Incentives for Early Retirement and Pension Reform*

Kathleen McKiernan†
kathleen.mckiernan@vanderbilt.edu

September 9, 2022

Abstract

The share of retirees and the size of benefits paid are critical to determine an economy's aggregate spending on Social Security. Increasing the statutory retirement age is a popular policy proposal to decrease the burden of aging populations on pension systems by decreasing the share of households eligible pension benefits. However, in a system in which pension benefits are a function of lifetime earnings, changes in both the extensive and intensive margins of labor supply in response to a reform impact pension costs. Using a heterogeneous-agent OLG model with endogenous retirement choice and pension benefits, I study a 2019 Brazilian pension reform which increased the retirement age. I find that while the reform decreases aggregate pension costs by around 3 percent of GDP, it leads to welfare losses for high-income households. Moreover, I find that a policy which limits the link between intensive margin labor supply and pension size leads to higher aggregate pension costs than the 2019 reform.

Keywords: Retirement, Social Security

JEL Classification Numbers: E6, H55, E13

*I thank Lilly Gaeto for excellent research assistance as well as participants at the NBER Summer Institute, VMACS Junior Conference, SED Annual Conference, NTA Annual Meeting, Meeting of the Brazilian Econometric Society, the Federal Reserve Board of Governors, the Midwest Macroeconomics Meetings, and the Barcelona Summer Forum for helpful comments and suggestions. All remaining errors are mine.

†Vanderbilt University, Department of Economics, Nashville, TN 37235, United States.

1 Introduction

Aging populations put increased pressure on public pension systems as the number of workers per retiree falls and the time citizens spend in retirement rises. Increasing the statutory retirement age–the age at which a worker becomes eligible to claim a pension–in order to incentivize later retirement is a common proposal to reduce the pressure that this demographic change places on Social Security programs. The impact of increasing the retirement age on the government budget, however, is not as simple as calculating the impact of decreasing the years workers spend in retirement. The change in aggregate spending on Social Security over time relies not only on how the share of the population receiving a pension varies over time but also on how the size of pensions paid to retirees changes.

The share of the population receiving a pension directly drives pension spending as more retirees require additional spending on pension benefits, holding pension sizes constant. This pensioner share reflects both the demographics of the economy considered and the retirement ages of households in the economy. First, the changing demographics associated with aging populations increase the share of the population at older ages and, thus, increase the share of the population receiving a pension. Second, if workers are permitted to retire at younger ages, a larger fraction of the population is eligible to claim pension benefits. As more workers receive a pension due to either demographics or lower retirement ages, aggregate pension costs rise.

In addition to the impact of the number of retirees on the total Social Security spending in an economy, movement in the pensions received by individuals also change aggregate spending. Even if the number of pensioners remains constant over time, total pension costs will vary as the size of household level pensions vary due to policy changes or changes in labor supply decisions. Policy changes which impact the formula used to calculate pension benefits directly change the pension received for the same level of lifetime earnings. Second, households can impact their own pensions through both extensive and intensive margins of labor supply. By changing participation and hours decisions, workers change their lifetime earnings and, thus, change their pensions. A more generous benefit formula or a higher earnings base on which benefits are calculated will also lead to higher aggregate pension costs.

A policy with the goal of decreasing aggregate pension spending must use policy change to combat the rising costs associated with demographic change. A reform which increases the minimum age at which workers can receive a pension directly decreases spending as it limits the share of households in the economy which are eligible to receive benefits. Although the population continues to age and put upward pressure on the pensioner share, the increase in the retirement age places a downward pressure on the fraction of workers eligible to claim benefits. Increases in the retirement age, however, will also result in changes to labor supply of households. As work-

ers spend more time in the labor force due to delayed retirement, average earnings continue to evolve. This equilibrium effect of the policy change on earnings impact the pension received by households. The direction of this effect is unclear and depends on how households change their decisions in response to the reform.

In order to quantify these impacts, I build an overlapping generations model with three key features. First, I include age and productivity heterogeneity to study how the reform impacts different birth cohorts and income levels differently. This productivity features a standard hump-shape profile over a worker's life-cycle and peaks when workers are between the age of 40 and 50. Second, I model the retirement decision of the worker. This allows me to study how different programs can push workers to exit the labor force at earlier or later ages. Finally, I allow for the pension benefits received to endogenously depend upon the labor supply decisions of the household. The household decision of how many hours to work impacts the average taxable earnings upon which the pension is calculated. Therefore, changes in earnings impact the pension received. Because the size of the pension is endogenously determined by the household's labor decision, the household internalizes that their labor choices impact future pension size.

The country of Brazil provides a laboratory to study the impacts of increases in the pension claiming age. Brazil is currently a relatively young country.[1] However, despite this demographic advantage, Brazil spends over 10 percent of its GDP on its pay-as-you-go pension payments. The incentives for early retirement present in the current Brazilian system induce workers to retire at young ages by creating two paths to retirement benefits: one through age and one through number of years of contributions to the pension system. Therefore, if workers enter the labor force young, they could be eligible for a pension at a young age. In this work, I use the case of Brazil to study not only the interaction between this incentive to claim benefits early and the Social Security program but also the impact of an increase in the retirement age. In 2019, the Brazilian legislature passed a reform which aims specifically at extending working lives and decreasing the aggregate spending on the pension system.

This 2019 reform increases the statutory retirement age by eliminating paths to early retirement based upon years of contributions to the system. Rather, the reform replaces the current pension program with a system in which pension eligibility is a function of only retirement age while pension size is a function of both average lifetime earnings as well as years of contributions to the pay-as-you-go program. By basing pension eligibility on age, the new program requires workers to reach age 65 prior to claiming pension benefits. By basing pension size of years of participation and earnings, longer working lives may also change the base for pension calculations. How this base changes, however, depends endogenously on how labor supply decisions change in response

[1] Brazil currently has nearly 8 workers (age 15-64) per retiree (age 65+) while the United States only has slightly more than 4 workers per retiree.

to the reform.

I find that the passed increases the average retirement age in the economy by around 4 years and decreases the long-run share of workers claiming pension benefits from 32.6 percent of the population to 27.0 percent of the population. Without the reform, the aging of the population leads pension costs to increase to 21 percent of GDP by 2120 while these long-run costs are 18 percent of GDP with the reform. This indicates that the reform is able to counteract some of the impacts of the demographic change. While the reform decreases aggregate spending and has only a small welfare impact on public sector and low-income private sector workers, middle- and high-income private sector workers experience welfare losses of around 5 percent of lifetime consumption. These welfare losses are driven largely by decreases in leisure caused by increases in extensive margin labor force participation. Since the reform requires workers to stay in the labor for until age 65, households experience decreased leisure throughout these years and endure long-run welfare losses.

The analysis of the impact of the 2019 reform on aggregate pension spending includes both the direct and equilibrium effects of increasing the retirement age. The direct effect decreases the share of the population receiving a pension by changing eligibility standards; the equilibrium effect allows changes in labor supply induced by the reform to impact lifetime earnings and pensions. In order to quantify this equilibrium effect, I consider a counterfactual reform in which pension benefits are calculated based upon earnings up until age 55 rather than lifetime earnings. Therefore, the additional years households spend in the labor force due to the higher statutory retirement age do not change the average earnings used as a basis for pension benefits. The impact of this reform on aggregate spending demonstrates the importance of the household response to the policy.

This counterfactual policy leads to aggregate pension spending of around 19 percent of output. Therefore, while this reform decreases costs relative to the case of no reform, the counterfactual policy is more expensive than the reform as passed. This increase is driven by the income distribution in Brazil. The hump-shaped pattern of productivity means that calculating the average earning up until age 55 is associated with a higher level of average earning. While these higher earnings translate to higher pension benefits for high-income workers, low-income workers continue to receive the minimum pension and experience no increased benefits or consumption. As these lower income workers represent over 50 percent of the Brazilian labor force, the only difference in aggregate pension spending comes from the slightly larger pensions received by high-income households. The income structure of the economy, thus, limits the quantitative impact that the equilibrium effect has on aggregate pension spending.

The paper precedes as follows. Section 2 presents related literature. Section 3 discusses the current Brazilian pension system as well as the proposed reform. Section 4 describes the model. Section 5 details how parameters are estimated from the data and discusses model fit. Section 6

presents and discusses the results of the proposed reform. Section 7 performs and discusses the policy experiment to isolate the mechanisms. Section 8 concludes.

2 Related Literature

Much of the macroeconomic literature on Social Security reform focuses on moving from a pay-as-you-go program to a privatized system. Papers such as Huang et al. (1998), Kotlikoff et al. (1999), Conesa and Krueger (1999), Nishiyama and Smetters (2007), Huggett and Parra (2010), Imrohoroglu and Kitao (2012), andMcGrattan and Prescott (2017) focus on under what conditions these welfare gains are realized and maximized. While related to this literature, in this work I also make the contribution of focusing on how the system pushes workers to retire at younger or older ages. I demonstrate that these incentives make a difference in the results of a reform.

In addition to these papers that present analysis of changes to Social Security, this paper also contributes to studies which focus on how increases in the statutory retirement age may impact these programs. There has been much microeconomics work studying how the statutory retirement age impacts retirement decisions of workers. Specifically, there is a large literature studying how changes in benefits generosity affect the timing of retirement. Papers such as Burtless (1986), Krueger and Pischke (1992), Borsch-Supan and Schnabel (1998), Coile and Gruber (2007), Liebman et al. (2009), Manoli and Weber (2016), Staubli and Zweimuller (2013) study this issue empirically. Additionally, Rust and Phelan (1997)), Gruber and Wise (1998), Gruber and Wise (2002) Mastrobuoni (2009) find that increases in the retirement age leads to large increases in labor supply and participation of older workers. This work adds to this literature by analyzing how this labor supply response can be included in a macroeconomic setting and impact the aggregates in the economy.

The key difference area of study in this paper is related to the household's choice of when to retire. This endogenous retirement choice and its interaction with the Social Security program is a growing area of literature. In public finance, specifically, papers such as Ndiaye (2020), Michau (2014), Cremer et al. (2004), Choné and Laroque (2014), and Shourideh and Troshkin (2015) study the optimal tax and Social Security benefit structures when retirement is a choice. Outside of optimal taxation, Hosseini and Shourideh (2019) studies the system and timing of retirement in an overlapping generations economy while Moser and Olea de Souza e Silva (2019) looks at the optimal design of Social Security when workers are present-biased. My work contributes to the literature by taking the lessons from these optimal tax studies and including them in a quantitative study of a reform.

Finally, as this paper focuses on the economy of Brazil, it contributes to literature on Social Security and informality in developing countries. Among these works are Joubert (2015) and

McKiernan (2021) which focus on Social Security and the labor market in Chile and Moreno (2022) which studies similar issues in Peru. Strongly related to this paper are Jung and Tran (2012) and Tkhir (2022) which also consider the case of Brazil.

3 Social Security in Brazil

3.1 Current System

Currently, government-sponsored pensions in Brazil operate under a pay-as-you-go program with different regimes for public sector and private sector employees.[2] Public sector workers have access to a particularly generous program which pays a pension equal to 100 percent of the last basic salary as long as the individual worked in civil service for at least five years. The minimum retirement age under this regime is 60 years for men and 55 years old for women.

