Female	8.4	7.6	8.8	10.9	12.4	12.9	10.9	8.6	6.9
Balance	**-6.3**	**-4.1**	**-8.1**	**-13.9**	**-18.8**	**-21.9**	**-18.8**	**-14.4**	**-11.0**
Male	-1.9	-1.1	-3.3	-6.3	-9.0	-10.9	-9.6	-7.2	-5.5
Female	-4.4	-3.1	-4.8	-7.6	-9.8	-11.0	-9.2	-7.1	-5.5

Source: Author.

Furthermore, there is also a substantial increment in private savings (see ***Table 20***, ***Eq. 28*** and ***Eq. 31***).

Table 20 – Scn7 additional pension CFs projections (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Tcost	0.0	0.0	0.6	1.6	2.5	3.2	3.7	3.4	3.1
Male	0.0	0.0	0.3	0.8	1.3	1.6	1.9	1.8	1.6
Female	0.0	0.0	0.3	0.8	1.2	1.6	1.7	1.6	1.5
IATS	0.0	0.1	3.5	12.4	26.8	46.5	67.9	84.3	98.4
Male	0.0	0.0	1.8	6.3	13.7	23.7	35.5	45.8	55.4
Female	0.0	0.0	1.7	6.1	13.1	22.8	32.4	38.6	43.0
MGP	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
Male	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Female	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1

Source: Author.

$IATS$ denotes the individual accounts total stock generated by the new pension scheme (see ***Eq. 28***), $TCost$ is the transition cost of switching from a DB system to a DC system, calculated as the difference between the contributions before and after implementing the DC system, and MGP is the cost of the minimum guaranteed pension (see ***Eq. 31***).

3.7.2. Scenario 8: Transition from a PAYGO to a private FDC pension scheme in fully shift

Chile (1981) was the first country to shift from a public PAYGO to a privatized FDC. Other examples are Mexico (1997), Bolivia (1997) and El Salvador (1998) (Bonasia & Napolitano, 2006).

Table 21 (cf. ***Eq. 1*** to ***Eq. 5*** and ***Eq. 27*** to ***Eq. 37***) shows that there is a negative temporary effect in the short term, followed by a positive impact in the long term, over the sustainability of the system. As expected, the transition cost in this scenario (see ***Table 22***, ***Eq. 28*** and ***Eq. 31***) is greater than the one in the partial shift case (see ***Table 20***) and the savings generated is greater as correspond to a full shift case.

Table 21 – Scn8 pension CFs projections (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	8.4	9.2	7.3	4.9	2.6	0.5	0.0	0.0	0.0
Male	4.4	4.8	3.8	2.6	1.5	0.4	0.0	0.0	0.0
Female	4.0	4.5	3.5	2.3	1.2	0.2	0.0	0.0	0.0
Benef.	14.7	13.5	16.5	20.9	24.2	25.9	18.3	9.2	3.1
Male	6.3	5.9	7.7	10.0	11.9	13.1	9.6	4.6	1.5
Female	8.4	7.6	8.8	10.9	12.4	12.8	8.7	4.5	1.6
Balance	**-6.3**	**-4.3**	**-9.2**	**-15.9**	**-21.6**	**-25.4**	**-18.3**	**-9.2**	**-3.1**
Male	-1.9	-1.1	-3.9	-7.4	-10.4	-12.7	-9.6	-4.6	-1.5
Female	-4.4	-3.1	-5.3	-8.6	-11.2	-12.6	-8.7	-4.5	-1.6

Source: Author.

Table 22 – Scn8 additional pension CFs projections (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Tcost	0.0	0.0	1.2	3.2	4.9	6.4	7.3	6.7	6.2
Male	0.0	0.0	0.6	1.6	2.5	3.3	3.9	3.6	3.3
Female	0.0	0.0	0.6	1.6	2.4	3.2	3.5	3.2	2.9
IATS	0.0	0.1	7.0	24.8	53.5	93.1	135.8	168.7	196.9
Male	0.0	0.1	3.6	12.7	27.3	47.5	71.1	91.5	110.8
Female	0.0	0.1	3.4	12.2	26.2	45.6	64.7	77.1	86.1
MGP	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4
Male	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3
Female	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1

Source: Author.

3.7.3. Scenario 9: Transition from a PAYGO to a public NDC pension scheme in partial shift

This shift option was observed in Greece (2012) (Actuarial Association of Europe, 2019). In the case of Brazil, a material effect is observed under this scenario (see ***Table 23*** and cf. ***Eq. 1*** to ***Eq. 5***, ***Eq. 27***, ***Eq. 31***, ***Eq. 38*** to ***Eq. 46***). The revenue is the same as the one in the baseline scenario (see ***Table 8***) because the same contribution rate was assumed.

Table 23 – Scn9 pension CFs projections (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	8.4	9.5	9.5	9.0	8.3	7.6	7.0	6.4	6.0
Male	4.4	4.9	4.9	4.7	4.4	4.0	3.7	3.4	3.2
Female	4.0	4.6	4.6	4.3	4.0	3.6	3.3	3.0	2.8
Benef.	14.7	13.5	16.5	20.9	24.2	26.0	22.6	18.1	14.7
Male	6.3	5.9	7.7	10.0	11.9	13.1	11.5	9.1	7.4
Female	8.4	7.6	8.8	10.9	12.4	12.9	11.1	9.0	7.3
Balance	**-6.3**	**-4.0**	**-7.0**	**-11.9**	**-15.9**	**-18.4**	**-15.6**	**-11.7**	**-8.7**
Male	-1.9	-1.0	-2.7	-5.3	-7.5	-9.1	-7.8	-5.7	-4.2
Female	-4.4	-3.0	-4.2	-6.6	-8.4	-9.3	-7.8	-6.0	-4.5

Source: Author.

