Social Security Reforms, Retirement and Sectoral Decisions*

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Abstract

We study social security reforms in economies characterized by segmented labor markets and pension systems. We develop a general equilibrium life-cycle model with heterogeneous agents, endogenous retirement, and sectoral choice. In the model, individuals choose to work in the public sector, the private formal sector, or the informal sector, taking into consideration differences in compensation structures, pension eligibility rules, and benefit formulas across sectors. The model is calibrated to Brazil, a country characterized by high informality, generous public pensions, and rapid demographic transition. We evaluate reforms such as unifying pension systems and increasing the minimum retirement age. These policies reduce the projected social security deficit by nearly 40%, increase output, stimulate capital accumulation, and generate average welfare gains, despite redistributive effects across age groups, sectors, and along the transition path. Sectoral reallocation, particularly the shift out of public employment and into informal work, plays a key role in shaping the reforms' impact. Ignoring these margins can lead to a significant underestimation of the fiscal and macroeconomic effects of pension reforms.

Keywords: social security reforms, public employment, public deficit, informality
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1 Introduction

Population aging is increasing fiscal pressures on social security systems, especially in emerging markets where pension systems for public and private sector workers differ, and labor informality is widespread. In these settings, social security reforms influence not only retirement behavior but also workers' choices between formal, informal, and public sector jobs. Public employment typically offers relatively higher-paid and stable jobs with limited access, while informal jobs exempt workers from taxes but may still entitle them to some form of social security pension. These institutional features create strong incentives for strategic sectoral choices over the life cycle and can influence the effects of pension reforms on the economy.

This paper quantifies the macroeconomic and distributional consequences of social security reforms in economies with segmented pension systems and widespread informality. It develops a general equilibrium life-cycle model with heterogeneous agents who endogenously choose consumption, savings, retirement, and sectoral employment. The economy includes three labor market segments: private formal, private informal, and public, each with its own institutional asymmetries in pension eligibility, benefit formulas, and tax schemes. The model captures the dynamic interplay between pension systems, sectoral shifts, and retirement behavior, enabling an assessment of the short and long-term effects of reforms being discussed or implemented in many countries, such as pension system unification and increases in the minimum retirement age.

We calibrate the model to match key aspects of Brazil in 2013. With a rapidly aging population, widespread informality, and a relative generosity of its pension system, especially that of public workers, this country exemplifies the social security challenges several countries currently face or are likely to face soon. The calibrated model closely replicates aggregate moments of the social security deficit and income inequality, as well as the observed distribution of individuals across sectors, their decisions to apply for a public sector job, and their decisions to start collecting pension benefits.

Population aging poses significant fiscal challenges worldwide. In Brazil, without reforms, we find that the projected 2060 demographic changes will increase the social security deficit from 2.1% to 16.6% of GDP. The pension deficit attributed to public (private) retirees will increase from 1.3% (0.8%) to 5.2% (11.5%) of GDP. Moreover, the participation rate is projected to decline by 13 percentage points (pp), and the proportion of retirees to rise from 13.9% to 31.5%.

We then evaluate the long-run consequences of the *benchmark social security reforms*, which consist of both unifying the public and private pension systems and increasing the minimum retirement age to 65.[1] These reforms reduce the projected social security deficit from 16.6% to 10.2% of GDP. They also raise output by 3.6%, increase capital accumulation over the life cycle,

[1] Our findings illustrate the gains from reforming the pension system in isolation from all other structural changes in Brazil, and do not have a direct counterpart in actuarial studies from Brazil's National Treasury.

and reduce the share of retirees in the population from 31.5% to 18.7%. These gains stem from extended working lives and increased savings, as individuals adjust to less generous retirement benefits and delayed eligibility. Importantly, the reforms also lead to a significant reallocation of labor: fewer workers enter the public sector, and more workers engage in formal employment. Robustness exercises confirm these findings are stable to varying preferences, demographics, equilibrium conditions, and other pension reform details.

Next, we highlight the roles of the public sector and informality in shaping these findings. We show that abstracting away from sectoral choices or incorrectly sizing the public sector may bias the estimated effects of reforms. For example, when sectoral transitions are held fixed exogenously, the output gains from the benchmark reforms fall by roughly 70%. Moreover, reductions in the pension deficit are substantially smaller when the public sector shrinks. Allowing workers to respond to changes in pension incentives leads to large reallocations away from public sector jobs and informal work, expanding the tax base and amplifying fiscal and macroeconomic gains. These findings underscore the need to jointly model retirement and sectoral behavior, especially in economies with segmented labor markets.

We then turn to the dynamic path of the economy following the benchmark reforms. The transition is gradual but beneficial in the aggregate. Younger cohorts experience consumption-equivalent welfare gains of up to 5%. As the pension deficit decreases, so do consumption tax rates necessary to balance the government budget, increasing workers' expected lifetime income. In contrast, older cohorts—especially those close to retirement—may lose between 3 and 10% in consumption-equivalent welfare, as they face reduced benefits and tougher eligibility conditions without enough time to adjust their savings. The reforms also substantially increase household savings during the transition—especially among public-sector workers—reflecting individuals' efforts to self-insure against less generous pension systems. These transitional dynamics highlight both the economic value and political aspects of the reform, helping policymakers identify the most vulnerable segments of the population.

Lastly, we investigate policy options to fully eliminate the pension deficit by 2060. The analysis shows that raising the minimum retirement age to 72 or halving the replacement rates would each be sufficient to close the deficit. In contrast, for Brazil, raising contribution rates alone would be insufficient and counterproductive: higher payroll taxes reduce GDP between 5 and 10% and sharply increase informality, eroding the tax base. These findings suggest that contribution-based adjustments of pension systems are highly distortionary in economies with high and persistent informality, while parametric reforms targeting retirement age or benefit levels are more effective and efficient to ensure the sustainability of pension systems.

This paper contributes to three strands of literature. First, it contributes to a long-standing literature on population aging and pension reforms in developed countries. Huggett (1996), Huggett and Ventura (1999), Conesa and Krueger (1999), and Kitao (2014) study the macroeco-

nomic effects of pension reforms under exogenous retirement decisions. Subsequent work—such as Gustman and Steinmeier (2005), Imrohoroglu and Kitao (2012), Ferreira and Santos (2013), and Kitao (2018)—incorporates endogenous labor force participation and early retirement options.[2] Other papers explore the interaction between heterogeneous mortality, heterogeneous demographic changes, and pension reforms (Laun et al., 2019; Sanchez-Romero et al., 2020; Jones and Li, 2023).[3] We contribute to this literature by considering endogenous retirement and sectoral choices in a model with segmented labor markets and pension systems.

Second, we contribute to a recent literature on pension reforms in emerging markets. McKiernan (2021b) and Kudrna et al. (2025) study pension reforms in Chile and Indonesia, respectively, highlighting how informality influences reform outcomes. Glomm et al. (2009), Santos and Pereira (2010), Jung and Tran (2012), Dos Reis and Zilberman (2014), Ferreira and Parente (2018), Santos and Cavalcanti (2021), and McKiernan (2021a), look at the case of Brazil.[4] Most closely related, McKiernan (2021a) develops a multi-sector model in which individuals allocate working hours across formal and informal sectors. In contrast, agents in our model choose endogenously among public, private formal, and private informal sectors. This discrete sectoral choice is central to our findings: we show that reforms induce significant reallocation across sectors, and that accounting for endogenous public sector and informality decisions meaningfully alters the quantitative impact of reforms. Additionally, whereas McKiernan (2021a) focuses on changes to the minimum retirement age, our analysis takes a broader perspective by also examining the unification of public and private pension systems and assessing alternative policy tools to eliminate the pension deficit.

Third, we contribute to the literature exploring how the informal sector modulates the impact of government policies on the economy (Ulyssea, 2020). Narita (2020) studies labor market policies in economies with both informal employees and self-employed individuals. Franjo et al. (2022) argues that accounting for the informal sector is essential to understanding the relationship between financial and economic development. Machado Parente (2024) shows that the presence of informality changes the impact of the minimum wage on earnings inequality. We contribute to this literature by showing that the informal sector lowers the effectiveness of some policy instruments (e.g., the contribution rate) to improve the fiscal sustainability of pension systems.

The rest of the paper is organized as follows. Section 2 presents empirical evidence motivating the key model features. Section 3 describes the general equilibrium life-cycle model with endogenous sectoral and retirement decisions. Section 4 outlines the calibration strategy.

[2] See Vestad (2013) for a list of countries that have early retirement possibilities.

[3] Fehr et al. (2017) explores the role of family insurance on social security dynamics.

[4] Our paper extends Ferreira and Parente (2018) by implementing a more sophisticated model calibration, conducting a detailed analysis of the heterogeneous effects of pension reforms on different groups of agents, and studying transitional dynamics after reforms.

Section 5 assesses the model's fit against Brazilian data. Sections 6 and 7 evaluate the short- and long-run effects of the benchmark pension reforms, while Section 8 explores additional policy scenarios. Section 9 concludes.