There are two paths to a pension for private sector workers: through age or through years of contributions. A worker is eligible for a full pension through the age track if he is over 65 years of age and has contributed for 15 years of more. On the years of contributions tracks, a worker is eligible for a pension if he has contributed to the pension system for 35 years. Additionally, if the worker began contributing to the system prior to 1998, he is eligible for a proportional pension for early retirement. He can claim this pension if he is over the age of 53 and has contributed to the system for at least 30 years.[3]

When a private sector worker claims a pension through either of the paths mentioned above, the pension is calculated based upon earnings, age at retirement, and years of contributions. This calculation corrects pension size so that workers who retire younger or with fewer years of contributions receive smaller pensions than those who retire at older ages.

In addition to these pay-as-you-go systems, there is also a complementary system which consists of an optional, privately managed and fully-funded regime. This portion is relatively small and available to all workers. The Brazilian government also provides a welfare pension system for workers who do not qualify for a pension through the means discussed above. Specifically, if household income per capita falls below one quarter of the minimum wage they receive a pension equivalent to the minimum wage. Eligibility for this program is revised every two years.

[2]Details of the pension system before the 2019 reform are discussed in OECD (2019), Bonturi (2002), and Medici (2004)

[3]Because only those workers who began contributing to the system (or entered the labor force) prior to 1998, the number of people who are eligible for this early retirement path is decreasing. This early retirement option will eventually disappear.

3.2 Reform

In February 2019, the Brazilian government passed a reform to the current pension system which was aimed at reducing the burden on the public pension program.[4] The key part of the policy change is to eliminate the path to pension eligibility through years of contributions and increase the minimum retirement age. Specifically, the statutory minimum age will increase to 65 years old for men and 62 years old for women. The increase in these ages will occur gradually–with the statutory retirement age increasing 6 months every year until the new age is reached.

There are three transitional plans open to those workers who are in the workforce at the time of the reform. First, those workers who are within 2 years of retirement at the time of the reform may choose to retire at the previous age. However, a worker who chooses this option must pay a 50 percent penalty. This means that if the current system would allow a worker to retire in 1 year, the worker must pay contributions equivalent to 1.5 years. Second, for workers who are in the labor force but not within 2 years of retirement, there will be a "points" based system. A workers can retire once the sum of his or her age and years of contributions reaches a threshold. This threshold begins at 96 for men and 86 for women and will increase one point per year until it reaches 105 for men and 100 for women. Finally, the last transitional plan is to achieve the 35 years of contributions (30 for women) required for retirement. This transitional period is expected to last until 2033.

At the end of the transitional period, there will no longer be an option for retirement due to contribution time. Rather, at the statutory age of retirement (65 for men, 60 for women), a retiree will earn a pension based upon the number of years he or she had contributed. The minimum contributions needed to be eligible for pension benefits is increased from 15 years of contributions to 20 years of contributions. Additionally, the worker needs 45 years of contributions to take the full entitlement, regardless of age. Those who contribute for 20 years will receive 60 percent of their median salary while those who contribute for 45 years will receive 110 percent of their median salary. Those who contribute between 20 and 45 years will receive a proportional pension between 60 percent and 110 percent of their median salary.

4 Model

I use an overlapping generations model with heterogeneous households based upon Auerbach and Kotlikoff (1987) and Huggett (1996) to analyze the impact of the reform to the Brazilian pension system. The economy is populated by households that differ in age, productivity, and preference for the informal sector. Productivity has two components: a fixed level, $\overline{\varepsilon}$, which is

[4] Details of the pension system after the 2019 reform are discussed in OECD (2021) and Bonturi (2002)

constant across the life-cycle and an age-specific component g_j, which captures the hump-shaped evolution of productivity over a worker's lifetime. Productivity of an age j household is given by:

$$\varepsilon_j = \overline{\varepsilon}\,(1 + g_j) \tag{1}$$

where time since entry into the workforce is called the age of the household and denoted by j. Households face a risk of dying between ages j and $j+1$, λ_{j+1}; the maximum age is given by J. Households become pension eligible at age j_P and all households are assumed to be retired after age j_R.

A measure $\mu_t^{1,\overline{\varepsilon}}$ enter as working age (age 1) households with fixed skill level $\overline{\varepsilon}$ at the beginning of period t. $\mu_t^{j,\overline{\varepsilon}}$ is the measure of households of age j and skill level $\overline{\varepsilon}$ at time t.

The parameters $\mu_t^{1,\overline{\varepsilon}}$ define the population dynamics. In particular,

$$\mu_{t+1}^{1,\overline{\varepsilon}} = (1 + g_{nt})\,\mu_t^{1,\overline{\varepsilon}} \tag{2}$$

with $\sum_{\overline{\varepsilon}} \mu_0^{1,\overline{\varepsilon}} = 1$. The growth rate of households entering the workforce is given by g_{nt}. This parameter is assumed to be the same across productivity levels but is permitted to vary across time.

4.1 State Vector

The state vector of the economy, S_t, is defined as:

- t: the time period
- $\left(a^{j,\overline{\varepsilon}}, \overline{y}^{j,\overline{\varepsilon}}, \chi^{j,\overline{\varepsilon}}, t_R^{j,\overline{\varepsilon}}, \mu^{j,\overline{\varepsilon}}\right)$: the joint distribution of assets, average taxable earnings, years of contributions to the public pension system, and retirement age of an age j and skill level $\overline{\varepsilon}$ household and the measure $\mu^{j,\overline{\varepsilon}}$ of these households
- K_m : the aggregate stock of market capital
- B, G, τ : the government fiscal policy variables (the series for debt, government spending, and taxes on consumption, labor, and firm profits and distributions)

4.2 Household's Problem

The value function of an agent of age $j \in \{1, ..., j_P, ..., j_R, ..., J\}$ with fixed productivity level $\overline{\varepsilon}$ is given by[5]:

[5]Specific decisions faced by the household will depend upon the stage of life the household is in (working-life, pension eligible, or retired). Detailed household problems for each stage of life are shown in Appendix A

$$V_{j,\overline{\varepsilon}}(a_t, \overline{y}_t, \chi_t, t_{R,t}, S_t) = \max_{a_{t+1}, c_t, h_{ft}, h_{it}, f_{t+1}} u(c_t, l_t) + \beta \lambda_{j+1} V_{j+1,\overline{\varepsilon}}(a_{t+1}, \overline{y}_{t+1}, \chi_{t+1}, t_{R,t+1}, S_{t+1}) \quad (3)$$

Households of age j and fixed productivity $\overline{\varepsilon}$ enter period t with asset holdings a_t, average taxable income $\overline{y}_t$, years on contributions to the public pension system χ_t, and retirement age $t_{R,t}$. These households also face the aggregate state S_t. Utility takes consumption and leisure as inputs into the function $u(\cdot)$. This leisure input is defined by:

$$l_t = 1 - h_{mt} \quad (4)$$

Leisure is a linear function of hours spent working in the market, h_{mt}. As informality is an important part of the labor market in many developing countries, including Brazil, I include an option for households to work in either the formal or the informal sector of the economy.[6] In the model, informal labor will show up in two places: in the utility function and in the taxes paid. First, market labor is a function of the time spent working in the formal sector and the time spent working in the informal sector of the economy. Therefore, utility is a function of both formality and informality. The function $\Gamma_{\overline{\varepsilon}}(\cdot)$ defines this relationship and differs by fixed productivity type, $\overline{\varepsilon}$.[7]

$$h_{mt} = \Gamma_{\overline{\varepsilon}}(h_{ft}, h_{it}) \quad (5)$$

I assume the function $\Gamma_{\overline{\varepsilon}}(\cdot)$ is convex so that formality and informality are imperfectly substitutable in the utility of the household.

In addition to the utility relationship between formal and informal labor, there is also a wage benefit to working as well as taxes the workers must pay. These taxes paid can be different in the formal and informal sectors. The household maximizes utility subject to its budget constraint. The budget constraint is given by the following:

$$(1 + \tau_{ct}) c_t + \lambda_{j+1} a_{t+1} = (1 + r_t) a_t + w_t \varepsilon_j (h_{ft} + h_{it}) - T_t^{j,\varepsilon}(w_t \varepsilon_j h_{ft}, \overline{y}_t, \chi_t, t_{R,t}) \quad (6)$$

Households choose consumption, c_t and pay a consumption tax, τ_{ct}, on this consumption. Additionally, the household chooses savings for period $t+1$, a_{t+1}. The income side of the market budget constraint is made up of three items. First, the household receives interest on the savings

[6] Estimates in Meghir et al. (2015) indicate that roughly 40 percent of the Brazilian economy works informally.

[7] The fact that this function differs by productivity type will allow formal and informal sector participation to differ across types. This will help me to match facts about informal participation across the income distribution. This will be discussed in depth in the Section 5.4.2

from the previous period, $(1+r_t)\,a_t$. Second, the household receives a wage, w_t, for hours worked in both the formal and informal sectors of the economy during working years.[8] Total labor income in these sectors is given by $w_t\varepsilon_j\,(h_{ft}+h_{it})$ where labor income is determined by the wage rate, w_t, the age-specific productivity of the household, ε_j, and the total hours worked, $h_{ft}+h_{it}$. Finally, the household pays taxes and receives transfers according to a net tax function, T_t^{j,ε_j}. This net tax function is given by the following equation:

$$T_t^{j,\varepsilon_j} = \tau_{ht} w_t \varepsilon_j h_{ft} - \psi_{j,\bar{\varepsilon}}^{R}\left(\overline{y}_t, \chi_t, t_{R,t}\right) - \psi^c \tag{7}$$

The household pays a labor income tax, τ_{ht}, on the income received for work in the formal sector of the economy. It then receives a retirement transfer, $\psi_{j,\bar{\varepsilon}}^{R}\left(\overline{y}_t, \chi_t, t_{R,t}\right)$ which is dependent on the average taxable earnings in period t as well as years of contributions and retirement status. Finally, the household receives a common transfer, ψ^C which is independent of age, skill, and lifetime labor supply decisions. During working years, the value of the retirement transfer is 0. During retirement, households do not work in the market. Therefore, labor tax paid during retirement is 0 and the function simplifies to only the transfers.

Finally, once pension eligible, the household chooses whether to be retired or work next period. Specifically, $f_{t+1}=0$ indicates a household choice to work the next period while $f_{t+1}=1$ represents a household choice to enter retirement the next period. Once a household enters retirement, it is assumed that the household stays in retirement for the remainder of its life.