Obviously, the individual accounts are notional in the NDC scheme and the country cannot benefit from the savings generated (see ***Table 24***, ***Eq. 38*** and ***Eq. 40***). The transition cost is the same as the one in ***Scenario 7***.

Table 24 – Scn9 additional pension CFs projections (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Tcost	0.0	0.0	0.6	1.6	2.5	3.2	3.7	3.4	3.1
Male	0.0	0.0	0.3	0.8	1.3	1.6	1.9	1.8	1.6
Female	0.0	0.0	0.3	0.8	1.2	1.6	1.7	1.6	1.5
IATS	-	-	-	-	-	-	-	-	-
Male	-	-	-	-	-	-	-	-	-
Female	-	-	-	-	-	-	-	-	-
MGP	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.3
Male	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2
Female	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1

Source: Author.

3.7.4. Scenario 10: Transition from a PAYGO to a public NDC pension scheme in fully shift

Sweden (1991-1998) was the first country to shift from a public PAYGO to a public NDC. Other examples of full shift are Italy (1995), Norway (2009), Poland (1997-1998) and Latvia (1996) (Guardiancich, Weaver, Demarco, & Dorfman, 2019). This option of a full shift to a scheme based on notional individual accounts has the advantages of avoiding the transition costs and risk shifting that occur in a switch to a FDC scheme (Holzmann, Palmer, & Robalino, 2013).

Table 25 – Scn10 pension CFs projections (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Contrib.	8.4	9.5	9.5	9.0	8.3	7.6	7.0	6.4	6.0
Male	4.4	4.9	4.9	4.7	4.4	4.0	3.7	3.4	3.2
Female	4.0	4.6	4.6	4.3	4.0	3.6	3.3	3.0	2.8
Benef.	14.7	13.5	16.5	20.9	24.2	25.9	18.8	10.3	4.4
Male	6.3	5.9	7.7	10.0	11.9	13.1	9.8	5.0	2.0
Female	8.4	7.6	8.8	10.9	12.4	12.8	9.0	5.2	2.5
Balance	**-6.3**	**-4.0**	**-7.0**	**-11.9**	**-15.9**	**-18.3**	**-11.8**	**-3.8**	**1.5**
Male	-1.9	-1.0	-2.7	-5.3	-7.5	-9.1	-6.1	-1.6	1.2
Female	-4.4	-3.0	-4.2	-6.6	-8.4	-9.2	-5.7	-2.2	0.3

Source: Author.

Table 25 (cf. ***Eq. 1*** to ***Eq. 5***, ***Eq. 27***, ***Eq. 31***, ***Eq. 38*** to ***Eq. 46***) shows a positive impact in the long term. In fact, it is the best scenario in the sense that there is even a surplus in 2100. The surplus outcomes from the fact that contributions are made at the same level of the baseline scenario (see ***Table 8***) and benefits are now "less expensive", as they are provided by a whole life annuity purchased using the balance in the notional account immediately before retirement (subject to MGP criterion). As expected, the transition cost in this scenario (see ***Table 26***, ***Eq. 38*** and ***Eq. 40***) is greater than the one in the partial shift case (see ***Table 24***) and equal to the FDC full shift case (see ***Table 22***).

Table 26 – Scn10 additional pension CFs projections (% GDP)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Tcost	0.0	0.0	1.2	3.2	4.9	6.4	7.3	6.7	6.2
Male	0.0	0.0	0.6	1.6	2.5	3.3	3.9	3.6	3.3
Female	0.0	0.0	0.6	1.6	2.4	3.2	3.5	3.2	2.9
IATS	-	-	-	-	-	-	-	-	-
Male	-	-	-	-	-	-	-	-	-
Female	-	-	-	-	-	-	-	-	-
MGP	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.7
Male	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.4
Female	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3

Source: Author.

Summarizing, results show that, if no additional measures are taken, the deficit will decrease over roughly the next ten years, then an increase might be observed from that time on - although of a reduced amount, in comparison with a pre-2019 reform scenario (***Scenario 1***). Indexing the retirement age to the longevity (***Scenario 2***) showed a way to achieve sustainability. Scenarios Scenario ***3*** and ***Scenario 5*** had insufficient impact; ***Scenario 4*** performed a little better. ***Scenario 6*** is essentially a theoretical exercise, has indeed no practical application. ***Scenario 7*** and Scenario 8 correspond to substantial increments in private savings and support the sustainability of the pension system in the long run. ***Scenario 9*** and ***Scenario 10*** also have a very positive response in terms of the long run sustainability, in particular ***Scenario 10***.

Chapter V – Conclusion

The aim of this master thesis was to examine the Brazilian pension system, which has incurred in a deficit for a long time, to project its cash flows until 2100, following the 2019 reform, and to present parametric and systematic scenarios with additional changes, still required to guarantee the sustainability of the system in the long run.