2 Empirical Motivation

This section argues that a model studying the macroeconomic and sectoral consequences of social security reforms in emerging markets (EMs) should include the following features: (i) a well-paid and stable public sector with costly access; (ii) a public pension system that is relatively more attractive and expensive than the private pension system; and (iii) an informal sector where workers may not contribute to the social security system but may benefit from it. Although the model will be calibrated to Brazil, these features are common across many poor-to-medium-income countries.

Population aging is a widespread phenomenon that governments worldwide must address in the coming decades. This trend is expected to place significant pressure on pension spending, especially in emerging markets (EMs), where the current demographic structure remains skewed toward the working-age population. As a result, government expenditures on retirement benefits are projected to rise substantially by 2050, particularly in EMs such as Brazil, Mexico, Chile, India, and China (OECD, 2018).

Two salient features in the context of EMs must be considered when analyzing reforms to social security systems. First, many EMs have over 10% of workers working in the public sector (Table 1).[5] These jobs are relatively well paid, as shown by the large share of government expenditures on compensation of public workers–over 20% of expenditures–and by a relatively high public sector wage premium.[6] Besides being relatively well paid, the public sector often offers stable jobs (Sodergren and Gammarano, 2024), and ultimately attracts high-skilled individuals from the private sector (Santos and Cavalcanti, 2021).

[5]The ILO classification of public and informal workers is broader than that used in this paper. In the case of public workers, the ILO includes employees of State-Owned Enterprises, which we exclude, as their retirement and employment regulations tend to follow those of the private sector. Regarding the informal sector, the ILO includes self-employment, unpaid family work, and informal employers, all of which we omit. Consequently, their figures are different than ours.

[6]IMF's public-private sector compensation premia are constructed using the estimations from country-level micro-data of compensation levels in public and private sectors, controlling for differences in education and other individual characteristics. The estimates are obtained from econometric analysis of household survey data. For more details, see Abdallah et al. (2023).

Table 1: Informality and public employment across emerging markets

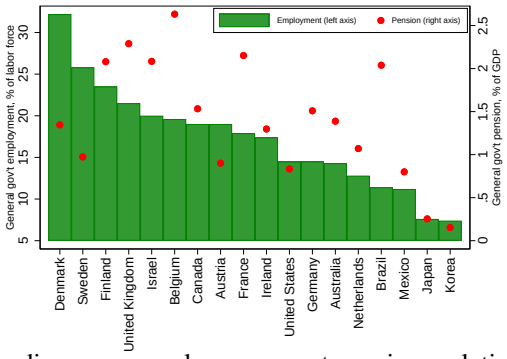
Country	Informality	Public employment share	Public wage bill (% of govt. expenditure)	Public wage premium
ARG	50.4	18.1	26.6	3.1
BRA	36.5	12.3	25.3	14.1
CHL	27.5	3.2	25.1	13.3
COL	56.1	3.9	15.2	50.3
HUN	1.3		21.2	-9.3
IDN	81.2	8.9	29.0	-33.9
KEN	86.5	10.3	17.2	12.3
MEX	56.3	11.6	16.4	11.0
NGA	93.0	3.6	12.0	35.5
PER	71.6	8.9	25.4	-4.1
POL	7.7	24.2	22.4	
ROU	2.6		22.7	8.4
TUR	27.3	15.3	18.5	34.9
ZAF	34.9	16.3	31.8	43.9
EMs	60.9	17.5	26.8	11.6
AEs	4.0	18.5	23.4	5.2

Notes: EMs and AEs correspond to the average across countries in each database. The first and second columns show the informal and government labor shares, respectively. The third column shows the share of general government expenditure devoted to public workers' compensation. The last column shows estimates for the public wage premium from Abdallah et al. (2023). Sources: ILOSTAT; IMF FAD Government Compensation and Employment Dataset, 2023; and Abdallah et al. (2023).

Public workers in many countries tend to have better retirement conditions than their private sector peers because of separate retirement systems.[7] On average, public-sector pensions account for 20% of overall pension expenditures, according to OECD data. Moreover, these pensions represent a large share of output. Figure 1 shows that the general government accounts for, on average, 17% of the labor force, and their retirement benefits sum up to 1.5% of GDP. Hence, it is not surprising that many proposed or implemented reforms emphasize the unification of the retirement systems for private and public workers (e.g., in France and Brazil).

[7] See Kings et al. (2007) and OECD (2018) for examples of countries where retirement conditions of public and private workers differ.

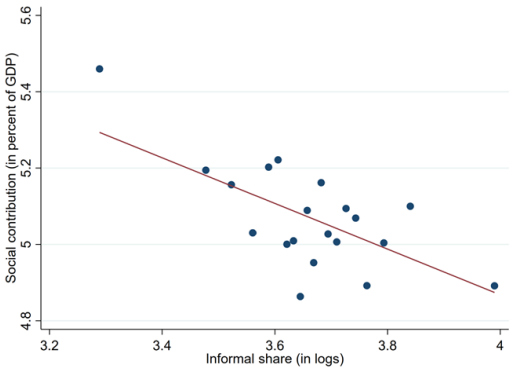
Figure 1: Spending on general government pensions



Notes: This figure plots the spending on general government pensions relative to GDP (right) and the size of the general government in the labor force (left) in 2013. Sources: OECD Social Security Expenditure Database, Brazilian National Accounts and Annual Report on Social Security (IBGE and Ministry of Social Security), and ILOSTAT.

Second, a large share of workers in EMs are informal. Due to the lack of job security and selection of employers in that sector, the informal sector absorbs individuals who have, on average, less schooling and lower incomes (Ulyssea, 2018). The informal sector also attracts workers who do not contribute to the social security system. This is evident by the negative correlation between contributions to social security systems and the informal share of labor across EMs (Figure 2).[8] Importantly, many informal workers have access to social security benefits at older ages, even if they have never contributed to it, putting pressure on the sustainability of pension systems.

Figure 2: Social security contributions versus informality across countries



Notes: This figure shows the conditional binscatter plot between social contributions (y-axis) and log informality (x-axis), conditional on log GDP per capita, country and year fixed effects. Sources: ILOSTAT and WB WDI.

The quantitative part of the paper specializes in the case of Brazil, where 12% of workers are in the public sector and 5% are statutory public workers–the focus of our analysis.[9] In line

[8] We control for log of GDP per capita and country and year fixed effects.

[9] Statutory public workers are subject to a separate pension system. Politicians and administrative/clerical jobs

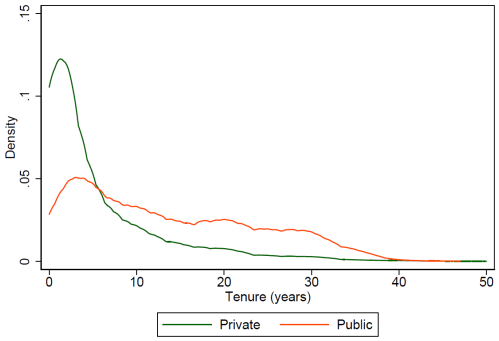
with other EMs, public sector jobs in Brazil are relatively better paid, secure, and attract more educated individuals.

Figure 3: Wage premium and job tenure across sectors

Public and informal wage premia

	(1)	(2)	(3)
Public worker	0.169*	0.094*	0.090*
	(0.004)	(0.005)	(0.006)
Informal worker	-0.188*	-0.056*	-0.053*
	(0.002)	(0.002)	(0.003)
Individual FE		✓	✓
Sample	All	All	25-55
N	2053458	1773520	1270749
R^2	0.615	0.899	0.898

Private and public job tenure



Notes: Left table shows public sector and informal sector coefficients of a regression of log hourly wages on employment sector dummies, controlling for age, age-squared, tenure, race (when there are no individual fixed effects), and occupation, sector, and education fixed effects. Table G.3 in the Appendix presents the full version of the table used to calibrate the model. Robust standard errors in parentheses. $*p < 0.001$. The right panel shows the density estimation of the on-the-job tenure for public (red) and private (green) workers. We restrict our sample to male employees between 16-75 years old. Bandwidth=1.5; Kernel=Epanechnikov; Sample weights are used. Sources: IBGE 2012q1-2018q4 PNADC and IBGE 2013 PNAD databases.

Figure 3, left panel, shows the results of Mincerian regressions of log earnings on a public sector dummy, controlling for informality status, age, age squared, education, occupation, sector, and individual and year fixed effects, using household survey data (PNAD and PNADC). Public workers earn between 9% and 16% more than their private sector peers.[10] At the same time, the right panel of Figure 3 contrasts job tenures in the public and private sectors and shows that the average tenure of a private (public) job is 5.3 (13.6) years. Lastly, PNAD data for 2013 shows that 6% of the population, which accounted for 23% of people with 15+ years of education, took a public exam to enter the public sector.

Moreover, more than a third of Brazil's labor force is informal and 18% are employees without a signed working contract—our concept of informality.[11] These workers do not pay most taxes and are typically not under the protection of the Social Security Administration.[12] Informal jobs also tend to be less paid: informal workers earn between 5% and 18% less than their formal sector peers (Figure 3, left panel). Additionally, informal employees tend to be

in the government are examples of such workers. Employees of publicly owned enterprises are not considered statutory public servants.