The individual states, a_t, $\overline{y}_t$, χ_t, and $t_{R,t}$ evolve based on the choices of savings, a_{t+1}, and formal sector work, h_{ft}. Specifically, savings are set as the chosen asset holdings for period $t+1$. Average taxable income evolves based on how much income a worker earns in the formal sector in time t:

$$\overline{y}_{t+1} = \begin{cases} \frac{(j-1)\overline{y}_t + w_t\varepsilon_j h_{ft}}{j} & \text{, if } t_{R,t}=0 \\ \overline{y}_t & \text{, if } t_{R,t}>0 \end{cases} \tag{8}$$

The years of contributions to the public pension system also evolves according to the choice of formal labor supply. If the workers chooses formal labor supply above a threshold, $\underline{h}$, he accumulates a year of contributions.[9] If the worker chooses formal sector labor supply below this threshold, the years of contributions remains constant.

[8]This assumption of the same wage in both sectors is motivated by evidence workers who move from informal positions to formal positions within formal firms do not experience wage gains.

[9]Because I model formality and informality as imperfect substitutes, every household will choose strictly positive participation in both sectors. Therefore, we cannot define contributing to the public pension system by participation in the formal sector. Therefore, we set a threshold and define contributing based upon this threshold.

$$\overline{\chi}_{t+1} = \begin{cases} \chi_t + 1 & \text{, if } h_{f,t} \geq \underline{h} \\ \chi_t & \text{, if } h_{f,t} < \underline{h} \end{cases} \tag{9}$$

The retirement age evolves based on the choice of f, the retirement indicator. There are three options for the evolution of the retirement age state. First, if the worker chooses to continue working, the retirement age remains 0. Second, if the household was working in the current period but has chosen to retire tomorrow, the retirement age is set to be the age in the next period, $j+1$. Third, if the household was already retired, the retirement age is non-zero and constant.

$$t_{R,t+1} = \begin{cases} 0 & \text{, if } t_{R,t} = 0 \text{ and } f_{t+1} = 0 \\ j+1 & \text{, if } t_{R,t} = 0 \text{ and } f_{t+1} = 1 \\ t_{R,t} & \text{, if } t_{R,t} > 0 \end{cases} \tag{10}$$

The aggregate states of the economy evolve with a function, G, that is assumed to be known by the household.

$$S_{t+1} = G\left(S_t\right) \tag{11}$$

4.3 Technology

The production function for the market sector good is given as follows:

$$Y_t = f\left(K_{mt}, H_{mt}\right) \text{ where } H_{mt} = H_{ft} + H_{it} \tag{12}$$

Production uses aggregate market capital and aggregate market labor supply, where aggregate market labor supply is the sum of aggregate formal labor and aggregate informal labor. Additionally, capital evolves according to the following equation, where δ represents depreciation and X_{mt} is investment in market capital.

$$K_{mt+1} = (1-\delta)K_{mt} + X_{mt} \tag{13}$$

4.4 Government

Government policy is defined as a series of sequences, $\{\tau_{ct}, \tau_{pt}, \tau_{dt}, T_t^j(\cdot), B_t, G_t\}$ which represent various fiscal policy elements. τ_{ct} denotes a tax rate on consumption. τ_{pt} represents a tax on accounting profits of the firm. τ_{dt} is a tax on distributions of the firm.

Profits and firm distributions must be defined in order to define the budget constraint of the

government. Accounting profits of the firm, Π_t, and the distributions of these firms, Δ_t, are given by the following equations:

$$\Pi_t = Y_t - w_t \left(H_{ft} + H_{it}\right) - \delta K_{mt} \tag{14}$$

$$\Delta_t = \left(1 - \tau_{pt}\right) \Pi_t - K_{mt+1} + K_{mt} \tag{15}$$

Additionally, $T_t^{j,\varepsilon_j}(\cdot)$ represents the net tax function from the household problem which combines the payroll tax, retirement transfers, and common transfers. The object that enters the government budget constraint is the sum of this transfer function over all households in the economy in time t. B_t denotes government debt, and G_t represents government consumption of a pure public good.

The government budget constraint is defined as:

$$B_{t+1} + \tau_{ct} C_t + \tau_{pt} \Pi_t + \tau_{dt} \Delta_t + \sum_{j,\overline{\varepsilon}} \mu_t^{j,\varepsilon} T_t^{j,\varepsilon} \left(w_t \varepsilon_j h_{ft}, \overline{y}_t, \chi_t, t_{R,t}\right) = (1 + r_t) B_t + G_t \tag{16}$$

On the revenue side of the government budget constraint are issuance of new debt, B_{t+1}, and collection of taxes. These taxes are the consumption tax on market consumption and durable spending, the profit tax on accounting profits of the firm, the distributions tax on the firm's distributions, and the outcome of the net tax function when aggregated over the heterogeneous households alive in any period t. The budget constraint requires that revenue must be equal to government spending. Total government spending is the sum of interest paid on the debt from the previous period, $(1 + r_t) B_t$ and government spending on a pure public good, G_t.

I assume that government debt and government spending are a percentage of output. Specifically,

$$B_t = \phi_B Y_t$$

$$G_t = \phi_G Y_t$$

The net tax function of the household, T_t^{j,ε_j}, includes a per-capita, lump-sum transfer, ψ^c. This transfer will adjust to balance the government budget throughout the transition path.[10]

[10]The welfare results may likely be impacted by what is used to balance the government budget through the transition. Future iterations will consider this issue.

4.5 Equilibrium

An equilibrium in this economy is given by government policies, prices, and allocations such that[11]:

1. Given the government policies, interest rate, and wage rate, the value functions and allocations solve the household's maximization problem given the state variables
2. Given government policies and prices, the firm optimizes
3. The government budget constraint holds in each period
4. All markets clear

5 Parameters

The model includes heterogeneity in fixed productivity, $\overline{\varepsilon}$, and many parameters are permitted to vary by this fixed type. I choose to have four types in the model which are defined by sector of employment and income level. I separate types into these groups: those in which the head of household works in the public sector, those in which the household head works in the private sector and earns less than 2,000 BRL monthly, those in which the household head works in the private sector and earns between 2,000 and 4,000 BRL monthly, and those in which the household head works in the private sector and earns above 4,000 BRL monthly.

5.1 Government Policy Parameters and Fiscal Series

In the baseline, fiscal series remain constant for the entirety of the demographic transition path; the values for the debt position, government spending, consumption taxes, general labor income taxes, profit taxes, and dividend taxes are set equal to their 2018 values.[12]

5.1.1 Labor Income Taxes and Contribution Rates

Both general labor income taxes as well as the Social Security contribution rates before and after the 2019 reform are progressive in nature. Because the model is one of the household rather

[11] A detailed definition of the equilibrium is included in Appendix B.

[12] More details on the various fiscal series and government policy parameters that are not related to the Social Security system are in Appendix D.

Table 1: Household Tax Rates

	Income Tax Rate (τ_h)	Contribution Rate (τ_{ss})	
		Before Reform	After Reform
Public Sector	5.11%	13.43%	13.65%
Private Sector	3.07%	28.08%	29.24%
$\leq 2,000$ BRL	0.00%	28.02%	28.27%
$2,000 - 4,000$ BRL	1.45%	28.37%	29.47%
$> 4,000$ BRL	10.35%	27.59%	30.06%

Notes: Employers of private sector workers also contribute 20 percent of payroll which is assumed to be passed on to the household.

than the individual, I use weighted average of tax rates across the all members as the input into the model. The tax rates used are shown in Table 1 and calculated from the 2015 PNAD survey.[13]

Under the current Brazilian pension system, the contribution rate, τ_{ss}, is based upon sector worked and income. Public sector workers pay a rate of 11 percent of income. Private sector workers pay either 8 percent, 9 percent, or 11 percent of formal sector income as a Social Security payroll tax.[14] The base for contributions is subject to both a minimum level–set to be the minimum wage–and a cap. For those workers in the private sector, employers contribute an additional 20 percent of payroll which is assumed to be passed on to the worker.

5.1.2 Statutory Retirement Age and Retirement Transfers

The retirement transfer, $\psi^R_{j,\bar{\varepsilon}}(\overline{y}_t, \chi_t, t_{R,t})$, is different depending on the reform that is considered as well as the time period–as the time period defines the location in the transition path. I will define this transfer formula for the baseline economy and the reformed economy.

Baseline

Under the baseline pension program, public sector workers, ($\bar{\varepsilon} = \text{public}$), are entitled to a pension equal to their last salary at age 60 if the worker has 15 years of contributions.[15]

[13] Important to note is that the minimum monthly earnings used to calculate contributions are the legal monthly minimum wage (954 BRL in 2019). The maximum monthly earnings used to calculate contributions are 5,645.80 BRL (in 2019).

[14] Appendix Table 1 shows the the details of the income levels and contribution rates.

[15] A previous reform in 1998, increased the retirement age for public sector workers from 53 years of age to 60. I use the age of 60 for the public sector in this work.

$$\psi_{j,\overline{\varepsilon}}^{R}\left(\overline{y}_t, \chi_t, t_{Rt}\right) = \overline{y}_t \tag{17}$$

Before the reform, the Brazilian pension system included two paths to retirement benefits for private sector workers, ($\overline{\varepsilon} =$ private): retirement on the basis of contributions and retirement on the basis of age. If workers qualify for retirement on the basis of contributions, pension size is calculated based on Equation (18). This full pension formula applies for those who meet the minimum requirement of being over the age of 53 ($t_{R,t} \geq 33$) and contributing for at least 30 years, ($\chi_t \geq 30$), if the worker entered the labor force prior to 1998, or contributing to the system for at least 35 years ($\chi_t \geq 35$) if the household entered the labor force after 1998.

$$\psi_{j,\overline{\varepsilon}}^{R}\left(\overline{y}_t, \chi_t, t_{Rt}\right) = \overline{y}_t \times \underbrace{\left[\frac{0.31 \times \chi_t}{le\left(t_{R,t}\right)}\left(1 + \frac{t_{R,t} + j_0 + 0.31 \times \chi_t}{100}\right)\right]}_{\text{Fator Previdenciário}} \tag{18}$$

Pensions are calculated by taking the average taxable income of the worker[16], $\overline{y}_t$, and multiplying by an actuarial coefficient which adjusts the size of benefits based upon retirement age and life expectancy at the time of retirement. This actuarial coefficient is called the Fator Previdenciário.

The formula for the Fator Previdenciário takes into consideration the contributions that the worker has made at the time of retirement, $(0.31 \times \chi_t)$[17], the worker's life expectancy at retirement $le\left(t_{R,t}\right)$, and the age (not the working life) of the citizen, $(t_{R,t} + j_0)$, where j_0 represents the age at which the worker enters the labor force.

If, rather, workers qualify for retirement on the basis of age (i.e. $t_{R,t} \geq 45$), the pension is calculated slightly differently. This formula is shown in Equation 19.

$$\psi_{j,\overline{\varepsilon}}^{R}\left(\overline{y}_t, \chi_t, t_{Rt}\right) = \max\left\{0.70 + 0.01 \times t_{R,t}, 1.0\right\} \times \overline{y}_t \times \max\left\{1, \underbrace{\left[\frac{0.31 \times \chi_t}{le\left(t_{R,t}\right)}\left(1 + \frac{t_{R,t} + j_0 + 0.31 \times \chi_t}{100}\right)\right]}_{\text{Fator Previdenciário}}\right\} \tag{19}$$

The pension calculation for these workers begins, once again, with the average taxable earnings of the worker, $\overline{y}_t$. These earnings, however, are augmented by the number of years of contributions a worker has made. This base is multiplied by 70 percent plus 1 percentage point for each year of

[16] In practice, the system takes the average of the highest 80 percent of earning years rather than the uncontrolled average. I use the average over all working years for tractability reasons.