For this purpose, all relevant concepts and methodologies were detailed in ***Chapter 2*** and ***Chapter 3*** (the work followed closely the methodology established in (Acosta-Ormaechea, Espinosa-Vega, & Wachs, 2017)). After setting the framework, several different proposals (scenarios) to help solving the deficit problem have been suggested. Such proposals are basically related to changes in some of the parameters defined in the rules to calculate the pension amounts and to systematic shifts. The results associated to each of the scenarios were carefully documented in ***Chapter 4***.

This final ***chapter*** contains a survey of the main results of the study, followed by the explanation of limitations and the lack of data faced by the author during the research. The closing paragraphs give recommendations for possible lines of action and an outlook for further research projects on the topic.

The findings proved that the 2019 reform (***Baseline***) improves the balance and allows the huge deficit in RGPS to decrease, but not as much as required. Therefore, it is very likely that the discussion about the sustainability of the system will be again the order of the day in a few years. Results show that the deficit will decrease over roughly the next 10 years, then an increase will be observed from that time on - although of a much less amount than what would have been in a pre-reform scenario (***Scenario 1***). In fact, the 2029 reform is a good starting point to fight the existing disequilibrium.

Exploring the different scenarios, the most effective proposals seem to be to increase the retirement age by linking it to longevity (***Scenario 2***) and the switch to a DC scheme (***Scenario 7*** to ***Scenario 10***). In particular, ***Scenario 10***, seems to solve the problem in the long run. Moving into a DC context may be a fair option, in the sense that benefits are fully linked to contributions, not to mention that there is a possible boost in economic growth through the accrued savings. However, it is important to emphasize that this is not an easy transition and most of the risks may fall entirely on pensioners. In Brazil, this can be in some way mitigated, as pension benefits cannot be below the minimum wage by law.

The limitations felt result mostly from the lack of data. For instance, the constraint that pension benefits cannot be below the minimum wage was proxied by assuming that they will increase according to the CPI – otherwise an assumption about the income distribution by cohorts of pensioners would be necessary, and there is no information enough for it. Another issue is that the forecast of the population that is available was made taking five-year age groups, but it would be desirable to have information per age. A third aspect is that the study did not consider the peculiarities of the rural sector and the RPPS. There is also an important lack of data by gender, for instance the unemployment rate, the labor force participation rate and the size of the informal sector.

Various recommendations for action can now be suggested. Apart from ***Scenario 2***, linking the retirement age to longevity, most of the parametric reforms in the DB system do not address the sustainability problem properly and other are too extreme to be implemented. Regarding the systematic reform, there is an important positive impact in the long run, if the system shifts to a (partial or full, private or public) DC scenario. The full shift to public NDC (***Scenario 10***) appears to be the most effective strategy in the long run, but a decision must be made concerning the short and medium terms.

The methodology along with the findings described might be helpful to support the decision-making process. In general, the conclusions of the study indicate that the 2019 reform is a first step in the good direction, although still not enough given the enormous current deficit. Brazil might consider an indexation of the retirement age or follow the examples of other Latin countries and shift to a DC system (either total or partial shift), which are the best choices to address the rising level of pension spending and the demographic risk. Naturally, any of them is easily put into practice, for various well-known reasons.

Future research on the topic is mostly linked to the limitations described before. The essential point is to complete data, so that the analysis can be more accurate and extended to the other regimes in Brazil.

The pension system in the country is so complex that many different studies can be conducted. The objective is to obtain a deeper view of the existing situation, related to income after retirement, and how this should be financed for different social and economic strata. In short, the purpose must always be to identify the problems that need to be solved in the several cases and to try giving a contribution to the possible ways to solve them.

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Appendix 1 - Demographic Analysis

This appendix aims to briefly explain the current demographic situation in Brazil, which is the main factor leading the pension system to an insolvency situation. The demographic risk associated specifically to fertility issues will also be addressed.

A. Demographic Transition Model (DTM)

The DTM describes demographic mechanisms based on historical data and trends, especially on the birth and death rates. According to it, the demographic evolution in a country goes through various stages, as the country expands economically. This theory was proposed by (Thompson, 1929) and is supported by a vast literature (Kingsley, 1945; Coale, 1973; Caldwell, 1976). The main objective is to model the relationship between population progression and socioeconomic development since this is the key responsible for fluctuations in birth and death rates. Demographic transition happens at different paces in different countries, mostly because of the specific socio-economic development in each one.