[10]See Appendix Section F for more details on the databases used in this paper, including PNAD and PNADC.

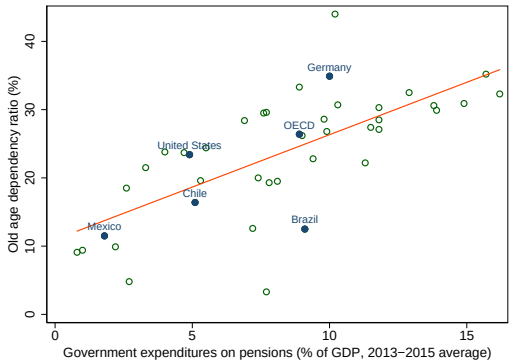
[11]A working contract is a document that, when signed by the employer, guarantees the employee access to social security policies like minimum wage, unemployment insurance, and severance payments.

[12]PNAD data from 2013 shows that only 17% of informal workers contributed to the social security system.

younger than formal employees. As these workers age, they tend to leave wage employment for either old-age retirement—discussed below—or self-employment, which is outside the scope of this paper (Narita, 2020).

Brazil is representative of countries likely to face problems in their pension systems for two reasons. First, Brazilian demographics follow global trends, with the share of individuals aged 65 and over projected to grow from 4% in 1980 to 22% in 2050, according to data from the Brazilian Institute of Geography and Statistics (IBGE). Second, given its current demographics, Brazil already spends a large share of its GDP on pensions. Figure 4 plots the cross-country relationship between government spending on pensions and the old-age dependency ratio. Brazil is as "young" as Chile and Mexico but spends a similar share of GDP on social security as Germany and the OECD average, which have older populations.

Figure 4: Demographics and pensions expenditure by country



Notes: This figure shows the cross-country relationship between the old-age dependency ratio (ratio of 65+ to 20-64 years old individuals) and the government expenditures on pensions as a share of GDP. Sources: 2017 Pensions at a Glance (OECD).

Three characteristics of Brazil's retirement sector contribute to its relatively large pension spending.[13] First, the lack of a minimum retirement age in the private sector until 2022 makes early retirement a prevalent feature in Brazil. Table 2 shows that the average age at which men retire is 56 years old in Brazil (under the contribution modality), but 64 in the average OECD country. Second, Brazil has a social assistance program where low-income individuals older than 65 can retire receiving the minimum wage. Hence, old-age informal workers can access retirement benefits without ever contributing to the pension system. Third, public sector workers were entitled to a pension system where, until 2013, they could retire receiving their uncapped average working salaries. As such, Figure 1 shows that Brazil has the widest discrepancy between government size and the size of government retirees' pensions. These features of Brazil's retirement system have contributed to persistent pension deficits, averaging 2.6% of

[13] See Pereira (2014) for an overall description of the Brazilian pension system and Section 4 for more details on the main features considered in this paper.

Table 2: Early retirement in Brazil

	Retirement Age		Expected Duration	
	Men	**Women**	**Men**	**Women**
OECD	64	63	16	21
Latin America	62	60	17	21
World	62	60	16	21
Brazil:				
Private: Contribution	56	52	23	29
Private: Age Modality (Rural)	60	55	19	26
Private: Age Modality (Urban)	65	60	16	22

Sources: Tafner et al. (2015).

GDP between 2013-16, with public sector pensions alone accounting for 1.2% of GDP.

3 The Model

The model environment comprises a general equilibrium life-cycle model of sectoral choices and retirement behavior. Individuals can work for the government or in the private sector, collecting pension benefits when they are eligible to do so. All decisions are endogenous, so individuals will only enter the retirement sector—and start collecting pension benefits—or work in the public sector if it is worth it.

The economy has three production sectors: public, private formal, and private informal. The government is responsible for paying non-competitive wages to its workers in exchange for producing a public good and managing a PAYG retirement system for both public and private sector retirees. The government taxes consumption, capital, and labor income to balance its budget. Formal private firms use a Cobb-Douglas technology with capital and labor, and informal private firms produce with labor only. All firms act competitively and produce goods that are perfect substitutes in consumption. Uncertainty in the economy comes from idiosyncratic shocks to labor efficiency and the life span of the agents. Agents can save in a risk-free asset to smooth consumption against these shocks.

3.1 Demography, Preferences and Choices

The economy is populated by a continuum of mass one agents who may live at most J periods. Each agent has a time endowment of $\bar{H}$ hours per period.

There is uncertainty regarding the time of death in every period, and everyone faces a probability ψ_j of surviving from age j to age $j+1$. The age profile of the population, denoted by $\{\varphi_j\}_{j=1}^{J}$ follows the law of motion $\varphi_{j+1} = \frac{\psi_j}{1+g_n}\varphi_j$ and satisfies $\sum_{j=1}^{J} \varphi_j = 1$, where g_n is the

population growth rate.[14] Because agents die at random, a fraction of the population leaves accidental bequests, which are assumed to be equally distributed to all surviving individuals in a lump-sum basis (ζ). There are no private annuity markets in the economy.

Agents enjoy utility over effective consumption, $\tilde{c}_j$, and leisure time, l_j. They maximize lifetime expected utility:

$$\mathbb{E}_0\left[\sum_{j=1}^{J}\beta^j\left(\prod_{k=1}^{j}\psi_k\right)u(\tilde{c}_j,l_j)\right], \quad u(\tilde{c}_j,\bar{H}-h_j)=\frac{[\tilde{c}_j^{\gamma}\cdot l_j^{1-\gamma}]^{1-\sigma}}{1-\sigma} \tag{1}$$

where β is the intertemporal discount factor and $\mathbb{E}_j$ is the expectation operator conditional on time j. The effective consumption is given by $\tilde{c}=c+\varepsilon Y_G$, with c being private consumption and Y_G the consumption of a public good. The parameter σ determines the risk aversion, γ denotes the share of consumption in the utility, and ε measures the relative importance of public consumption in overall consumption. All economic agents can save and lend their savings to a private competitive firm.

Agents can be private workers, public servants, or retirees. Let $m\in\{P,G,R\}$ denote these individual states, respectively.[15] Agents choose how much to consume, $\tilde{c}_j\geq 0$, and make a discrete choice to work for $h_j\in\{0,H<\bar{H}\}$ hours. We assume it is mandatory for government workers to work. In contrast, private workers and retirees make an extensive margin decision of working H hours or staying home.[16] Upon going to work, private workers and retirees can further decide whether to work formally or informally.

Agents in the private sector can choose to take an open exam and try their luck in the public sector. This exam is costly, where the time cost is a function of their current age, $c_p(j)$. We assume that retirees cannot enter the public sector, and that public workers cannot retake the exam. Leisure hours ultimately depend on two discrete choices of whether to work or not, and whether to take the public exam or not: $l_j=\bar{H}-h_j-c_p(j)$.

As workers become older, and conditional on meeting the eligibility requirements of their respective sectors, they can become retirees and start collecting social security benefits. We assume that formal and informal private workers follow the same retirement conditions. Importantly, we assume that the public and retirement sectors are absorbing states. For example, once individuals enter the public sector, there is no turning back until they start collecting pensions and enter the retirement sector. At the same time, retirees cannot reapply for retirement nor apply for public sector jobs.

[14] The fraction of newborns is $\varphi_1=\left[1+\sum_{j=1}^{J-1}(1+g_n)^{-j}\prod_{i=1}^{j}\psi_i\right]^{-1}$.

[15] There is endogenous migration between sectors, to be detailed in the next sections.

[16] We allow for retirees to choose whether to work or not endogenously. This is the case in Brazil, where 13.5% of retirees in 2013 were also employed, according to PNAD data.

Figure A.1 in Appendix A illustrates the timeline of a representative agent. As discussed later, agents are all born in the private sector. Over time, and conditional on eligibility requirements detailed below, agents can endogenously move from the private sector to the government sector or retirement.

3.2 Labor Income, Efficiency, and Budget Constraints

Conditional on their respective sector, individuals make a discrete choice of whether to work or not and a continuous choice on asset accumulation. Let w_f (w_i) denote the competitive wage that formal (informal) firms pay. An individual aged j who works a discrete amount of $h_j \in \{0, H\}$ hours produces a total of units of consumption before taxes given by:

$$y_j(\omega, m) = \begin{cases} \omega e^{z+\eta_j} \cdot h_j, & \text{if} \quad m = \text{Private, Retirement} \\ (1+\theta) w_f e^{z_G+\eta_j} \cdot H, & \text{if} \quad m = \text{ Government,} \end{cases} \tag{2}$$

where $\omega \in \{w_f, w_i\}$. Importantly, we already incorporated in the equation above that public sector workers must go to work.

We assume that the idiosyncratic productivity z follows a first-order Markov process with transition matrix Π. There is no uncertainty regarding the public sector, and z_G is the productivity that the private worker had when they decided to take the admission test for the public sector and succeeded. The function η_j is a deterministic age-specific component of labor efficiency. The parameter θ corresponds to the wage premium or economic rent that public sector workers receive relative to their counterparts in the formal private sector.