[17] Pension calculation uses a rate of 31% for contributions no matter the true income or contribution rate of the worker. Because this represents the sum of the contribution rates for high income workers and employers, this is a built in form of redistribution within the pension system

contributions. The Fator Previdenciário is only applied in this calculation if it is greater than 1.

Both calculations are constrained by the same minimum, $\underline{\psi}^R$, and maximum, $\overline{\psi}^R$, limits.

Reform

The proposed reform includes no changes for public sector workers but changes the formula for calculating the pension of private sector workers in a few important ways. First, this reform changes the thresholds at which the worker is eligible for any pension. Second, the reform proposed a change to the formula used to calculate the pension. Age determines whether the worker is eligible for a pension at all; given that the worker is eligible, the years on contributions determines the size of the pension. The post-reform pension formula is given by:

$$\psi^R_{j,\bar{\varepsilon}}\left(\overline{y}_t, \chi_t, t_{R,t}\right) = \begin{cases} 0 & \text{,if } t_{R,t} < 45 \\ 0.6\overline{y}_t & \text{,if } t_{R,t} \geq 45, \chi_t = 20 \\ \left(0.6 + 0.02\left(t_{R,t} - j_0\right)\right)\overline{y}_t & \text{,if } t_{R,t} \geq 45, 20 < \chi_t < 45 \\ 1.1\overline{y}_t & \text{,if } t_{R,t} \geq 45, \chi_t \geq 45 \end{cases} \tag{20}$$

If a worker retires before the age of 65 ($t_{R,t} < 45$), he receives no pension. If, however, he retires at age 65 or older, he receives a pension whose size depends upon the years of contributions he accumulated. If he contributed for 20 years, he receives a pension equivalent to 60 percent of his average salary, $\overline{y}_t$. On the other extreme, he contributed for at least 45 years, he receives a pension equal to 110 percent of his average salary. If he contributes between 20 and 45 years, he receives a pension which linearly increases with his years of contributions.[18] The ceiling and floor on pensions, $\underline{\psi}^R$ and $\overline{\psi}^R$, also apply on this calculation.

Implementation of this reform requires a transition period between the two models. Although the reform includes three different path to a pension for transitional generations, I model the eligibility for a pension throughout the transition path as a gradual increase in the statutory retirement age. Specifically, the age at which workers become eligible to retire increases by 1 year every 2 years.[19] Workers may choose early retirement at this new retirement age if he has accumulated 35 years of contributions.

[18]This imply that for each additional year of contributions, the worker is eligible for an addition 2.8 percent of the average salary. For example, after 21 years of contributions the worker receives a pension of 42.8 percent of his average salary, after 22 years, he receives a pension of 45.6 percent of his average salary and so on.

[19]This is because the reform increases the age by 6 months every year.

5.2 Market Labor Supply Parameters

I choose a constant elasticity of substitution function to represent the relationship between market labor supply parameters, $\Gamma_{\overline{\varepsilon}}(\cdot)$. Specifically,

$$h_{mt} = \Gamma_{\overline{\varepsilon}}(h_{ft}, h_{it}) = \left\{a_\varepsilon h_{ft}^{b_\varepsilon} + (1 - a_\varepsilon) h_{it}^{b_\varepsilon}\right\}^{\frac{1}{b_\varepsilon}}$$

I will use Brazilian micro data in order to estimate the parameters of this function. The parameter a governs the share of formal and informal work while b will determine the substitutability between these sectors. These parameters will be estimated separately for each fixed productivity type, $\overline{\varepsilon}$.

5.2.1 Data and Sample

Data for the estimation is from Pesquisa Nacional por Amostra de Domicilios (PNAD). PNAD is a national survey of Brazilian households which has been collected since 1981 and contains demographic and employment information for respondents. For this work, the year 2015 is used in the estimation.

Important for the analysis presented here, this data set includes details regarding the earnings, hours, and employment situation of the workers. Because the data contains information on whether a worker is employed formally or informally, I can classify both hours worked and income earned as either formal hours and income or informal hours and income.

The final sample for the estimation contains all household heads between the ages of 20 and 55 and households that work at least 50 market hours per month. The final sample contains 57,357 household observations.[20]

5.2.2 Estimation and Results

In order to measure the parameters a and b, I estimate the following linear regression derived from the first order conditions of the structural model:

$$\ln\left[\frac{h_f}{h_i}\right] = \beta_0 + \beta \ln(1 - \tau_h) + \mu \tag{21}$$

where $\beta_0 = \frac{1}{b_\varepsilon - 1} \ln\left[\frac{1-a_\varepsilon}{a_\varepsilon}\right]$ and $\beta_1 = \frac{1}{b_\varepsilon - 1}$

This regression equation follows the methodology in McKiernan (2021) where the substitution between formality and informality will be identified by differences in the ratio of formal hours to

[20] Additional details related to the sample is included in Appendix E.1.

informal hours across the cross section of labor tax rates.[21] I include controls for education level, age, martial status, race, gender, as well as the number of people included in the household.

I perform the estimation separately for each productivity group. The results of the estimation are shown in Table 2. This table shows the structural parameters that are constructed from the regression coefficients as well as the elasticity of substitution between formal and informal hours which is implied by these parameters.[22]

Results demonstrate that there is substantial differences in these preference parameters both across public and private sector workers but also across income levels within the private sector. The weight parameter, a_ε, varies between 0.417 for low-income private sector workers to 0.787 for the highest income private sector workers. This results indicate that those with higher income levels have market work which is more heavily weighted to formal hours. This reflects that in the data higher income households tend to have a higher share of total hours coming from hours worked in the formal sector.

There are larger differences in b_ε, the parameter which governs the elasticity of substitution between sectors, across groups. Most notably is once again the difference between the lowest and highest income private sector workers. Those private sector workers who earn less than 2,000 BRL monthly have $b_\varepsilon = 0.977$. This implies a very high elasticitiy of substitution between these groups; for the lowest income groups, formal and informal work are nearly perfectly substitutable. This substitutability, however, decreases with income level. Middle income private sector workers and public sector workers are estimated to have an elasticity of substitution of around 2. This indicates that while formal and informal hours are substitutable for these groups, they are not perfectly substitutable. For those highest income private sector workers, I estimate $b_\varepsilon < 0$ this indicates that for these households formal and informal sector work is more complementary. This variation across groups reflects that there is less variation in the ratio of formal to informal sector hours across the distribution of labor income tax rates as higher levels of income are considered.

5.3 Other Parameters

The remaining parameters are either set outside the model based on previous literature and data or internally calibrated to match macroeconomic aggregates. These parameters are shown in Table 3.

[21]The methodology used to estimate these parameters is based upon the methodology used to estimate the substitutability between home production and market work used in papers such as Aguiar et al. (2013), Benhabib et al. (1991), and Rupert et al. (1995).

[22]Regression results and sensitivity on these results are included in Appendices E.2 and E.3

Table 2: Estimated Parameter Values

	Estimate				Elasticity of Substitution
public sector	$a =$	0.479	$b =$	0.503	$\eta = 2.012$
		(0.167)		(0.032)	
private sector					
$\leq 2,000$ *BRL*	$a =$	0.418	$b =$	0.977	$\eta = 42.903$
		(0.005)		(0.004)	
$2,000 - 4,000$ *BRL*	$a =$	0.450	$b =$	0.428	$\eta = 1.749$
		(0.143)		(0.084)	
$> 4,000$ *BRL*	$a =$	0.787	$b =$	-0.486	$\eta = 0.673$
		(0.430)		(0.256)	

Notes: The elasticity of substitution is calculated as $\eta = \frac{1}{1-b_\varepsilon}$

5.3.1 Parameters Set Outside the Model

Coefficient of Relative Risk Aversion

The utility function is represented by a CRRA function.

$$U(c, l) = \frac{\left(c^{\gamma} l^{1-\gamma}\right)^{1-\sigma} - 1}{1 - \sigma}$$

I set $\sigma = 2$ in the analysis that follows.

Production Parameters

I choose a Cobb-Douglas function for the market production function:

$$Y_t = (K_{mt})^{\alpha} (H_{ft} + H_{it})^{1-\alpha}$$

The weight of capital in market consumption, α, and the depreciation rate of capital, δ, are also set outside the model. In accordance to other literature, I set $\alpha = 0.33$ and $\delta = 0.05$ in the analysis.

Life-Cycle Productivity

Growth in labor productivity over the life-cycle, g_j, is assumed to be a function of age and the same for all fixed productivity types. This profile is estimated from PNAD.[23]

[23]Details on this estimation is in Appendix F

Table 3: Other Parameters

Parameter	Description	Value	Target	Source
β	Discount rate	0.972	$\frac{K}{Y} = 2.76$	World Bank
γ	Weight of consumption in utility	0.235	Annual formal hours worked per worker $= 1,381$	PNAD 2015*
$\overline{\varepsilon}$	Productivity	$\{1.4, 0.4, 0.8, 2.7\}$	public sector: 39% $\leq 2,000$ BRL: 11% $2,000 - 4,000$ BRL: 20% $> 4,000$ BRL: 30%	PNAD 2015
α	Weight of capital in production	0.33		
δ	Depreciation	0.05		
σ	Risk aversion	2		
$\underline{h}$	Contribution threshold	0.247	Average formal hours worked per worker among contributing households = 1,284	
$\underline{\psi}^R$	Floor on pensions	0.244	954 BRL monthly	
$\overline{\psi}^R$	Ceiling on pensions	1.443	5,645.80 BRL monthly	
j_0	Age of Labor Force Entry	20		
J	End of Life Age	80	Exit the model at age 99	

Notes: *The average annual formal hours per worker are calculated from the 2015 wave of PNAD. Total annual hours (formal and informal) from PNAD matched well with aggregate annual hours worked per worker from FRED.

Contributions

The threshold of hours at which a worker is considered as contributing to the public pension system is set based upon the average formal sector hours worked per worker among households that report contributing to the public pension system. In the PNAD data, these contributing household report that on average each worker works 107 formal hours monthly or 1,284 formal hours annually. Assuming 100 disposable hours weekly, this translates to a threshold of $\underline{h} = 0.247$ or slightly above part-time hours in the formal sector.

Ceiling and Floor on Pensions

The ceiling and floor on the pensions received are set based upon the 2019 pension policy. The minimum pension received is equivalent to the minimum wage, or 954 BRL monthly. The ceiling on pensions, then, is equivalent to 5,645.80 BRL monthly. In the model, this is equivalent to setting the floor on pensions, $\underline{\psi}^R$, to 0.244 and setting the pension ceiling, $\overline{\psi}^R$, to 1.443. These values are chosen by matching the average income (conditional on working) in the model to the average income in the data.