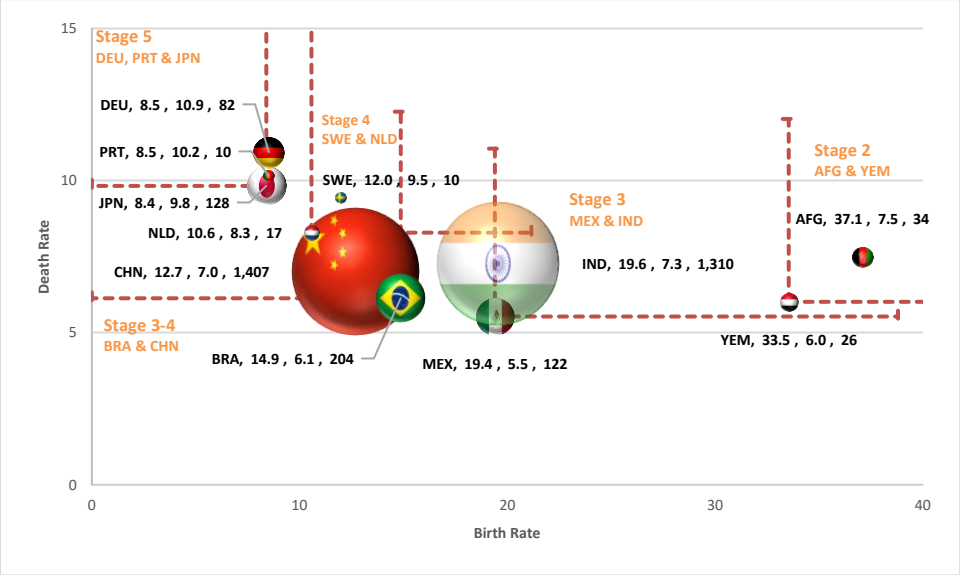
Table A1 - Demographic Transition Model summary

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Birth rate	High rate	High rate	Failing	Low rate	Rising again
Death rate	High rate	Declines quickly	Falls more slowly	Low rate	Low rate
Balance	Stable and rapid fall in each upward age group; short life expectancy.	Rapidly increase; more living in mid-age; slightly longer life expectancy.	Slowly turndown; more people living to old age.	Failing and then stable; higher dep. ratio; longer life expectancy.	Stable or slow increase; old-age greater than youth-age group; very high life expectancy.

Source: Author, based on https://ourworldindata.org/world-population-growth.

The classical DTM (Kingsley, 1945) considers four stages ,according to fluctuations in mortality and birth rates, however the modern approach (Myrskylä, Kohler, & Billari , 2009) includes a fifth stage, as shown in ***Table A1***.

Figure A1 - Birth rate vs Death rate vs Population (Million)



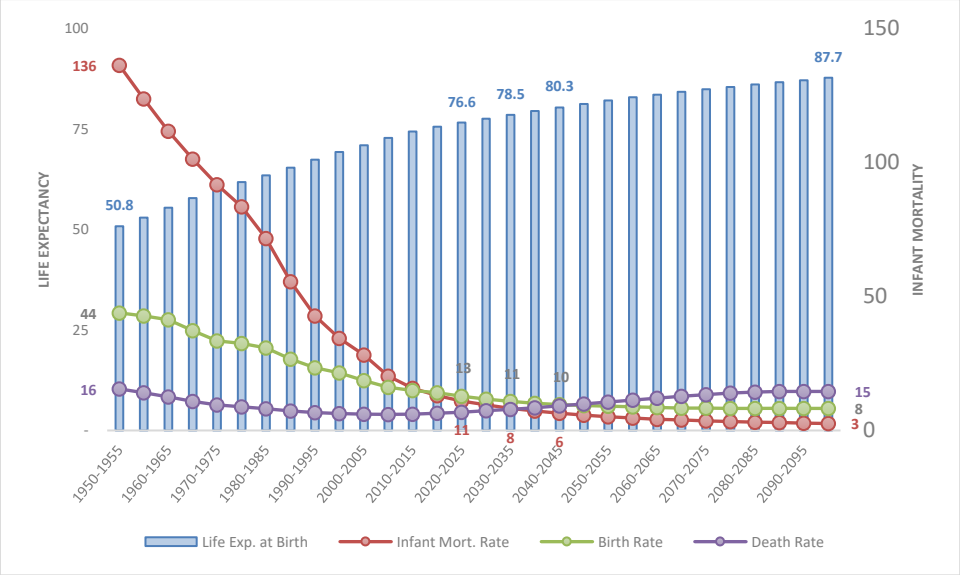
Source: Author, based on UN (United Nations, 2019 a) data.

In ***Figure A1*** examples are given of countries at different stages (along with summarized information on birth rates, death rates and the size of populations). Brazil (and China) is an example of countries that have moved through stages very fast, because the economic and social evolution. On the other hand, countries in Africa have been struggling to leave stage two, due to their economic situations and the prevalence of diseases like AIDS and malaria[9].

In recent years, Brazil has experienced a remarkable increase of life expectancy at birth. According to the UN projection, it will move from 76.57 years in 2020 to 78.50 years in 2030 and to 80.33 years in 2040 (80.87, 82.42 and 83.74 years, respectively, for the OECD population). This is be explained by a reduction in infant mortality and an improvement in the expected lifetime at old-ages. The next figure (see ***Figure A2***) summarizes the principal aspects of demography in Brazil.

[9] For more details, https://www.intelligenteconomist.com/demographic-transition-model/

Figure A2 - Brazilian demographic index



Source: Author, based on UN (United Nations, 2019 a) data.

The birth rate has been decreasing since the 1950s, which is explained by the advance and access to various contraceptive methods, the introduction of family organization and the entrance of women in the work market. It has decreased from 44 in 1950, to 13 in 2020 and the projection for 2050 is 9. Naturally, the same movement occurred in the fertility rate: 6.10 children on average per woman in 1950, 1.86 in 2005 (below the replacement level) and is currently at the same level of OECD members, 1.67. Infant mortality rate (IMR) has also fallen expressively over the last 70 years (136 per 1000 in 1950, 11 in 2020 and the projection for 2050 is 5 per 1000), coming closer to that of OECD countries. The government has been acting to spread the concept of family planning, discouraging low-income families to have many children, improving education, acting on prenatal care and distributing vaccination. The expansion of urban areas, with better sanitary conditions and developing of social environment (Borges, Ervatti, & Jardim, 2015) is another important factor.