All economic agents pay capital income tax τ_k and consumption tax τ_c. Workers face labor income tax rate of $\tau_y(m)$, and those who are not retired must additionally contribute a fraction $\tau_{ss}(m)$ of their labor income (up to a maximum taxable income, or social security ceiling, y_{max}) to the social security system. The revenue from $\tau_{ss}(m)$ is used to finance the social security benefits of the retirees, and the revenue from $\tau_y(m)$ finances overall government expenditures not related to the social security system. Retirees pay a tax rate of τ_b over their social security benefits. Informal workers do not pay labor income taxes, nor contribute to the SS system.

Individuals save in a risk-free asset that pays a competitive interest rate r. They cannot have negative assets at any age, so that the amount of assets carried over from age j to $j+1$ is such that $a_{j+1} \geq 0$. Furthermore, given that there is no altruistic bequest motive and death is certain at age $J+1$, agents at age J consume all their assets, that is, $a_{J+1} = 0$. We normalize the continuation value after age J to zero.

The budget constraint for the non-retired individuals in the private sector is given by:

$$(1+\tau_c)c + a' = \begin{cases} [1+(1-\tau_k)r]a + (1-\tau_y(P))y_j(w_f, P) - \tau_{ss}(P)\min\{y_j(w_f, P), y_{\max}\} + \zeta, & \text{if formal} \\ [1+(1-\tau_k)r]a + y_j(w_i, P) + \zeta, & \text{if informal} \end{cases} \tag{3}$$

The budget constraint for the public sector workers is:

$$(1+\tau_c)c + a' = [1+(1-\tau_k)r]a + (1-\tau_y(G)-\tau_{ss}(G))y_j(w_f,G) + \zeta \tag{4}$$

Lastly, the budget constraint for retirees is:

$$(1+\tau_c)c + a' = \begin{cases} [1+(1-\tau_k)r]a + (1-\tau_y(P))y_j(w_f,R) + (1-\tau_b)b + \zeta, & \text{if formal} \\ [1+(1-\tau_k)r]a + y_j(w_i,R) + (1-\tau_b)b + \zeta, & \text{if informal,} \end{cases} \tag{5}$$

where b denotes the retirement benefits the retiree is entitled to. These benefits are calculated upon retirement, with rules that depend on the worker's state vector, detailed in Section 4.

3.3 Public Sector Recruitment

We model public sector recruitment as closely as possible to the Brazilian case. According to constitutional rules, the hiring process for civil servants in Brazil is governed by public competition. Candidates must take a nationwide open exam, and only those who score the best fill the job vacancies. In the model, agents who want to work in the public sector must perform well at costly "exams", and only those who obtain the best grades become eligible to fill a predetermined number of job positions. Once a private sector worker passes the exam, they become a public servant in the following period and must remain in government employment until retirement.

The timing is as follows. First, an agent chooses to apply at age j, paying the time cost $c_p(j)$. Their score q_{jz} is then revealed in the next period, according to:

$$\log(q_{jz}) = \log(e^{z+\eta_j}) + \nu, \tag{6}$$

where $\nu \sim N(0,1)$. The above equation decomposes the test score into two parts: one that is linked to the individual's skill and age, and another that is random in nature.[17] If $q_{jz} \geq \bar{q}$, they will necessarily work for government from age $j+1$ onward. Otherwise, they will remain in the private sector. The threshold score, $\bar{q}$, is chosen by the government in equilibrium to balance the demand and supply of public servants. In what follows, we define the probability of a worker being approved in the public exam as: $q_p \equiv Pr(q_{jz} \geq \bar{q})$.

[17] The random component of the score allows for individuals to perform well in the public exam despite being of lower skill. An equivalent approach to modeling public exams in Brazil can be found in Brotherhood and Delalibera (2020) and in Brotherhood et al. (2023).

3.4 Social Security

Private and public sector workers are subject to different social security rules, which will be discussed in detail in Section 4. In the private sector, retirement pensions are based on a replacement rate applied to average capped past earnings x, where the replacement rate depends on factors such as retirement age, modality, and years of contribution. In the public sector, pensions are generally more generous and based on a replacement rate applied to the worker's uncapped last wage.

3.5 Value Functions

We now detail the agents' problems. We first describe the state space and the policy functions, then we detail the value functions for each agent in the economy.

We divide an individual state depending on the sector of the economy in which they are located. The state of an agent in the private sector is $s_P = (j,a,z,x,t_C) \in S_P \equiv \{1,...,J\} \times \mathbb{R}_+ \times \mathscr{Z} \times \mathscr{X} \times \{0,...,J\}$, where j is their age, a their asset holdings, z is the agent's idiosyncratic productivity, x is their average past earnings, and t_C is the number of years contributed to the SS system. The state of a public worker is $s_G = (j,a,z,t_C,t_G) \in S_G \equiv \{1,...,J\} \times \mathbb{R}_+ \times \mathscr{Z} \times \{0,...,J\} \times \{0,...,J\}$, where t_G is the number of years worked in the government. Finally, for the retirees, the relevant state is given by $s_R = (j,a,z,b) \in S_R \equiv \{1,...,J\} \times \mathbb{R}_+ \times \mathscr{Z} \times \mathscr{B}$, where b denotes the retirement benefits.

Solving the recursive problem yields the policy functions for working hours $d^h(s_m) \in \{0,H\}$, asset holdings $d^a(s_m) \in \mathbb{R}_+$ and consumption $d^c(s_m) \in \mathbb{R}_{++}$ for all $m \in \{P,G,R\}$; retirement $d^r(s_m) \in \{0,1\}$ for $m \in \{P,G\}$; informality $d^i(s_m) \in \{0,1\}$ for $m \in \{P,R\}$ and the public sector application $d^p(s_P) \in \{0,1\}$.

3.5.1 Retired Workers

A retiree chooses between working formally, informally, or staying at home. Their value function is given by:

$$V(s_R) = \max_{\substack{(c,a') \geq 0, \\ h \in \{0,H\}, \\ I^i \in \{0,1\}}} u(\tilde{c}, \bar{H} - h) + \beta \psi_j \mathbb{E}\left[V(s'_R)\right] \tag{7}$$

$$\begin{aligned} \text{s.t.} \quad (1+\tau_c)c + a' = {} & [1 + (1-\tau_k)r]a \\ & + (1-I^i)(1-\tau_y(P))y_j(w_f,P) \\ & + I^i y_j(w_i,P) + (1-\tau_b(R))b + \zeta, \end{aligned} \tag{8}$$

where the evolution of the state follows $s'_R = (j+1, a', z', b)$ and $\mathbb{E}[V(s'_R)] = \sum_{z'} \Pi(z, z') V(s'_R)$ is the standard expected value conditional on the current productivity, z.

3.5.2 Public Servants

At each age j, a public sector worker decides whether to migrate into the retirement sector. Letting I^r be an indicator function that assumes the value of 1 if the individual decides to retire and zero otherwise, the value function of the public employee is given by:

$$V(s_G) = \max_{\substack{(c,a') \geq 0, \\ I^r \in \{0,1\}}} u(\tilde{c}, \bar{H} - H) + \beta \psi_j \Big\{ (1 - I^r) V(s'_G) + I^r V(s'_R) \Big\} \tag{9}$$

$$\begin{aligned} \text{s.t.} \quad (1+\tau_c)c + a' = {} & [1 + (1-\tau_k)r]a \\ & + (1 - \tau_{ss}(G) - \tau_y(G)) y_j(w_f, G) + \zeta, \end{aligned} \tag{10}$$

with next period state being $s'_G = (j+1, a', z, t_C + 1, t_G + 1)$ when they do not retire and $s'_R = (j+1, a', z, b' = b(s_G))$ in case of retirement. The variable $b(s_G)$ denotes the retirement benefits the agent will receive as a function of their state variables.[18]

3.5.3 Private Workers

At each age j, the formal private worker makes decisions in three dimensions, in addition to the consumption/saving choice. First, if eligible, they decide whether to enter the retirement sector. Second, they decide whether to work (formally or informally) or to stay at home. Third, they decide if they should take the public exam.[19] Letting I^p be an indicator function that assumes the value of 1 if the individual decides to take the public exam and the zero otherwise, the private worker value function can be written as:[20]

$$\begin{aligned} V(s_P) = \max_{\substack{(c,a') \geq 0, \\ h \in \{0,H\}, \\ (I^r, I^l, I^p) \in \{0,1\}^3}} u(\tilde{c}, \bar{H} - h - I^p c_p(j)) + \beta \psi_j \Big\{ & I^r \mathbb{E}\left[V(s'_R)\right] \\ & + (1 - I^r) I^p q_p V(s'_G) \\ & + (1 - I^r) I^p (1 - q_p) \mathbb{E}\left[V(s'_P)\right] \\ & + (1 - I^r)(1 - I^p) \mathbb{E}\left[V(s'_P)\right] \Big\} \end{aligned} \tag{11}$$

[18] The benefits function $b(\cdot)$ for public workers is specified in Section 4. We assume a large negative value for $b(s_G)$ and $V(s'_R)$ whenever retirement eligibility conditions are not met.