Demographic Parameters

The growth rate of the population, g_{nt}, is set so as to match the growth rate of the Brazilian population. The population growth is expected to decline from 0.75% in 2019 to below 0.1% by 2050. I assume that the population growth stays constant after 2050 until the end of the transition path. The survival probabilities, and the life expectancies implied by these survival probabilities, are also used as inputs.[24]

Age of Labor Force Entry and Exit

The age at which workers enter the labor force is important for understanding retirement dynamics, particularly in a country which exhibits early retirement. Additionally, the age at which workers die is important to understand the length of time workers spend in retirement. In this work, I set the age at which workers enter the labor force at age $j_0 = 20$. Therefore, $j = 1$ represents a household in which the head is 20 years old.[25] The maximum possible age in the model is set to be age 99 or $J = 80$.

[24]Details on these demographic parameters are in Appendix G

[25]The average Brazilian workers enters the labor market between the ages of 15 and 18. Over 90 percent of workers have entered by age 20.

5.3.2 Internally Calibrated

In the final stage of the estimation, parameters are internally calibrated to match macroeconomic aggregates. The discount factor, β, the weight of consumption in utility, γ, and the fixed productivity level, $\overline{\varepsilon}$, are set so as to match the capital-output ratio of the economy, the aggregate formal hours worked, and the fraction of total labor income received by each of the types.

The aggregate data used to calculate the target moments come from two sources. First of these sources is the Brazilian National Accounts. The capital-to-output ratio is calculated from this source. National account data provides time series for investment and GDP that are used in this calculation. A time series for the capital stock is constructed using this data. The calculation returns a ratio of capital-to-output of 2.76 for 2015.

The second data source, the PNAD dataset, is used for the measure of annual formal hours worked per worker. Data shows that annual formal hours worked per worker in Brazil was 1,381 hours in 2015.[26] I, once again, assume discretionary time per week is 100 hours. Therefore, the fraction of time spent working is 0.27.

Next, fixed productivity terms in the model are chosen in order to match the fraction of labor income received by each of the types in the model. Data shows that public sector workers represent 28 percent of the population and earn 39 percent of income. Low income private sector workers (less than 2,000 BRL monthly) are 32 percent of the population while they earn 12 percent of income; middle income (2,000-4,000 BRL monthly) are 26 percent of the population and earn 20 percent of labor income; high income private sector workers (more than 4,000 BRL monthly) are 14 percent of the population and earn 30 percent of labor income. The model reproduces these facts when $\{\varepsilon_1, \varepsilon_2, \varepsilon_3, \varepsilon_4\} = \{1.4, 0.4, 0.8, 2.7\}$

5.4 Model Fit

5.4.1 Targeted Moments

The fit of the model is shown in Table 4. As shown, the model does a good job of replicating these targeted moments. In particular, the model can get very close to matching the capital to output ratio for the economy as well as the aggregate market hours worked: the data shows a capital to output ratio of 2.76 while the model produces a capital to output ratio of 2.79 and the aggregate formal hours worked are calculated as 0.27 in the data while the model reproduces a fraction of time worked formally equal to 0.26. Additionally, the model does particularly well at matching the income distribution and replicates the percentage of labor income earned by each of

[26]Formal hours are used as the target rather than aggregate hours. Specifically, it is unclear if aggregate data on hours workers per worker (from FRED, for example) is the total of formal and informal or just formal hours. This is discussed in additional detail in Appendix H

Table 4: Model Fit

Targeted Moments	Data	Model
Capital-to-output ratio	2.76	2.79
Aggegrate formal hours worked	0.27	0.26
Share of labor income earned by		
public sector	0.39	0.38
private sector earning $< 2,000$ *BRL*	0.11	0.12
private sector earning $2,000 - 4,000$ *BRL*	0.20	0.20
private sector earning $> 4,000$ *BRL*	0.30	0.30
Untargeted Moments		
Average retirement age	58	60
public sector	–	60
private sector earning $< 2,000$ *BRL*	–	65
private sector earning $2,000 - 4,000$ *BRL*	–	56
private sector earning $> 4,000$ *BRL*	–	56
Percentage of GDP spent on pensions	12.7	11.5
public sector	4.1	3.7
private sector	8.6	7.8
Share of private sector retirees receiving minimum	0.67	0.81
Formal/informal hours ratio	0.73	1.34
public sector	1.47	1.28
private sector earning $< 2,000$ *BRL*	0.70	0.89
private sector earning $2,000 - 4,000$ *BRL*	1.42	1.31
private sector earning $> 4,000$ *BRL*	1.67	3.33

Notes: Data estimates of pension spending as a percentage of GDP use 2018 as the reference year (World Bank Group (2022))

the three productivity types, although it slightly underpredicts the labor income share of the public sector workers while slightly overpredicting the labor income of private sector workers who earn less than 2,000 BRL monthly.

5.4.2 Untargeted Moments

Model fit is also assessed based on how the model can match statistics which are not targeted in the calibration reasonably well.

A major part of the Brazilian system and the reform proposals considered is the early age at which workers retire. As shown in Table 4, the data indicates that the average retirement age of Brazilian workers is 58 years.[27] The model produces an average retirement age of 60 years. While I do not have data counterparts on retirement age by income and employment, Table 4 also shows that the model predicts heterogeneity in retirement age. Higher income workers, who are more likely to have formal sector jobs and obtain the necessary contributions for pension eligibility by years of contributions, have a retirement age of 56 while those lower income workers wait until age 65 to retire.[28]

In addition to the age at retirement, the model is also able to replicate results regarding the aggregate spending on pensions and the percentage of workers who receive only the minimum pension. First, data indicates that the Brazilian government spends roughly 12.7 percent of GDP on pensions (4.1 percent on public sector pension and 8.6 percent on private sector pensions). The model predicts spending of 11.5 percent of GDP on pensions with 3.7 percent on public sector and 7.8 percent on private sector pensions.[29] Therefore, the model underpredicts, although only by a small amount, pension spending in each of these areas. Finally, data estimates that two-thirds of private sector workers earn below the minimum wage and, therefore, receive only the minimum pension. The model predicts this share of below minimum wage workers to be 81 percent.

A final untargeted moment relates to the ratio of formal to informal hours.[30] In the data, the ratio of formal to informal hours is 0.73. The model produces this ratio at 1.34. While the model over predicts the average ratio of formal to informal hours, however, it does well at predicting this

[27] In Brazil, the average retirement age for men in 58 years old. The average retirement age for women is 53 years.

[28] These retirement ages, especially the retirement age for those who retire based upon contributions, depend critically on the age at which workers are assumed to enter the labor force. For each year earlier that workers are assumed to enter the labor force the age at which they reach 35 years of contributions. For example, if worker enter the labor force at age 18, a worker could reach retirement eligibility at age 53. This would decrease the average retirement age in the model.

[29] Estimates for pension spending on private and public sector pensions are for the year 2018.

[30] These ratios depend critically on whether zeros are included for the ratio of formal to informal hours. A zero value for this ratio implies the household participates only in the informal sector and biases these averages down. If these zeros are included, the aggregate mean is 0.89. Across types, this mean because 1.88 for public sector workers, 2.0 for private sector workers earning below 2,000 BRL monthly, 2.06 for private sector workers earning between 2,000 and 4,000 BRL monthly, and 2.29 for private sector workers earning more than 4,000 BRL monthly.

ratio by income level. The highest ratio of formal to informal hours in among the public sector workers and the highest earning private sector workers; the lowest ratio of formal to informal hours is among the poorest private sector workers. The model replicates this pattern. The model also replicates this ratio is below 1 (indicating the household spends more hours working informally than formally) for low earnings private sector households while this value is above 1 for the other groups. The model does, however, quantitatively over predict the share of formal to informal hours among the highest-earning private sector workers.

6 Results

This section will present the results of two transition paths and the welfare comparisons between them. In both transition paths, the population will age due to the falling population growth. In the first transition path, the pension system continues unchanged. In the second transition path, I allow the pension formula to change to the reform that was passed in February 2019.

In the follow sections, I discuss the impact of this reform on labor supply–specifically the extensive margin of retirement choice as well as the intensive margins of hours worked and contributions to the public pension system–,aggregate pension costs, and welfare.

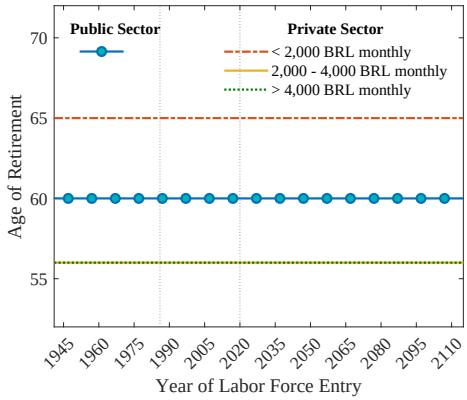
6.1 Labor Supply

The Brazilian pension reform makes substantial changes to the statutory retirement age as well as the formula used to calculate pension benefits. These changes to the pension system impact both the choice of what age to exit the labor force and the choice of how many hours to work while in the labor force. In addition to changes to the benefits side of the pension program, the 2019 reform also makes small changes to the contribution rates paid by workers. The contribution rate impacts the choice of formal and informal hours and, thus, the years that a worker contributes to the Social Security system. The changes to the retirement age and years of contributions are shown in Figure 1 are discussed below. As the years of contributions to the public pension system are determined by hours worked in the formal sector of the economy, I will use years of contributions as a measure of the intensive margin of labor supply.

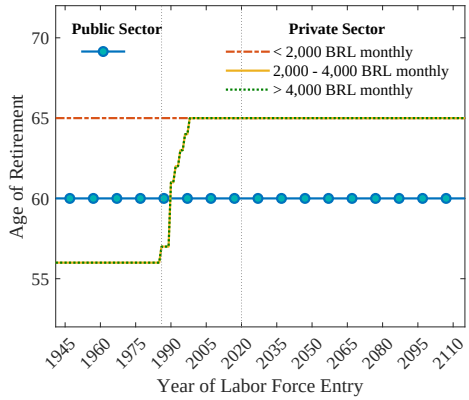
Figures 1a and 1c show how the retirement age for each productivity type varies by cohort throughout the transition path for the case of no reform while Figures 1b and 1d show these variables for the case of the reform. Cohorts at the far left side of these graphs are those who are the oldest at the time when the transition path begins. Later years of labor force entry (moving right on the x-axis), the cohorts are younger at the beginning of the transition or are cohorts who are new to the labor force after the transition path begins.