The obvious conclusion is that in Brazil the transition through the different stages is occurring faster than the way it was observed in developed countries, with the associated consequences.

Brazil is now under transaction from stage 3 to stage 4 in DTM (Anderson & Schneider, 2014) and thus an important demographic cycle is starting that will lead to a significant raise in senior population and a declining population. The large number of old-age individuals will change the social-economic structure and will pressure the pension and health systems. The government and society in general should be prepared to deal with a new demand of providing pensions, personal savings, and medical care.

Population pyramids (see ***Figure A3***), projected according to UN data from 2020 to 2100, show that there is a steady movement towards an aged population: the group of people above 60 years old will increase from roughly 30 million in 2020 to more than 67 million in 2050, which represents almost 25% of the whole population.

Figure A3 - Population pyramid *(10^6)*: (a) 2020, …, (i) 2100

Figure A3.a – 2020

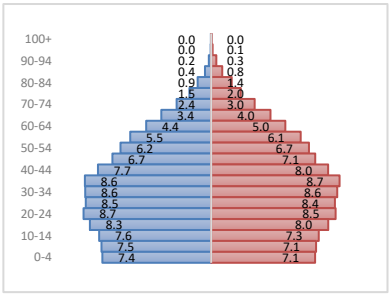


Figure A3.b - 2030

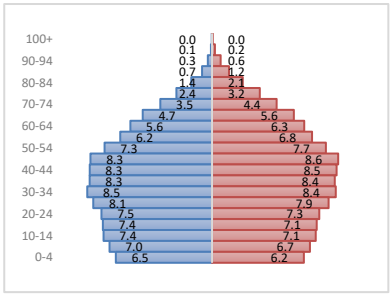


Figure A3.c - 2040

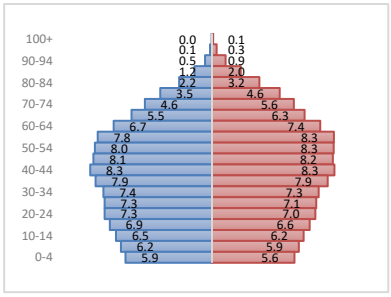


Figure A3.d – 2050

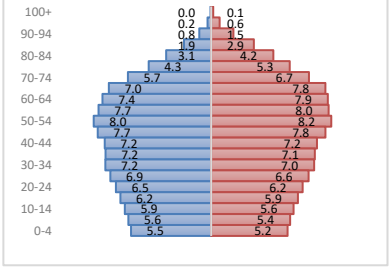


Figure A3.e - 2060

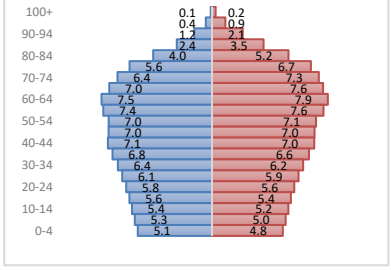


Figure A3.f - 2070

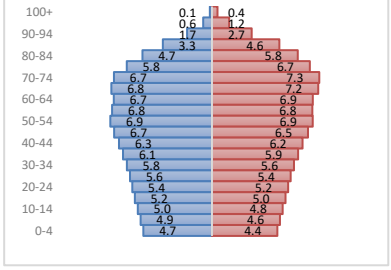


Figure A3.g – 2080

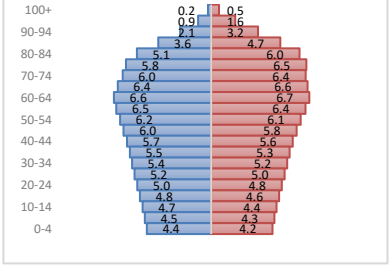


Figure A3.h - 2090

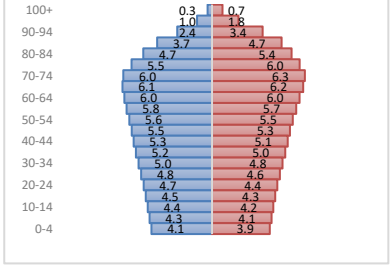
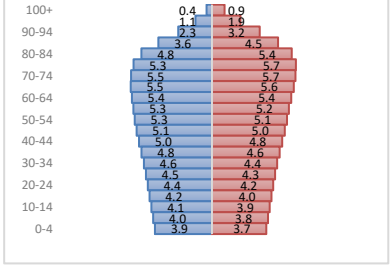


Figure A3.i - 2100



Source: Author, based on UN (United Nations, 2019 a) data.

B. Demographic risk

To include the effects of demographic uncertainty in the study of the sustainability of the pensions system, an additional exercise was performed assuming two stress scenarios (high and low fertility, in accordance with UN population projections (United Nations, 2019 a). Pension benefits, contributions

and finally the balance were computed in the two cases. ***Figure A4*** and ***Figure A5*** display the results, which speak for themselves and are as expected.