[19] See Appendix A for a visual representation of the decision tree of private agents in the model.

[20] Because retirement is a deterministic choice and we do not allow retirees to work in the government, there is no continuation value when the agent enters retirement and take the public exam.

$$\text{s.t.} \quad (1+\tau_c)c + a' = [1+(1-\tau_k)r]a + (1-I^i)\Big[(1-\tau_y(P))y_j(w_f,P) - \tau_{ss}(P)\min\{y_j(w_f,P), y_{max}\}\Big] + I^i y_j(w_i,P) + \zeta \tag{12}$$

$$(x', t_C') = \begin{cases} \left(\frac{(t_C-1)x+\min\{y_j(w_f,P),y_{max}\}}{t_C}, t_C+1\right) & , I^i = 0 \text{ and } h = H \\ (x, t_C) & , \text{otherwise} \end{cases} \tag{13}$$

The first term of the continuation value inside the brackets corresponds to retirement, the second to not retiring, applying to a public job, and passing the exam, the third is not passing the exam (and not retiring), and the fourth and final term corresponds to the decision of not retiring, and not applying to a public job.

The evolution of the state variable is, for the case of retirement, $s'_R = (j+1, a', z', b' = b(s_P))$;[21] for the case of entering the public career, $s'_G = (j+1, a', z, t'_c, 1)$; and, finally, $s'_P = (j+1, a', z', x', t'_c)$ for the case where they continue as a private sector agent.

3.6 Stationary Distribution

The stationary distribution of agents is characterized by probability distribution functions $\mu_m : S_m \to [0,1]$, for all $m = \{P, G, R\}$, such that $\sum_{(m,s_m)|j} \mu_m(s_m) = \varphi_j$ for all $j \in \{1, ..., J\}$. That is, $\mu_m(s_m)$ is the measure of individuals in sector m and state s_m in the population.

The stationary distribution is derived using forward induction, considering the agents' policy functions, the transition matrix for the income process, the survival probabilities, and the probability of entering the public sector. To calculate it, we assume that: (i) every agent starts their life cycle with zero assets, zero average past earnings and zero time of contribution; (ii) everybody starts as a worker in the private sector; and (iii) the initial distribution of the idiosyncratic productivity is the invariant distribution of the Markov process for z. A formal derivation of the equilibrium distribution can be found in Appendix B.

3.7 Technology

We assume that there are two representative firms producing perfect substitute goods. One operates in the formal sector and the other in the informal sector. The first one produces using capital and labor, whereas the second one uses only labor. Both of them act competitively and maximize profits given input prices.

[21] The benefits function $b(\cdot)$ for private workers are specified in Section 4. We assume a large negative value for $b(s_P)$ and $V(s'_R)$ whenever retirement eligibility conditions are not met.

The production function of the formal sector is Cobb-Douglas: $Y_f = A_f K^{\alpha} N_f^{1-\alpha}$, where K and N_f are the aggregate capital and private labor inputs, α is the capital's share in output, and A_f denotes the formal sector total factor productivity (TFP). Capital is assumed to depreciate at a rate δ each period. The problem of the formal firm is:

$$\max_{K,N_f} A_f K^{\alpha} N_f^{1-\alpha} - (1+\tau_w) w_f N_f - (r+\delta) K, \tag{14}$$

where τ_W is a tax rate the government charges to finance the social security system.

Informal firms have linear technology in labor: $Y_i = A_i N_i$ and maximize profits according to:

$$\Pi_i = \max_{N_i} A_i N_i - w_i N_i \tag{15}$$

As our analysis focuses on the household-level responses to social security reforms, we abstract from firm heterogeneity within the formal and informal sectors. By doing so, we deviate from the literature that looks at the impact of informality on development and firm-level behavior.[22] That literature typically considers an increasing, strictly convex labor cost for operating under informality, which represents the probability of being caught by government authorities. Our simplified assumption and calibration exercise implicitly embed these costs in the informal sector productivity parameter, A_i.

3.8 Government Sector

The government taxes consumption, capital, income, wages, and social security benefits to finance the social security coverage, the payroll of public servants, and its non-productive consumption. We assume that the government consumes a constant fraction of the formal GDP: $C_g = \alpha_g Y_f$.

In the labor market, the government hires a share $\bar{N}_G \in [0,1]$ of the population as public servants and uses them to produce a public good Y_G. We assume that the government production function is linear in the effective labor supply: $Y_G = L_G$.

In equilibrium, the government is responsible for choosing $\bar{q}$ to balance the demand and supply of public workers. This assumption hinges on the fact that, over the 2005-2013 period, the Brazilian government consistently employed around 5% of the population according to PNAD data.

[22] See Ulyssea (2018), Meghir et al. (2015), Almeida and Carneiro (2012) and de Paula and Scheinkman (2011).

3.9 Equilibrium

We now define the recursive competitive equilibrium in this economy. A recursive competitive equilibrium consists of allocations of households and firms, prices (wages and interest rate), government taxes and threshold score, a stationary distribution of agents, bequests, and public goods such that: (i) households and firms optimize; (ii) individual and aggregate behaviors are consistent; (iii) the government sets threshold scores and consumption taxes to balance the size of the public sector in the population and its budget constraint; (iv) the stationary distributions evolve according to the policy functions of the agents; and (v) the amount of public goods and bequests are consistent with individual behavior. A complete equilibrium definition can be found in Appendix C, and the algorithm used to compute the equilibrium is detailed in Appendix D.

4 Data and Calibration

Using publicly available micro and macro data from different sources,[23] we calibrate the model to match features of the Brazilian economy in 2013, the year before the implementation of pension reforms that approximated the public and private pension systems. Tables G.1 and G.2 in the Appendix summarize the parameter values of this exercise.

4.1 Demography and Endowments

A model period corresponds to one year, and we assume agents live from 16 to 75 years old, so J = 60. The survival probabilities are taken directly from the IBGE 2013 mortality tables. We calibrate the population growth rate to $g_n = 0.019$ to match the population age profile obtained from PNAD data in 2013. Appendix Figure G.1 plots the survival probabilities in the model (left panel) and compares the population age profile in the data and in the model (right panel). Lastly, we follow Ferreira and Gomes (2017) and assume that agents have $\bar{H}$= 8,760 hours per year (365 days x 24 hours per day), and can work either zero or 8 hours per day, the contractual full-time routine in Brazil in 2013, which implies H = 2,016 hours (252 days x 8 hours per day).

4.2 Preferences and Technologies

We first detail the calibration of the preference parameters. The discount rate β is set to match a capital-to-output ratio of 2.5. This value is obtained from Morandi (2016), which applies the Perpetual Inventory Method to compute a historical series of the capital stock in Brazil. This number is in the range of 2.5 and 3, values commonly used in the Macro literature and

[23] See Appendix F for details.

administrative data for Brazil.[24] We set the risk aversion parameter σ to 2.5 based on the literature on consumption, surveyed by Attanasio (1999). This value is in line with estimates of the risk aversion parameter for Brazil.[25] The consumption share in the utility function γ is chosen to match the participation rate of 72.3% in 2013, according to PNAD data. Lastly, we set ε to 0.5 following the work of Ferreira and Nascimento (2005).

The technology parameters are calibrated as follows. For the formal sector, we set the capital share in output α to 0.4, and the depreciation rate δ to 6%, values commonly used in the Macro literature.[26] We calibrate the formal sector TFP A_f to match the 2013 GDP per capita of R$26,520, and we calibrate the informal labor productivity A_i to match a share of informal workers in the population of 18.9%.

4.3 Estimation of Labor Income

We now turn to the estimation of the stochastic process for z, the public sector wage premium θ, and the age-efficiency profile η_j. We estimate these parameters using microdata from the IBGE's Pesquisa Nacional por Amostra de Domicilios Continua (PNADC) from 2012q1 to 2018q4.

We estimate the state space $\mathscr{Z}$ and the transition probabilities $\Pi(z,z')$ of the idiosyncratic labor productivity z non-parametrically, following Hansen et al. (2014), De Nardi et al. (2016), and Ferreira and Gomes (2017).[27] Because labor income fluctuations in the model only happen in the private sector, we restrict the data to this sector. We start by assuming that the age-efficiency profile is quadratic and using the model to write down the log hourly wages of individual i as:

$$\log\left(\frac{y}{h}\right)_{ij} = C + \alpha_1^{\eta} j + \alpha_2^{\eta} j^2 + z_{ij}, \tag{16}$$

where C is a constant that varies only with the agent's working sector. We then obtain the empirical counterparts of z_{ij} as the residuals from Regression (16) (see Column 1 Table G.3 in the Appendix). We split the residuals into five groups: the top 5%, the next 20%, 25%, 25%, and the bottom 25%, and set each element in the state space $\mathscr{Z}$ as the mean residual within each respective group. To construct the transition probabilities, we calculate the fraction of individuals moving between every two groups over a year. Table G.4 in the Appendix displays

[24] For academic literature, see Santos and Cavalcanti (2021), Glomm et al. (2009), and Ferreira and Nascimento (2005). This number also aligns with figures from the Institute for Applied Economic Research (Ipea), which estimates Brazil's capital-to-output ratio to fluctuate around 2.5 since 1990.