Figure 1: Retirement Age and Years of Contributions by Cohort

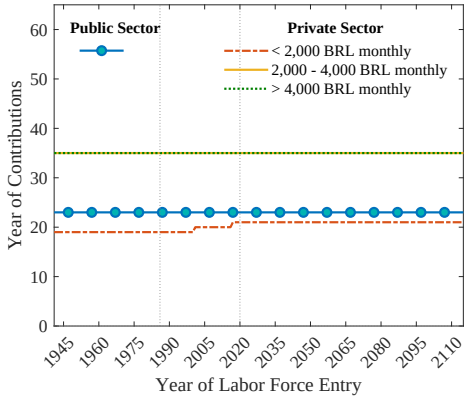
(a) Retirement Age, No Reform



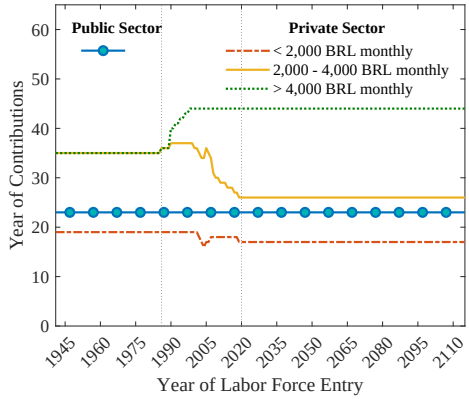
(b) Retirement Age, Reform



(c) Years of Contributions, No Reform



(d) Years of Contributions, Reform



Note: vertical lines separate cohorts into those who are (from left to right) roughly retired (over age 56), working age, or not yet entered the labor force at the beginning of the transition path

Figure 1a shows that prior to the reform workers of different sectors and income levels make different decisions with regards to retirement. Workers choose to retire as soon as they are eligible for a pension, and differences in when workers become eligible drive differences in retirement ages across fixed productivity types. Public sector workers become eligible at age 60 and thus choose retirement at this age. However, for private sector workers the prior system featured two paths to qualify for a pension–either through age or through years of contributions. These different paths are evident in Figure 1c. Higher-income households work a higher share of their total hours in formal sector jobs and accumulate the 35 years of contributions necessary for pension eligibility and retire at age 56. Low-income workers do not work sufficiently in the formal sector to qualify along the contributions path. Rather, these workers have only 23 years of contributions and retire at age 65 when they become pension eligible through the age path.

When the reform occurs, retirement ages, shown in Figure 1b, change based upon the new

eligibility rules. The oldest private sector cohorts make the same retirement decision as in the case in which the current system continues. These workers are either grandfathered in or are early enough in the transition that they qualify for the pension based upon the early retirement rules instituted as part of the transitional policy. For workers who enter the labor force after roughly 1988, the reform has a large, discrete impact on the retirement age of middle and high-income private sector workers (those who earn 2,000-4,000 BRL or more than 4,000 BRL monthly) while not impacting public sector or low-income private sector workers. The pension reform does not make changes to the eligibility for public sector workers, and, therefore, these workers continue to retire at age 60. Low-income private sector workers, additionally, previously retired under the age path and continue this as the reform phases out the path based upon years of contributions. For high-income workers, on the other hand, the transitional policy requires a gradual increase in the retirement age. Throughout the years of the transition path between statutory retirement ages, the retirement age increases from 56 to 65. This retirement age remains at age 65 for all these higher income private sector workers who enter the labor force at later years.

In the long-run, this reform implies an aggregate average retirement age of 64 years of age–a 4 year increase from pre-reform baseline.

Figure 1d shows how the years of contributions of these cohorts evolve throughout the transition path in which the reform occurs. Once again, those workers who entered the workforce at the earliest years (furthest left on the graph) are grandfathered in under the previous system. There are large differences in the years of contributions across the groups, as discussed above. As the transition occurs, the changes to eligibility in the pension system lead to movements in years of contributions for private sector workers. Low-income private sector workers receive only a welfare pension. As the eligibility levels for these pensions do not change, there are not substantial movements in contributions levels for these lowest income workers. The reform, however, leads to changes in contributions for both middle-income and high-income private sector workers. Changes to the pension system mean that higher number of years of contributions lead to higher pensions; this leads high-income workers to increase labor supply, accumulate additional years of contributions, and receive higher pensions. Middle-income workers, however, do not have sufficient income to finance a pension higher than the minimum despite having 35 years of contributions. As the reform lowers years of necessary contributions for a pension to 20 years, these workers decrease their labor supply and years of contributions. Because of their income, they continue to receive the same minimum pension despite contributing for fewer years.[31]

[31] Change in contributions across middle- and high-income workers also reflects the higher contribution rates these workers face after the reform. Higher contribution rate change the share of formal hour to informal hours. However, as these changes in contribution rates are small, they can only explain a small portion of these movements in contributions

6.2 Aggregate Spending on Pensions

Define aggregate pension spending as:

$$\Psi_t^R = \sum_{j,\overline{\varepsilon}} \mu_t^{j,\overline{\varepsilon}} \left(\mathbb{I}\left\{f_t = 1\right\}\right) \psi_{j,\overline{\varepsilon}}^R \left(\overline{y}_t, \chi_t, t_{R,t}\right) \tag{22}$$

where $\mu_t^{j,\overline{\varepsilon}} \left(\mathbb{I}\left\{f_t = 1\right\}\right)$ is the share of pensioners of age j, type $\overline{\varepsilon}$ in time t and $\psi_{j,\overline{\varepsilon}}^R \left(\overline{y}_t, \chi_t, t_{R,t}\right)$ is the pension benefits received by an age j, type $\overline{\varepsilon}$ household in time t.[32] Then, the change in the aggregate pension spending over time can be simply expressed as:

$$\Delta\Psi^R = \underbrace{\Delta\mu^{j,\overline{\varepsilon}} \left(\mathbb{I}\left\{f = 1\right\}\right)}_{\Delta \text{ share of pensioners}} + \underbrace{\Delta\psi_{j,\overline{\varepsilon}}^R \left(\overline{y}, \chi, t_R\right)}_{\Delta \text{ size of pension benefits}} \tag{23}$$

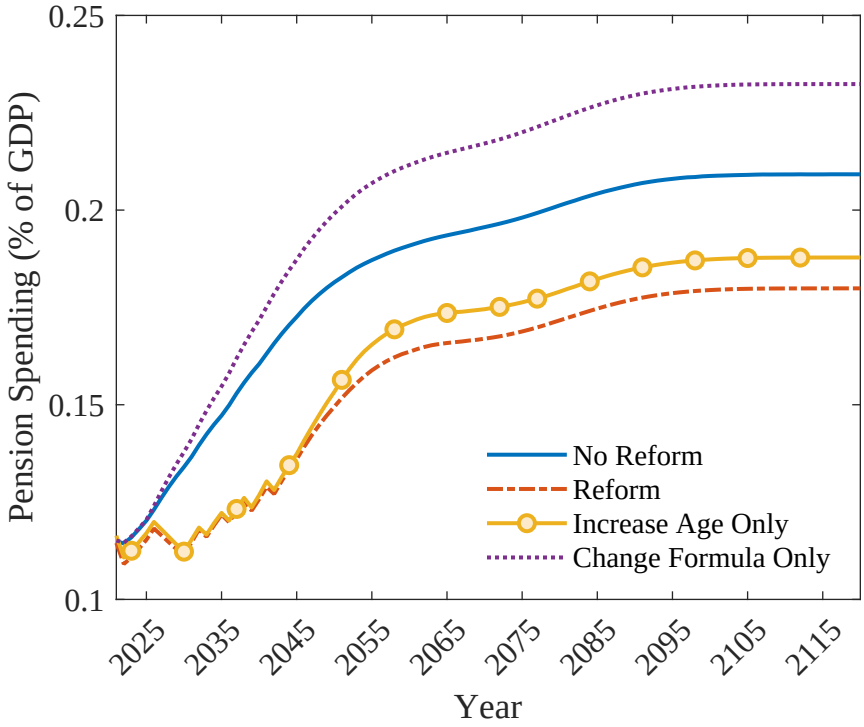
The first term of Equation 23, $\Delta\mu^{j,\overline{\varepsilon}} \left(\mathbb{I}\left\{f = 1\right\}\right)$, captures that over time the share of the population receiving a pension may change either due to changes in the demographics or to changes in when workers claim a pension. The second term of the equation, $\Delta\psi_{j,\overline{\varepsilon}}^R \left(\overline{y}, \chi, t_R\right)$, shows how pension spending over time evolves based upon how the size of the per period pension received by a pensioner varies. This per period pension could change if the formula which translates earnings into pension benefits changes or the inputs into the formula themselves change. This relationship is independent of whether or not a reform occurs, but the relative importance of the mechanisms will be different in each case considered.

The time series of aggregate pension spending is shown in Figure 2. First, consider the case of a transition path in which no reform occurs. Then, there are no changes to either the age at which workers retire nor the formula used to calculate the pension. Therefore, all growth in pension spending can be attributed to changes in demographics or changes in the inputs into the pension benefits formula. As labor supply decisions do not largely change over time when no reform occurs, the portion of the increase in spending from changes in household decisions is minimal; for this reason, I focus on the impact of demographic change.[33] Throughout the transition, the share of the population receiving a pension increases from 21.2 percent of the population to 32.6 percent of the population. This leads to an increase in the number of pensioners and pension costs. These forces push aggregate pension spending to increase to around 21 percent of GDP by 2120 if no reform occurs.

[32] Because retirement and pension claiming are a single decision in this model, the share of pensioners is equivalent to the share of households who have chosen retirement $(f_t = 1)$. If the worker chose to retire before achieving the requirements for a pension, then the value of the pension,$\psi_{j,\overline{\varepsilon}}^R$ would be 0.

[33] While labor supply decisions do not largely change throughout the transition path, increasing wages contribute to increasing average taxable earnings and pensions. Throughout the demographic transition path in the case of no reform, pensions for public sector workers increasing 22.4 percent while pensions for high-income private sector workers increases 9.2 percent. Pensions for low- and middle-income private sector workers are unchanged.

Figure 2: Aggregate Pension Spending in Proposed Reform



When the reform occurs, additional mechanisms enter the calculation. First, as the retirement age increases, the policy pushes against the forces of demographic change. While the population continues to age, in any given year fewer age cohorts, and thus fewer workers, are eligible to claim benefits. In this scenario, the share of the population receiving a pension increases from 21.2 percent to 27.0 percent of the population. Thus, the increases in the retirement age offset a portion of the increase in pensioners caused by the demographic change.

In addition to increasing the retirement age, the reform changes the formula used to calculate pensions. This implies that per period pensions received may be augmented by the modified formula. Table 5 shows how pensions for each productivity level vary between the no reform (Column 1) and reform cases (Column 2). Relative to the case of no reform, the reform impacts pension sizes for both public sector workers and high-income private sector workers while the pensions of low- and middle-income private sector workers are unchanged. In both cases, low- and middle-income workers receive only the minimum pension and, thus, the pension size for these households is unaffected by the reform. Public sector workers receive slightly larger pensions (0.2 percent higher) due to changes in their lifetime earnings in response to the reform. High-income private sector workers see the largest change. The reform leads these worker to receive a higher replacement rate and pensions which are 50.1 percent higher. These high-income private sector

Table 5: Long-Run Relative Pension Sizes

	No Reform	Reform	Increase Age Only	Change Formula Only	Counterfactual Reform
Public Sector	1.000	1.002	1.003	1.002	1.002
Private Sector					
$\leq$ *2,000 BRL*	1.000	1.000	1.000	1.000	1.000
$\leq$ *2,000-4,000 BRL*	1.000	1.000	1.004	1.026	1.000
$\leq$ *4,000 BRL*	1.000	1.501	1.712	1.335	1.542

Notes: Pensions are compared in the long-run balanced growth paths after the policy transition has occurred. All reform experiments are shown relative to the case of no reform.

workers, however, represent only 14 percent of the population. Therefore, this limits the aggregate size of the increase in the pension spending that comes from from high pensions

These changes due to the reform have a large impact on the long-run aggregate pension costs. Figure 2 demonstrates that with the addition of these forces, long-run pension costs are expected to only increase to 18 percent of output–implying that the reform decreases long-run pension costs by 3 percent of GDP. Throughout the transition path between the programs, the time-series of aggregate pension spending between the no reform and reform cases diverge immediately as the increases in the statutory retirement age required by the reform decrease immediate pensioners and transfers the payment of pension costs into the future.[34] This gap between aggregate pension spending in the cases of no reform and reform continue for the remainder of the transition paths considered. Increases in spending slow down and eventually flatten out around 2055 in both cases–around when population growth in assumed to reach a constant long-run rate.