Figure A4 - Fertility scenario population *(10^6)*: (a) Male, (b) Female and (c) Total

Figure A4.a - Male

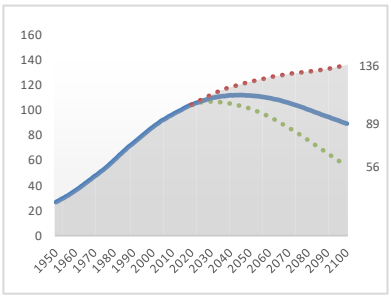


Figure A4.b - Female

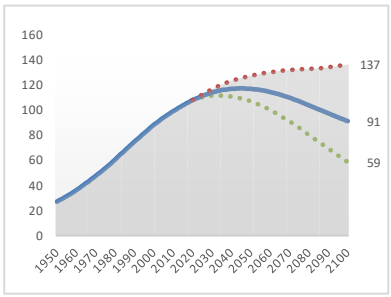
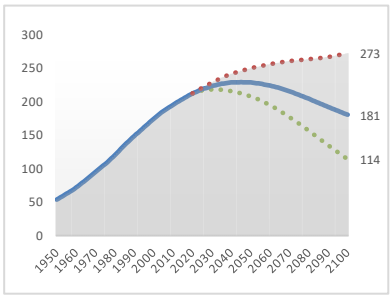
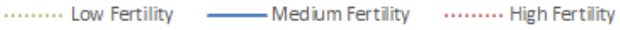


Figure A4.c - Total





Source: Author, based on UN (United Nations, 2019 a) data.

Figure A5 - Fertility stress scenario (% GDP): (a) Male Contr., …, (i) Total Bal.

Figure A5.a - Male Contr.

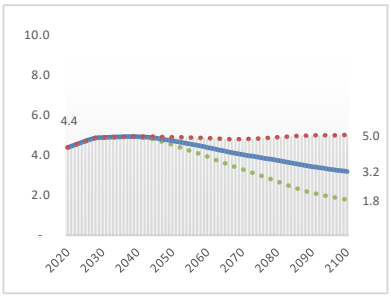


Figure A5.b - Female Contr.

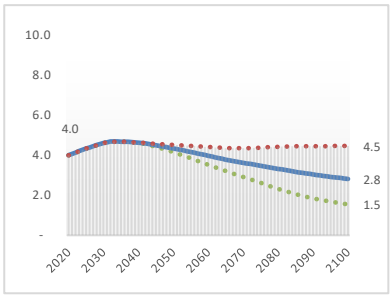


Figure A5.c - Total Contr.

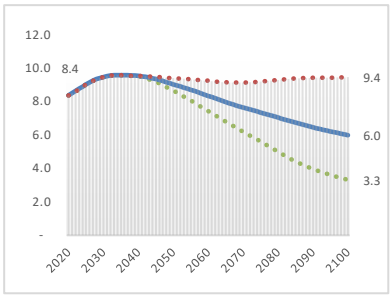


Figure A5.d - Male Ben.

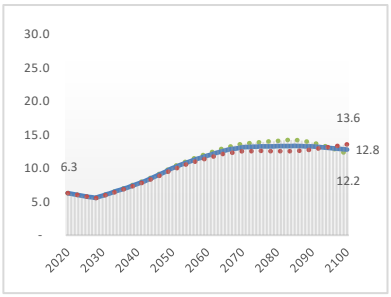


Figure A5.e - Female Ben.

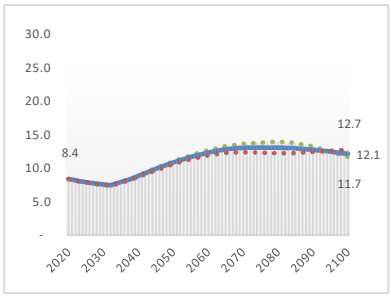


Figure A5.f - Total Ben.

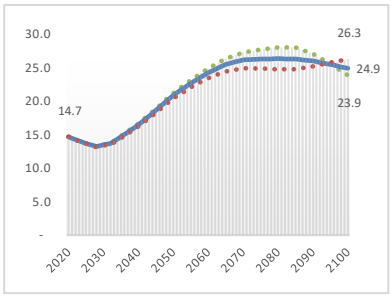


Figure A5.g - Male Bal.

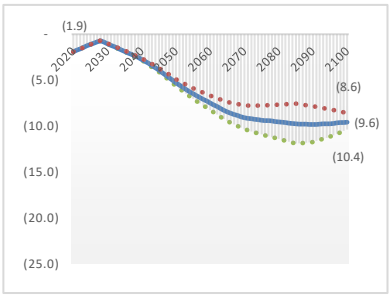


Figure A5.h - Female Bal.

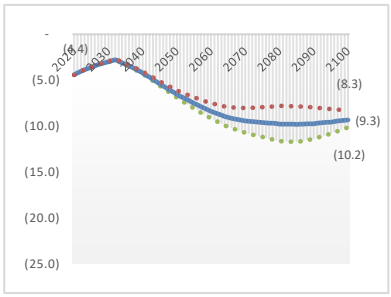
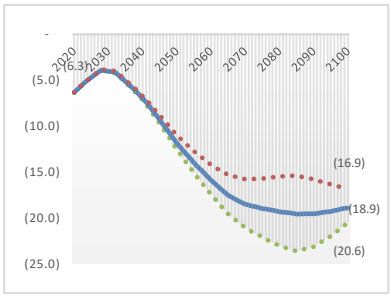


Figure A5.i - Total Bal.