[25] See Gandelman and Hernandez-Murillo (2015) and Fajardo et al. (2012).

[26] See Parente and Prescott (2002) for evidence on the depreciation rate and Gomes et al. (2005) for evidence on the capital share of formal output.

[27] We believe a non-parametric estimation of the income process is important as it captures empirical deviations from the normality assumption highlighted, for the Brazilian case, by Gomes et al. (2020). Guvenen et al. (2021) and De Nardi et al. (2016) also find large deviations from normality in the U.S. labor market.

the estimated grid and transition probabilities. Unlike traditional methods for income process estimation (Tauchen, 1986), we find asymmetry in both the transition probabilities and the elements in the state space.

The estimation of the public sector wage premium and the age-efficiency profile also relies on Regression (16). The Markovian nature of the idiosyncratic productivity process allows us to write:

$$\log\left(\frac{y}{h}\right)_{ij} = C + \alpha_1^{\eta} j + \alpha_2^{\eta} j^2 + \underbrace{g(z_{ij-1}) + \varepsilon_{ij}}_{=z_t}, \tag{17}$$

where the term $g(z_{ij-1})$ represents potential omitted variable problems in Regression (17). We address this concern by including a rich set of controls (such as education, occupation, and sector) and individual fixed effects. We estimate a public sector wage premium of 9.8% ($= exp(0.094) - 1$) from the "Public servant" dummy whose coefficient is displayed in Column (3) of Appendix Table G.3. We also estimate a concave age-efficiency profile with coefficients $\alpha_1^{\eta} = 0.028617$ and $\alpha_2^{\eta} = -0.000313$ by restricting the sample to individuals between 25-55 years old to avoid selection issues at older ages (see Column (4) in Table G.3 and Figure G.2 in the Appendix).

4.4 Social Security System

Brazil's social security system operates on a pay-as-you-go basis, transferring payroll contributions from current workers to existing retirees. There are two distinct pension systems: one for private sector workers—organized under the INSS (Instituto Nacional do Seguro Social)—and another for public servants, each with its own rules for contributions, eligibility, and benefit calculations. This section outlines the calibration of both systems in our model, based on the rules in place before the major pension reforms enacted after 2013.

4.4.1 Private Benefits

Private sector workers contribute to the INSS system and can retire under two modalities: retirement by years of contribution (contribution modality) and retirement by age (age modality). Under the contribution modality, workers can retire at any age as long as they have contributed for at least 35 years to the pension system. Under the retirement-by-age modality, workers qualify if they are 65 or older and have contributed for a minimum of 15 years.

In both cases, retirement benefits are a fraction of a worker's average lifetime earnings, x. The benefit formula is:

$$b(j^r, mod, t_C, x) = \Psi(j^r, mod, t_C) \cdot x, \tag{18}$$

where j^r is the retirement age, $mod \in \{Contrib, Age\}$ marks the retirement modality, t_C de-

notes the number of years the worker formally contributed to the social security system, and $\Psi(j^r, mod, t_C)$ denotes the replacement rate as a function of these variables.

The average lifetime earnings, x, is calculated by taking into account individual earnings up to the age of retirement that are lower than the maximum taxable income, $y_{\max}$, and its law of motion can be written as:

$$x_{j+1} = \frac{x_j(t_C - 1) + min\{y_j(w_f, P), y_{\max}\}}{t_C}, \quad \text{for } j = 1, 2, ..., j^r \tag{19}$$

Only earnings from the formal sector are considered in the calculation of x, as we assume that informal workers do not contribute to the social security system.[28]

For those who retire under the contribution modality, the replacement rate is given by:

$$\Psi(j^r, Contrib, t_C) = f(j^r, t_C) = \frac{0.31 t_C}{E(j^r)} \left[1 + \frac{(j^r + 0.31 t_C)}{100}\right], \tag{20}$$

where $f(j^r, t_C)$ is commonly known as the *fator previdenciário* (social security factor). This discount was implemented by Fernando Henrique Cardoso's presidency, to discourage early retirement in Brazil. $E(j^r)$ denotes the individual's life expectancy at the retirement age j^r, and t_C is the number of years of social security contributions. Depending on the number of years the worker has contributed to the social security system, and on the age of retirement, the social security factor can be greater than 1.[29]

Under the age modality, the worker can choose between the social security factor or an alternative replacement rate that gradually increases with years of contribution, starting at 85% of average earnings and potentially increasing up to 100%.[30] Hence, the replacement rate for the age modality reads:

$$\Psi(j^r, age, t_C) = \max\{f(j^r, t_C), \tilde{\Psi}(t_C)\}, \ \tilde{\Psi}(t_C) = \min\left\{0.70 + \frac{t_C}{100}, 1\right\} \tag{21}$$

Individuals older than 65 earning less than one-fourth of the minimum wage are also entitled to retirement with a pension equal to the minimum wage. This assumption replicates the LOAS (Lei Orgânica de Assistência Social). This social assistance program provides financial assistance to elderly individuals who do not participate in the formal private retirement system and do not have the means to support themselves. In the model, we calibrate the minimum wage

[28] Even though informal workers can contribute to the social security system, only a small fraction do so. In 2013, nearly 84% of the informal workers had not contributed to the social security system. On average, from 2002 to 2013, only 11% of the informal workers contributed.

[29] For instance, a 58-year-old worker who contributed for 35 years receives only 80% of their past earnings upon retirement. However, if the same worker contributed for 45 years, their replacement rate would be 106%. See more details in Figure G.3.

[30] This number comes from the 70% in the formula for $\tilde{\Psi}(t_C)$ plus the 15% required for eligibility.

to its observed annual value of R$8,136 in 2013.

We calibrate the contributions to the private social security system following the 2013 social security rules. Private workers paid 8%, 9% or 11% of their labor income up to the social security ceiling y_{max} in the following manner:

$$\tau_{SS}(P) = \begin{cases} 8\%, \ if\, y \leq R\$14,972 \\ 9\%, \ if\, R\$14,972 < y \leq R\$24,954 \\ 11\%, \ if\, R\$24,954 < min\{y, y_{max}\} \end{cases} \tag{22}$$

Private retirees have no tax on their benefits. We set the private social security ceiling $y_{max} = R\$50,000$ per year following the 2013 social security rules.[31]

4.4.2 Public Benefits

Public servants in Brazil have the right to a different pension system. Unlike the private pension regime, the wage base in the public retirement sector until 2013 did not have an upper limit and corresponded to the average of the 80% highest wages received during the public worker's career. Since we assume that a worker's productivity does not change after entering the public sector, this average equals the last wage.

The public pension system is also split into two modalities: contribution and age. Civil servants older than 60 who have contributed for at least 35 years and have been at least 10 years in the public sector can retire under the contribution modality. The benefits match the worker's current labor income, y:

$$b(y, Contribution) = y \tag{23}$$

Civil servants older than 65 who have been in the public sector for at least 10 years can retire under the age modality. In this case, individuals are entitled to a proportion of their last wage:

$$b(y, t_C, Age) = min\{\frac{t_C}{35}, 1\} \cdot y \tag{24}$$

Importantly, retirement in the public sector is mandatory at age 70.

Following the 2013 tax code, we assume that public workers compulsorily pay 11% of their income to the social security system and that public retirees pay an 11% tax on the benefits they receive in excess of the private social security ceiling.

[31] The value was defined as R$ 4,157 per month, which sums up R$ 49,884 annually.

4.4.3 Summarizing Private and Public Benefits

Appendix Table G.5 summarizes the public and private retirement schemes, while Appendix Figure G.3 plots effective replacement rates by retirement sector, age, contribution years, and lifetime earnings. Four main patterns emerge. First, only the private scheme allows for early retirement. Second, because of the social security ceiling, replacement rates in the private sector will converge to zero as earnings increase. Third, effective replacement rates for public pensions do not vary with workers' income. Fourth, public pensions generally offer higher replacement rates than private pensions, especially for high earners, given the absence of a pension cap.

4.5 Government Sector

The labor and capital tax rates are chosen based on the Brazilian macro literature.[32] We set them at $\tau_y(P) = 18\%$ and $\tau_k = 15.5\%$, respectively. We assume public workers face a lower effective labor income tax of $\tau_y(G) = 9\%$, partially reflecting that public workers may not contribute to the severance fund (FGTS) or to unions.[33] The consumption tax rate is chosen to balance the government budget constraint in equilibrium. Lastly, we use the 2013 Brazilian National Accounts to calculate that government consumption accounts for $\alpha_g = 19\%$ of GDP.

We use the PNAD data to calibrate the remaining variables associated with the government sector. We assume that the time cost for taking the public exam is quadratic: $c_p(j) = \alpha_2^p j^2 + \alpha_1^p j + \alpha_0^p$, and calibrate the parameters to minimize the distance between the fraction of test takers by each age in the model and the data. This procedure implies a convex cost function with coefficients $\alpha_2^p = 6$, $\alpha_1^p = -80$, and $\alpha_0^p = 266$. The size of the public sector is calculated directly from the PNAD data: $\bar{N}_G = 5\%$.