As passed, the Brazilian reform includes changes to both the statutory retirement age and the formula to calculate pension benefits. These changes together induce movements in aggregates spending through the various channels discussed above. To disentangle the impacts that each of these changes have on aggregate spending, I run two alternative reforms, one in which the statutory retirement age increases while the pension benefit formula stays the same and one in which the benefit formula changes while keeping the retirement age constant. The impact of these alternative reforms on pension sizes are included in columns 3 and 4 of Table 5; the evolution of spending in each of these cases is also shown in Figure 2.

First, consider an experiment in which the statutory retirement age increases but the pension

[34] Additionally, since the increases in the statutory retirement age were gradual and increased for a few cohorts at once, the change in spending features of stair-step pattern.

formula remains constant. This will highlight the importance of the using the retirement age to push against the increases in spending induced by an aging population. This experiment leads to spending projections only slightly above those of the passed reform; in the long-run pension spending is roughly 19 percent of output when the retirement age increases while the pension formula is constant. This indicates that decreasing pensioners by raising the retirement age has a large impact on spending. However, as shown in column 3 of Table 5, this leads to larger pensions for public sector workers (0.3 percent larger), as well as middle and high income private sector workers (0.4 and 71.2 percent larger than no reform, respectively). These higher pensions offset some of the gains from increasing the retirement age and lead to slightly higher costs.

Second, consider an experiment which changes only the benefit formula while holding retirement age constant.[35] This experiment shuts down the impact of the retirement age in decreasing the share of pensioners while keeping the impact of demographics. As shown in Figure 2, this experiment increases pension spending not only in the long-run but also steepens the initial growth in spending as workers–especially high- and middle-income workers–continue to retire young but receive the larger pensions that the reformed system gives. The presence of these larger pensions is evident in Table 5; pensions in this reform are 2.6 percent higher for middle-income workers and 33.5 percent higher for high-income workers. This alternative reform leads to long-run pension costs of 23 percent of GDP. These experiments highlight the importance of using the retirement age to offset the push of aging populations.

6.3 Welfare

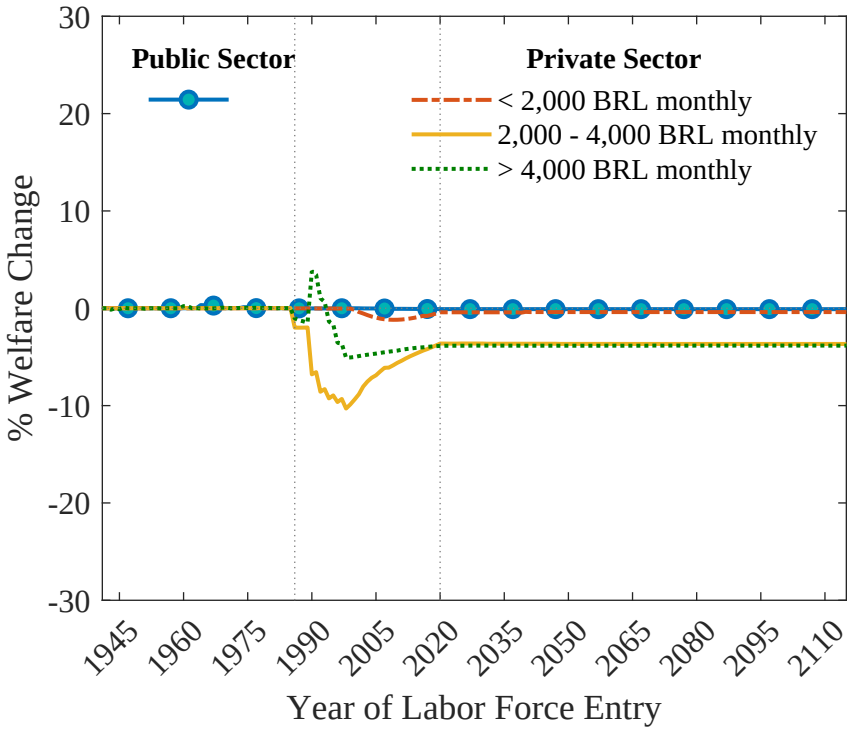
The welfare impact of this reform is shown in Figure 3. Welfare is measured as the percentage of lifetime consumption (or remaining lifetime consumption for cohorts already in the labor force or retired at the time of the reform) that makes workers indifferent between continuing the current system and reforming to the new system.

First, notice that the welfare impact of the reform on public sector workers is roughly 0 for all cohorts. This is expected as the reform does not change the eligibility standards or the pension formula for these workers. Small welfare changes for new cohort of public sector workers are driven by general equilibrium effects. As the demographic transition occurs, wages increase. This leads to increases in the average taxable income of public sector workers and thus pensions. However, because the general equilibrium impacts are small, these long-run welfare gains are also small.

There is heterogeneity in the welfare impact among the various types of private sector workers. Similar to public sector workers, private sector workers who earn less than 2,000 BRL monthly have roughly 0 welfare impact throughout the transition. Private sector workers who earn above

[35] In this experiment, this means that the path to a pension through years of contributions remains active

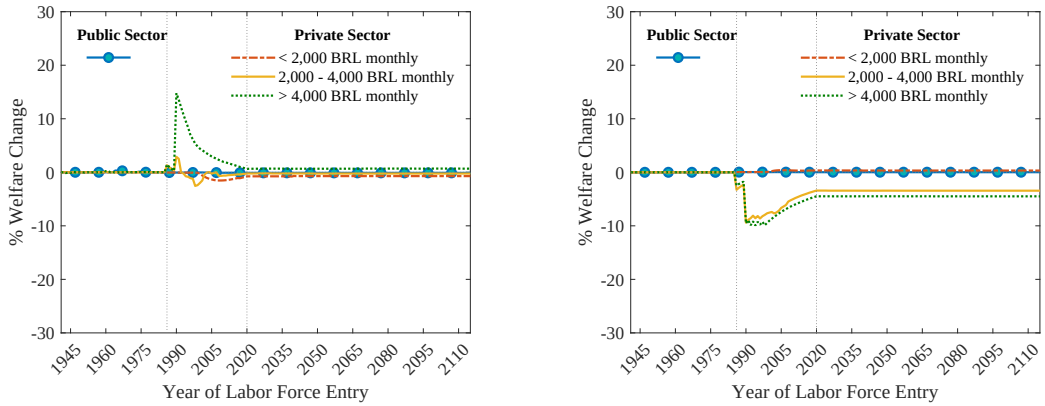
Figure 3: Welfare by Cohort: Continue Current Policy vs. Passed Reform



Note: vertical lines separate cohorts into those who are (from left to right) roughly retired (over age 56), working age, or not yet entered the labor force at the beginning of the transition path

Figure 4: Decomposing Welfare by Cohort

(a) Consumption (b) Leisure



Note: vertical lines separate cohorts into those who are (from left to right) roughly retired (over age 56), working age, or not yet entered the labor force at the beginning of the transition path

2,000 BRL monthly, on the other hand experience welfare losses both in the transition and in the long-run. Transitional generations of middle-income workers experience losses of around 10 percent of remaining lifetime consumption; transitional generations of high-income workers experiences losses of roughly 5 percent of remaining lifetime consumption. Future cohorts of both income levels experience losses of nearly 5 percent of lifetime consumption.

To understand the source of these welfare losses, I decompose these losses into those that come from changes in consumption and those that come from changes in leisure.[36] This is shown in Figure 4. Breaking down welfare in this way illuminates two main lessons. First, long-run welfare losses are primarily driven by the lower leisure induced by the reform (shown in Figure 4b). As the statutory retirement age increases, workers must remain in the labor force longer and delay the additional leisure of retirement. Second, transitional welfare losses for middle- and high-income private sector workers are the results of two forces that move in opposite directions. The gradual in the statutory retirement age leads to welfare losses along the leisure dimension for both income levels. However, the consumption dimension (Figure 4a) shows that higher pensions given to these high-income transitional generations as a part of the transitional policy lead to welfare gains from consumption.[37] These offsetting forces lead overall transitional welfare losses to be smaller than those that come from leisure alone. The welfare gains from consumption for high-income transitional households also lead their total welfare losses to be smaller than those of middle-income households.

[36]See Conesa et al. (2009) for more on this decomposition

[37]The transitional policy between programs leads these generations to receive larger pensions. The true measure of these pension is the result of which transitional system (points etc.) the worker uses to retire

7 Policy Counterfactual

Equation 23 highlights that changes in aggregate pension spending over time can be summarized by thinking about how changes to policy can impact spending either by changing the share of the population receiving benefits at a given point in time or through changing the size of the pension a worker receives. What the Brazilian reform as passed, as well as experiments of it, fail to highlight is the dual forces within the second term. Specifically, the size of pension benefits received can change either by changing the formula $\psi^R_{j,\varepsilon}$ or by changing the inputs into this function. In this section, I consider a policy example which highlights the impact of changing the inputs of the function, specifically the input of average taxable earnings, $\bar{y}$.