Low Fertility — Medium Fertility — High Fertility

Source: Author

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Appendix 2 - Assumptions

This section describes the demographic, macroeconomic and pension assumptions used in the thesis, the source and a brief description of each one.

A. Demographic assumptions

The *population* is the existing data throughout the projected horizon, it is on annual basis divided by five-year age groups and for the analysis is the medium fertility variant.

The *population growth rate* is assumed to be calculated as the ratio of total *population* and its previous value minus one.

The *labor force participation rate* is the available data until its last available value (2030), thereafter it is assumed to stay constant at the average of the last 5 available values (2026-2030) throughout the projected horizon and it is a percentage of total population ages 15-64.

Table A2 – Description of demographic parameters

	Male	Female	Total	Source
Population (**10^6**)	104.4	108.1	212.6	United Nations[10] (United Nations, 2019 a)
Population growth rate	0.7%	0.8%	0.7%	Author calculations
Labor force participation rate	80.1%	61.1%	70.5%	International Labour Organization[11] (International Labour Organization, 2017)

Source: Author.

B. Macroeconomic assumptions

[10] Available at: https://population.un.org/wpp/Download/Standard/CSV/
[11] Available at: https://www.ilo.org/shinyapps/bulkexplorer9/?lang=en&segment=&id=EAP_2WAP_SEX_AGE_RT_A

The *unemployment rate* is assumed is the available data until its last available value (2024), thereafter it is assumed to stay constant at the average of the last 5 available values (2020-2024) throughout the projected horizon and it is a percentage of total of youth adults ages 25+.

The *size of formal sector* is assumed is the existing data until its last available value (2015), thereafter it is assumed to stay constant at the average of the last 5 available values (2011-2015) throughout the projected horizon and it is a percentage of non-agriculture employment of a harmonized series.

The *GDP deflator* is the existing data until the last available value (2024), thereafter is assumed to be the multiplication of its previous value and the factor of *inflation rate* throughout the projected horizon.

The *inflation rate* (*GDP deflator growth rate*) is assumed to be calculated as the ratio of the *GDP deflator* and its previous value minus one until the last available value (2024) and thereafter it is assumed to stay constant at the average of the last 5 available values (2020-2024) throughout the projected horizon.

The *GDP deflator index* is assumed to be calculated as the ratio of the *GDP deflator* and its value in 2020 minus one until the last available value (2024).

The *GDP (current prices)* is the existing data until its last available value (2024) and thereafter will be calculated as a multiplication of the factor of the *nominal GDP (current prices) growth rate* and its previous value throughout the projected horizon.

The *nominal GDP (current prices) growth rate* is assumed to be calculated as the ratio of *GDP (current prices)* and its previous value minus one until the last available value (2024), thereafter is assumed to be calculated as a multiplication of the factors of *real GDP per capita growth rate*, *population growth rate* and *inflation rate* minus one.

The *real GDP (current prices) growth rate* is assumed to be calculated as the ratio of the division of the *GDP (current prices)* for its previous value and the division of the *GDP deflator* and its previous value minus one throughout the projected horizon.

The *GDP (constant prices)* is assumed to be calculated as the ratio of the *GDP (current prices)* and the *GDP deflator index* until the last available value (2024).

The *real GDP (current prices) per capita* is assumed to be calculated as the ratio of the *GDP (constant prices)* and the total *population* until the last available value (2024).

The *real GDP (current prices) per capita growth rate* is assumed to be calculated as the ratio of the *real GDP (current prices) per capita* and its previous value minus one until the end of the last data available (2024), thereafter it is assumed to stay constant at the average of the last 5 available values (2020-2024) throughout the projected horizon.

The *compensation of employees* is the existing data until its last available value (2017) weighted by the average of the last 5 available values (2009-2014) of the *wage gap gender*.

The *wage gap gender* is the existing data until the last available value (2014), thereafter it is assumed to stay constant at the average of the last 5 available values (2009-2014) throughout the projected horizon.

The *wage share* is assumed to stay constant at the average of the ratio of the *compensation of employees* and *GDP (current price)* of the last 5 available values (2013-2017) until its last available value (2024), thereafter is obtained on the basis of the aggregate wages in the economy and *GDP*.

The *real wage growth rate* is assumed to stay constant at the ratio of the factor of the average of the last 5 available values (2020-2024) of the *GDP (current prices) growth rate* and the factor of the average of the last 5 available values (2020-2024) of the *inflation rate* throughout the projected horizon.

The *discount rate*[12] is assumed to be division of the *real interest rate* minus the *real GDP (current prices) growth rate* over the *real GDP (current prices) growth rate* plus one and it was set to be 1% throughout the projected horizon.

The *real interest rate* is assumed to be the multiplication of the *discount rate* and the factor of the *real GDP (current prices) growth rate* plus the *real GDP (current prices) growth rate* throughout the projected horizon.

The *financial rate of return* is assumed to be the multiplication of the factor of the *real interest rate* and the factor of the *inflation rate* minus one throughout the projected horizon.