5 Equilibrium Features and External Validation

This section validates the equilibrium features of the calibrated model, showing that it matches the data in terms of macroeconomic aggregates, including those related to the social security system, and the life-cycle distribution of agents across sectors.

First, we discuss the main equilibrium variables in the calibrated economy. The equilibrium interest rate of 8.5% is relatively high by international standards, but not for Brazil. The formal sector wage rate of 4 Reais per hour is 1.4 times larger than wages in the informal sector, reflecting the fact that the informal sector tends to absorb low-productivity individuals. Finally, the consumption tax rate of 34.9% aligns with empirical estimates for the consumption tax rate

[32] See Glomm et al. (2009) and Pereira and Ferreira (2010).

[33] The baseline calibration of the model is robust to assuming $\tau_y(G) = 18\%$.

in Brazil.[34]

Table 3 displays aggregate non-targeted moments related to the social security system and income inequality. The model closely matches the 2013 data, with an overall social security deficit of 2.1% of GDP and a public sector pension deficit of 1.3% of GDP, accounting for over half the total deficit.[35] It also matches the early retirement age in Brazil, the average years of contribution upon retirement, and the distribution of retirement claims across different modalities (contribution vs. age). Lastly, the model replicates the average wage ratio between formal and informal workers as well as the income GINI coefficient.

Table 3: Non targeted moments: model vs. data

	Model	Data
Overall SS deficit (% GDP)	2.1%	2.1%
Public sector SS deficit (%GDP)	1.3%	1.2%
Fraction of contrib. modality claims	59%	61%
Average age at retirement	52.2	54.8
Average years contributed at retirement	35.0	35.3
Mean effective earnings Formal/Informal	1.4	1.5
Income GINI coefficient	53.2	52.7

Notes: This table shows moments related to the social security system in the model and in the data. "Average years contributed" are for the contribution modality only. Sources: model simulations, PNAD, World Bank, and Tafner et al. (2015).

Table 4 compares the distribution of the working age population (20-55 years old) across sectors. The model stands closely to the data, with 82% of the working age population participating in the labor force (vs. 89% in the data), 75% of the 20-55 population in the private sector (vs. 83% in the data), with 71% of those workers in the formal sector (vs. 75% in the data) and a public sector that accounts for about 6% of the working age population. Moreover, in the model, the retirement sector represents 13.9% of the total population and 2% of those between 20-55, closely matching the 13% and 3% respective figures in the data.

[34] According to Oliveira (2023), personal consumption taxation in Brazil in 2021 accounted for 15.1% of GDP, so that we have $\tau_c \cdot \frac{C}{Y} = 0.151$, where $C/Y = 57.6\%$ represents personal consumption as a proportion of GDP. Consequently, the actual τ_c would be approximately 26.3%. In addition, the figures used in the current tax reform project being discussed in Congress are around 29%, a figure that is also close to the calibrated $\tau_c = 34.9\%$.

[35] The social security deficit in the private sector is defined as:

$$Deficit_{Private} = \sum_{s_{RP}} (1-\tau_b) b \mu_{RP}(s_{RP}) - \tau_{ss}(P) \sum_{s_P} \left[(1-d^i(s_P)) \min\{w_f e^{z+\eta_j} d^h(s_P), y_{max}\} \right] \mu_P(s_P)$$

The first term represents the pensions paid to retirees in the private sector, while the second term accounts for the contributions made by active private sector workers. Similarly, the social security deficit in the public sector is expressed as:

$$Deficit_{Public} = \sum_{s_{RG}} (1-\tau_b) b \mu_{RG}(s_{RG}) - \sum_{s_G} \tau_{ss}(G)(1+\theta) w_f e^{z_G+\eta_j} H \mu_G(s_G)$$

In this equation, the first term indicates the pensions paid to public sector retirees, and the second term represents the contributions made by active public sector workers. The total social security deficit is calculated as the sum of both private and public sector deficits.

Table 4: Sectoral Composition of Working Age Population (20-55)

	Model	Data
Participation rate	81.6	89.0
Private sector	75.1	82.8
Formal	53.5	62.1
Informal	21.6	20.7
Public sector	6.5	6.2
Retirement	2.2	3.1

Notes: Sectoral composition of individuals between 20-55, in percent. Participation rate, private and public sectors do not consider retired people. Retirement is calculated out of the total population between 20 and 55 years old. Sources: Model simulations and 2013 PNAD.

Figure 5 shows that our calibrated model closely matches the age profile of individuals across the private, public, and retirement sectors. It replicates the age distribution of workers across sectors and captures early retirement trends in the private sector, which influence the effectiveness of minimum retirement age provisions in reducing the private-sector social security deficit. It also accurately captures the age profile of public servants, which is crucial in determining the social security deficit in that sector.

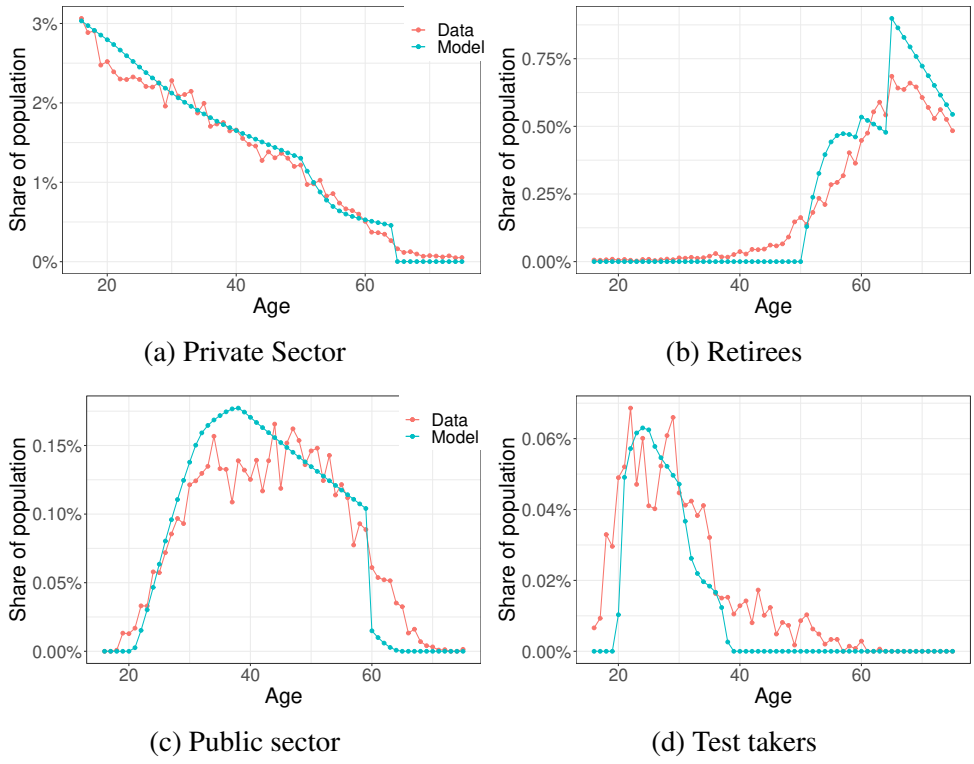
The timing of the public sector application decision pins down the flow of workers between the private and public sectors, determining the duration of government careers. This, in turn, will influence the amount of social security taxation and spending on public servants. The bottom-right panel of Figure 5 shows that the calibrated economy replicates the life-cycle profile of applicants in the data. This suggests that a convex application cost function captures well the nonlinearities over the life cycle in the decision to apply for a public sector job.

These findings support using the calibrated model to study the general equilibrium consequences of social security reforms under demographic changes, which we turn to next.

6 Benchmark Social Security Reforms

In this section, we use the calibrated model to quantify the steady-state effects of two social security reforms: the implementation of a pensions ceiling for public retirees, referred to as a "unification" of the pension systems, and the imposition of a minimum retirement age. We describe how we compute the counterfactual demographics and detail the policy reforms analyzed. We then discuss the quantitative results and robustness exercises. Lastly, we highlight the importance of both the public and informal sectors in evaluating the macroeconomic consequences of pension reforms.

Figure 5: Agents' equilibrium distribution by age and sector



(a) Private Sector

(b) Retirees

(c) Public sector

(d) Test takers

Notes: This figure plots, for each age, the percentage of the population allocated in each sector.

6.1 Explaining the Benchmark Reforms

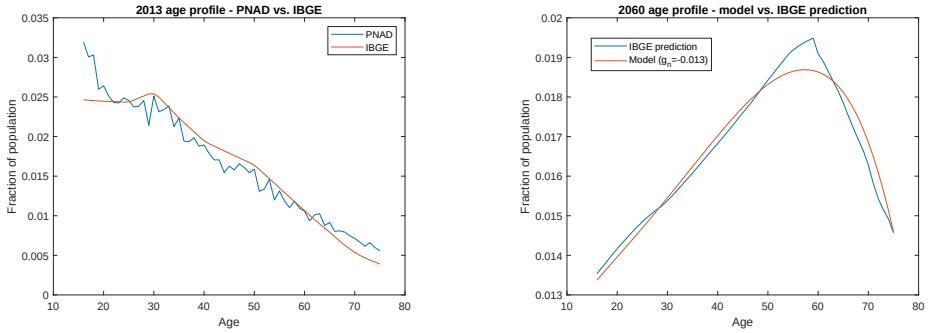
In the counterfactual exercises that follow, we compare two scenarios: one in which the population is older and no pension reforms are implemented, and one in which the population is older and the pension system is reformed.