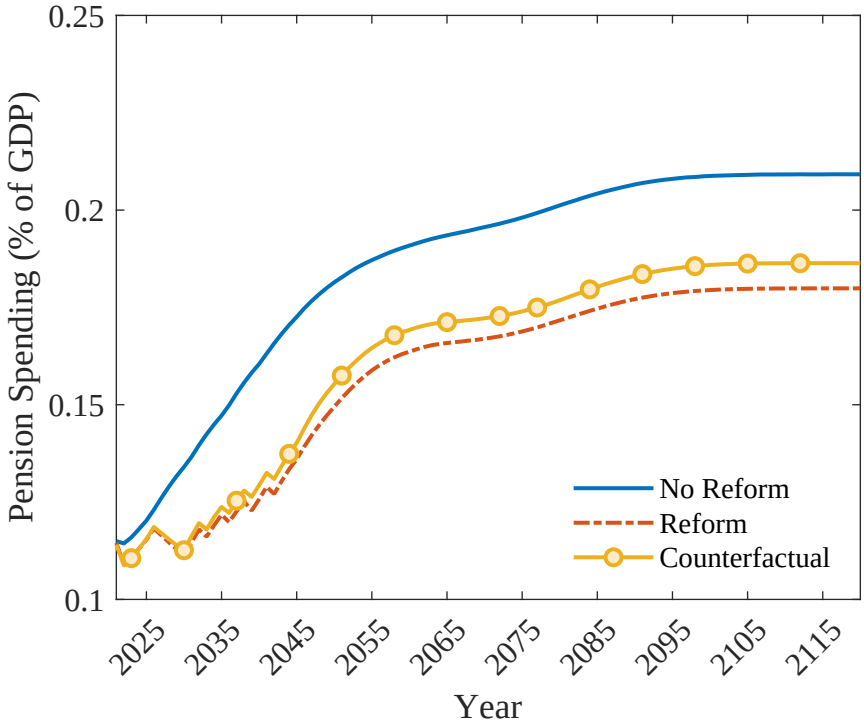
In order to isolate this, I consider a counterfactual reform that is identical to the proposed reform but the average earnings on which pensions are calculated stop accumulating at age 55.[38] Therefore, as workers remain in the workforce for additional years due to the reform, the size of their pensions are not impacted by their work decisions and earnings in these additional years. Define the pension formula used in this counterfactual as $\psi^R_{j,\bar{\varepsilon}}\left(\widetilde{y}_t, \chi_t, t_{Rt}\right)$, where $\tilde{y}_t$ represents the average taxable earnings up until age 55.

Figure 5 shows how pension spending as a percentage of GDP differs between the proposed reform and the counterfactual reform. While the passed reform decreases long-run aggregate pension spending from 21 percent to 18 percent of GDP, the counterfactual reform leads to long-run pension costs of roughly 19 percent of GDP. As shown in Column 4 of Table 5, indexing pensions to earnings up until age 55 rather than lifetime earnings delivers pensions for the highest earning households in the economy which are 54.2 percent higher than the case of no reform and 2.7 percent higher than the baseline reform. Low-income and middle-income workers, however, receive the same pension in both the reform and the counterfactual experiment since they receive the minimum pension in both scenarios. This implies that the increase in aggregate pension spending in the counterfactual relative to the passed reform is driven by higher pensions for high-income individuals and no change in pensions for low-income individuals.

This result demonstrates the importance of the income distribution and the presence of the minimum pension. In the long- run, 52 percent of the population receive only the minimum pension under the passed reform. Therefore, keeping these workers in the labor force for extra years has no impact on pension size, and the counterfactual reform does not change spending that comes from pension payments for low- and middle-income private sector workers. The increases in spending come solely from small increases in pension sizes for the highest earning workers as indexing pensions to earnings up to age 55 increases average taxable earnings for this group. Because these worker represent a small fraction of the economy (only 14 percent of the population), increasing

[38] Age 55 is chosen here because it is the last age prior to any workers retiring under the previous system

Figure 5: Aggregate Pension Spending Compared to Proposed Reform



their pensions in the counterfactual reform has only a small impact on the aggregate pension costs.

8 Conclusion

Aging populations across the globe are putting pressure on pay-as-you-go Social Security systems and leading to increases in aggregate pension spending. Changes in aggregate spending on pension benefits over time, however, are the result of two forces: changes in the share of the population receiving a pension and changes in the size of pensions received by pensioners. Changes in demographics obviously change the number of pensioners as more workers approach retirement age. Second, as populations age, equilibrium prices adjust. As a result, average taxable earnings of household and the pensions these household receive during retirement change. In the absence of reforms to the pension program, these general equilibrium effects are relatively small and most of the increase in pension spending reflects the impact of demographics. In the case of Brazil, this work projects that pension spending should increase to around 21 percent of GDP by 2120. Reforms to the program, as have been implemented, can change this projection.

In 2019, Brazil reformed its pension system to increase the statutory retirement age and to augment the formula which translate average taxable earnings to pension benefits received. While

this reform decreases projected pension costs by 3 percent of output, this reform and the decreases in leisure that the increase in the retirement age imply lead to long-run welfare losses, particularly for high-income individuals. When the impact of this reform on pension costs is decomposed into the portion from the increased retirement age and the portion from the changed formula, the majority of the decrease in pension spending is due to the increase in the retirement age. This highlights that while the change in the pension formula leads to higher pensions for higher-income workers, the increase in the retirement age–and the way this policy offsets the impact of demographics change–deliver significant decreases in aggregate pension costs.

The 2019 reform, and the previous analysis, focuses on how aggregate spending responds to the decrease in pensioners caused by the increase in the retirement age as well as the increase in the per period pension of some individuals caused by the change in the pension formula. However, this analysis does not highlight the importance of household level decisions and their impact on pensions received. In order to study this, I consider a counterfactual reform which indexes pensions to earnings up until only age 55. Therefore, in this counterfactual reform, the extra years of work which the reform requires do not change the average taxable earnings used in the calculation of the pension. In the long-run, this economy produces spending on pensions of 19 percent of output; this program is more expensive than the reform passed in 2019. As life-cycle productivity peaks at at around age 40-50, the increase in retirement ages puts downward pressure on lifetime earnings and leads to decreased pension costs.

References

Aguiar, M., Hurst, E., and Karabarbounis, L. (2013). Time use during the great recession. *American Economic Review*, 103(5):1664–1696.

Auerbach, A. A. and Kotlikoff, L. J. (1987). *Dynamic Fiscal Policy*. Cambridge University Press, Cambridge.

Benhabib, J., Rogerson, R., and Wright, R. (1991). Homework in macroeconomics: Household production and aggregate fluctuations. *Journal of Political Economy*, 99(6):1166–1187.

Bonturi, M. (2002). The Brazilian Pension System: Recent Reforms and Challenges Ahead. OECD Economics Department Working Papers 340, OECD.

Borsch-Supan, A. and Schnabel, R. (1998). Social security and declining labor force participation in germany. *American Economic Review*, 88(2):173–178.

Burtless, G. (1986). Social security, unanticipated benefit increases, and the timing of retirement. *Review of Economic Studies*, 53(5):781–805.

Choné, P. and Laroque, G. (2014). Income tax and retirement schemes. Sciences Po Economics Discussion Papers 2014-06, Sciences Po Departement of Economics.

Coile, C. and Gruber, J. (2007). Future social security entitlements and the retirement decision. *Review of Economic Statistics*, 89(2):234–246.

Conesa, J. C., Kitao, S., and Krueger, D. (2009). Taxing capital? not a bad idea after all! *American Economic Review*, 99(1):25–48.

Conesa, J. C. and Krueger, D. (1999). Social security reform with heterogeneous agents. *Review of Economic Dynamics*, 2(4):757–795.

Cremer, H., Lozachmeur, J.-M., and Pestieau, P. (2004). Social security, retirement age and optimal taxation. *Journal of Public Economics*, 88(11):2259–2281.

Gruber, J. and Wise, D. (1998). Social security and retirement: An international comparison. *American Economic Review*, 88(2):158–163.

Gruber, J. and Wise, D. (2002). Social security programs and retiremet around the world: Micro estimation. *Working Paper 9407*.

Hosseini, R. and Shourideh, A. (2019). Retirement financing: An optimal reform approach. *Econometrica*, 87(4):1205–1265.

Huang, H., Imrohoroglu, S., and Sargent, T. (1998). Two computations to fund social security. *Macroeconomic Dynamics*, 1(1):7–44.

Huggett, M. (1996). Wealth distribution in life-cycle economies. *Journal of Monetary Economics*, 73(2):469–494.

Huggett, M. and Parra, J. C. (2010). How well does the u.s. social insurance system provide social insurance? *Journal of Political Economy*, 118(1):76–112.

Imrohoroglu, S. and Kitao, S. (2012). Social security reforms, benefit claiming, labor force participation, and long-run sustainability. *American Economic Journal: Macroeconomics*, 4(3):96–127.

Joubert, C. (2015). Pension design with a large informal labor market: Evidence from chile. *International Economic Review*, 56(2):673–694.

Jung, J. and Tran, C. (2012). The extension of social security coverage in developing countries. *Journal of Development Economics*, 99(2):673–694.

Kotlikoff, L., Smetters, K., and Walliser, J. (1999). Privatizing social security in the united states–comparing the options. *Review of Economic Dynamics*, 2(3):532–574.

Krueger, A. and Pischke, J.-S. (1992). The effect of social security on labor supply: A cohort analysis of the notch generation. *Journal of Labor Economics*, 10(4):412–437.

Liebman, J., Luttmer, E., and Seif, D. (2009). Labor supply responses to marginal social security benefits: Evidence from discontinuities. *Journal of Public Economics*, 93(11-12):1208–1223.

Manoli, D. and Weber, A. (2016). Nonparametric evidence of the effects of financial incentives of retirement decisions. *American Economic Journal: Economic Policy*, 8(4):160–182.

Mastrobuoni, G. (2009). Labor supply effects of the recent social security benefit cuts: Empirical estimates using cohort discontinuities. *Journal of Public Economics*, 93(11-12):1224–1233.

McGrattan, E. and Prescott, E. (2017). On financing retirement with an aging population. *Quantitative Economics*, 8:75–115.

McKiernan, K. (2021). Social security reform in the presence of informality. *Review of Economic Dynamics*, 40:228–251.

Medici, A. (2004). The Political Economy of Reform in Brazil's Civil Servant Pension Scheme. Technical report, Inter American Development Bank.

Meghir, C., Narita, R., and Robin, J.-M. (2015). Wages and informality in developing countries. *American Economic Review*, 105(4):1509–1546.

Michau, J.-B. (2014). Optimal redistribution: A life-cycle perspective. *Journal of Public Economics*, 111:1–16.

Moreno, C. (2022). The impact of pensions in labor markets with informality. *Working Paper*.

Moser, C. and Olea de Souza e Silva, P. (2019). Optimal paternalistic savings policies. *Columbia Business School Research Paper*.

Ndiaye, A. (2020). Flexible retirement and optimal taxation. *Working Paper*.

Nishiyama, S. and Smetters, K. (2007). Does social security privatization produce efficiency gains? *Quarterly Journal of Economics*, 122(4):1677–1719.

OECD (2019). Pensions at a glance 2019: Country profiles brazil. *OECD Publishing*.

OECD (2021). Pensions at a glance 2021: Country profiles brazil. *OECD Publishing*.

Rupert, P., Rogerson, R., and Wright, R. (1995). Estimating substitution elasticities in household production models. *Economic Theory*, 6(1):179–193.

Rust, J. and Phelan, C. (1997). How social security and medicare affect retirement behavior in a world of incomplete markets. *Econometrica*, 65(4):781–831.

Shourideh, A. and Troshkin, M. (2015). Incentive and efficiency of pension systems. *Technical Report. Mimeo*.

Staubli, S. and Zweimuller, J. (2013). Does raising the retirement age increase employment of older workers? *Journal of Public Economics*, 108:17–32.

Tkhir, A.-M. (2022). Pension reforms in the presence of informality. *Working Paper*.

World Bank Group (2022). Subnational civil servant pension schemes in brazil: Context, history, and lessons of reform. Technical report.