The *income share held by lowest 20%* is the existing data until the last available value (2018), thereafter it is assumed to stay constant at the average of the last 5 available values (2014-2018) throughout the projected horizon.

Table A3 - Description of macroeconomic parameters

	Male	Female	Total	Source
Unemployment rate	7.3%	10.8%	8.8%	International Labour Organization[13] (Internation Labour Organization, 2019)
Size of formal sector	61.5%	62.7%	62.0%	International Labour Organization[14] (International Labour Organization, 2018)
GDP deflator	631	631	631	International Monetary Fund[15] (International Monetary Fund, 2019)
Inflation rate	4.2%	4.2%	4.2%	Author calculations
GDP deflator index	100	100	100	Author calculations
GDP (current prices) ($\mathbf{10^9}$)	7,650	7,650	7,650	International Monetary Fund[15] (International Monetary Fund, 2019)
Nominal GDP (current prices) growth rate	6.3%	6.3%	6.3%	Author calculations

[12] The rational is the interest paid in year t as a ratio to debt outstanding at the end of year $t-1$, which constitutes a safe proxy for the interest rate, roughly equal 1%, and it is equivalent to the average interest rate-growth differential (Escolano, 2010; Kogan, Stone, DaSilva, & Rejeski, 2015).
[13] Available at: https://www.ilo.org/shinyapps/bulkexplorer49/?lang=en&segment=&id=UNE_2EAP_SEX_AGE_RT_A
[14] Available at: https://www.ilo.org/shinyapps/bulkexplorer37/?lang=en&segment=&id=IFL_4IEM_SEX_ECO_IFL_RT_A
[15] Available at: https://www.imf.org/en/Publications/WEO/weo-database/2019/October/download-entire-database

Real GDP (current prices) growth rate	2.0%	2.0%	2.0%	Author calculations
GDP (constant prices) ($\mathbf{10^9}$)	7,650	7,650	7,650	Author calculations
Real GDP (current prices) per capita	73,248	70,750	35,989	Author calculations
Real GDP (current prices) per capita growth rate	1.4%	1.3%	1.3%	Author calculations
Compensation of employees ($\mathbf{10^9}$)	1,507	1,296	2,802	United Nations[16] (United Nations, 2019 b)
Wage gap gender	16.0%	16.0%	16.0%	International Labour Organization[17] (International Labour Organization, 2018)
Wage share	23.5%	20.2%	43.8%	Author calculations
Real wage growth rate	2.3%	2.3%	2.3%	Author calculations
Discount Rate	1.0%	1.0%	1.0%	Author calculations
Real interest rate	3.1%	3.1%	3.1%	Author calculations
Financial rate of return	7.4%	7.4%	7.4%	Author calculations
Income share held by lowest 20%	3.10%	3.10%	3.10%	World Bank[18]

Source: Author.

C. Pension assumptions

The *replacement rate* is assumed to stay constant at the average between the available values (2014 & 2018).

The *contribution rate* is assumed to stay constant at the level of the last available value (2020).

The *retirement age (after transition)* is assumed to stay constant at the level of the last available value (2020).

The *retirement age (initial)* is assumed to stay constant at the level of the last available value (2020).

The *minimum pension* is assumed to stay constant at the level of the last available value (2020).

[16] Available at: http://data.un.org/Data.aspx?q=Compensation+of+employees&d=SNA&f=group_code%3a401%3bitem_code%3a20
[17] Available at: https://www.ilo.org/shinyapps/bulkexplorer37/?lang=en&segment=&id=IFL_4IEM_SEX_ECO_IFL_RT_A
[18] Available at: https://data.worldbank.org/indicator/SI.DST.FRST.20

The *average number of contributions per year* to stay constant at the latest available value (2009) in Chile.

The *life expectancy (after retirement)* is assumed to stay constant at the latest available value (2018).

Table A4 - Description of pension parameters

	Male	Female	Total	Source
Replacement rate	61.20%	52.50%	56.78%	OECD[19] (United Nations, 2019 a)
Contribution rate	28.00%	28.00%	28.00%	USA Social Security administration[20] (Social Security Administration, 2019)
Retirement age (after transition)	65.0	62.0	63.5	Ministry of Finance[1]
Retirement age (initial)	61.0	56.0	58.5	Ministry of Finance[1]
Minimum pension	13,585	13,585	13,585	Ministry of Finance[21]
Average months of contributions per year	6.0	6.0	6.0	Ministry of Finance[22] (Chile)
Life expectancy (after retirement)	17.1	22.7	19.9	Brazilian mortality table[23] (Instituto Brasileiro de Geografia e Estatística, 2018)

Source: Author.

[19] Available at: https://data.oecd.org/pension/gross-pension-replacement-rates.htm
[20] Available at: https://www.ssa.gov/policy/docs/progdesc/ssptw/2018-2019/americas/brazil.pdf
[21] For more details, https://www.gov.br/economia/pt-br/assuntos/noticias/2020/02/novas-aliquotas-da-previdencia-entram-em-vigor-em-1o-de-marco
[22] Available at: https://www.dipres.gob.cl/598/articles-58451_doc_pdf.pdf
[23] Available at: https://biblioteca.ibge.gov.br/visualizacao/periodicos/3097/tcmb_2018.pdf