We first explain how we estimate the demographic change in Brazil. Using the IBGE Tables of Population Projections 2000-2060 and the model-implied age distribution, we calibrate the new population growth rate to $g_n = -0.013$ to match the demographic profile in Brazil in 2060. Because the age distribution used in the model was obtained from the PNAD, not IBGE, we also compare the age distribution in 2013 from these two sources. Figure 6 shows that the demographic structures are well aligned (left panel), giving us confidence in using these predictions for our counterfactual analysis. The figure also shows that the 2060 age profile from the model matches the Brazilian age profile in 2060 from IBGE (right panel).

We now explain the benchmark reforms, which consist of two parts. The first part approximates the private and public social security schemes. In 2013, Law 12.618 imposed a ceiling on the social security benefits received by new entrants in the public sector.[36] This cap is the

[36]The 2013 reform also introduced a complementary retirement scheme for civil servants, which we do not model for simplicity.

Figure 6: 2013 and 2060 population age profiles, model vs. data



Notes: The left panel compares the age profile in the 2013 PNAD with the one in the IBGE's Tables of Population Projections 2000-2060. The right panel plots the model-implied population under the counterfactual growth rate of $g_n = -0.013$ versus the IBGE's projection for the male Brazilian population in 2060. Sources: 2013 PNAD and IBGE's Tables of Population Projections 2000-2060.

same that limits private sector benefits, y_{max}. The eligibility conditions did not change, nor did the benefits' formulas. The contribution to the social security system was limited to 11% of the minimum between the earnings of the public worker and y_{max}. This reform approximated the two social security regimes and intends to alleviate, at least in an ex-ante manner, the fiscal pressure of public retirement on public accounts. In what follows, we also refer to this first part of the benchmark reforms as the "unification" reform. The second part of the benchmark reforms is at the core of most discussions regarding social security systems: an increase in the minimum retirement age. We choose to impose a minimum retirement age of 65 for all workers,[37] as it mimics what was implemented by the Brazilian government with the Constitutional Amendment 103 of November 12th, 2019.[38]

6.2 Steady State Results

What are the long-run macroeconomic and distributional effects of the benchmark reforms? We start discussing the impacts of population aging. The participation rate is projected to fall substantially by 2060, with the reduction in labor supply expected to raise wages to 4.06. The proportion of retirees is also predicted to rise from 13.9% in 2013 to 31.5% in 2060. The informal share of labor is predicted to fall to 7.1% in 2060 as workers become more productive on average and spend more time in the formal sector to leverage generous retirement conditions. These demographic changes will increase the overall social security deficit from 2.1% to 16.6% of GDP, with the public (private) portion of the deficit rising from 1.3% to 5.2% (0.8% to 11.5%)

[37] This is the age for men. For women, the minimum retirement age is 62 years old. We also abstract away from a large number of transition rules for simplicity.

[38] Different retirement modalities still exist for private and public workers. Aside from the unification reform discussed above, all modalities still have their respective eligibility criteria, contribution schemes, and benefits calculation. The key difference is that now *all workers* must wait until they are 65 to collect retirement benefits.

Table 5: Steady state consequences of the benchmark social security reforms

		2060 demography			
	2013 demography	**No reforms**	**Unification**	**Minimum age**	**Benchmark reforms**
SS deficit/GDP (%)	2.1	16.6	14.6	10.8	10.2
Public SS deficit/GDP (%)	1.3	5.2	3.2	1.8	1.4
Private SS deficit/GDP (%)	0.8	11.5	11.4	9.0	8.9
Consumption tax (%)	34.9	54.6	51.7	46.1	45.4
Avg. Consumption (C)	1.78	1.90	1.97	1.90	1.95
Avg. Capital (K)	6.58	7.22	7.92	7.37	7.88
Avg. Output (Y)	2.75	2.73	2.88	2.73	2.83
K/Y ratio	2.40	2.65	2.75	2.70	2.78
Participation rate (%)	73.0	60.0	60.9	58.5	58.7
Fraction of retirees (%)	13.9	31.5	33.7	18.7	18.7
Informality (%)	19.5	7.1	3.8	8.6	6.3
Public sector applicants (%)	0.72	0.46	0.47	0.38	0.39
Wage rate	4.03	4.06	4.1	4.17	4.19
Interest rate (%)	8.47	8.31	8.11	7.76	7.65

Notes: This table shows the effects of the benchmark social security reforms on aggregate variables. Except in Column "2013 demography", the model is evaluated with the 2060 demography. Avg. Consumption (C), Avg. Capital (K) and Avg. Output (Y) are expressed in 10,000 Brazilian reais (BRL) at 2013 prices. Participation rate and fraction of retirees are out of the total population. Informality is calculated out of the total workforce. In the last column (Benchmark reforms), both the unification and minimum age reforms are implemented.

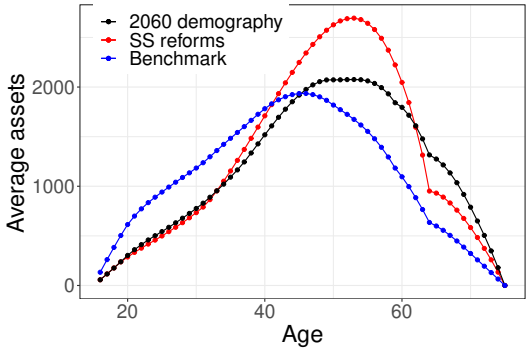
of GDP.

Population aging places significant pressure on the government budget, and the consumption tax rate is projected to increase from 34.9% to 54.6%. However, we estimate only a slight fall in GDP, while consumption and capital are projected to grow between 2013 and 2060. This happens as the 2060 demography has relatively more people aged 35-55 (Figure 6), at the peak of their labor productivity (Figure G.2). This raises the aggregate productivity of the workforce and partially offsets the negative effects of tax increases. Moreover, a higher capital-to-output ratio puts downward pressure on the interest rate, which falls from 8.47 in 2013 to 8.31 in 2060.

The last three columns of Table 5 show the aggregate effects of the benchmark social security reforms, holding the 2060 demography and all other parameters fixed. The third column shows the impact of unifying the two retirement systems, the fourth implements a minimum retirement age of 65, and the last combines both reforms.

A key result is a substantial reduction in the pension deficit. Under the benchmark reforms, the deficit falls by nearly 40% relative to the no-reform scenario, largely due to a drop in the share of retirees from 31.5% to 18.7%. While both reforms contribute to this reduction, only the higher retirement age cuts the number of retirees by keeping individuals in the labor market longer. In fact, raising the minimum retirement age reduces the deficit more than the unification. Since the social security ceiling is non-binding for low-productivity public workers, the unification does not affect their job choices. In contrast, the higher minimum age reduces the appeal of public jobs, as workers must now wait five more years to retire under the contribution modality. This shifts individuals away from the public sector towards either the informal sector—whose share rises from 7.1% to 8.6%—or out of the labor force, further lowering the public pension deficit.

Figure 7: The response of average savings over the life cycle



Notes: This figure plots asset accumulation over the life cycle in 2013 Brazilian Reais.

We now discuss the response of savings, both in aggregate and over the life cycle. The benchmark reforms raise aggregate savings by 9.1% with respect to the no-reform scenario. In addition to the incentives from lower taxation and a larger share of workers at the peak of their labor productivity, agents increase their savings to smooth consumption as the pension system becomes less generous. This is clear in Figure 7, which shows average savings over the life cycle under different scenarios. An older population induces more savings for people over 45, as the 2060 line is above that of 2013. However, when comparing the savings profile in 2060 with and without reforms, the figure shows a significant increase in total average assets from around 33 years old to 62 years old. After this age, individuals' assets fall below the levels of the no-reform world. This is because people are saving more to compensate for the fall in retirement income caused by changes in social security.

What are the effects of the benchmark reforms on labor market participation, public sector job application, and informality? The aggregate impact of the reforms on labor market participation is ambiguous: individuals will work longer and postpone retirement by law, but because of that, they may increase leisure time before retirement. Table 5 shows that the latter dominates and there is a mild reduction in the participation rate from 60.0% to 58.7%. This aggregate number masks substantial heterogeneity along the life cycle. On the one hand, the imposition of a minimum retirement age eliminates early retirement and mechanically increases the participation rate of people between 55 and 65 (Figure 8a and Figure 8d). Figure 9 shows that these are highly productive individuals who have now returned to the labor market.[39] On the other hand, individuals between 35 and 55 now have less incentive to work, as they can no longer claim early retirement benefits. Figure 9 shows that these tend to be agents of lower productivity who can no longer complement their labor market wages with early retirement benefits.

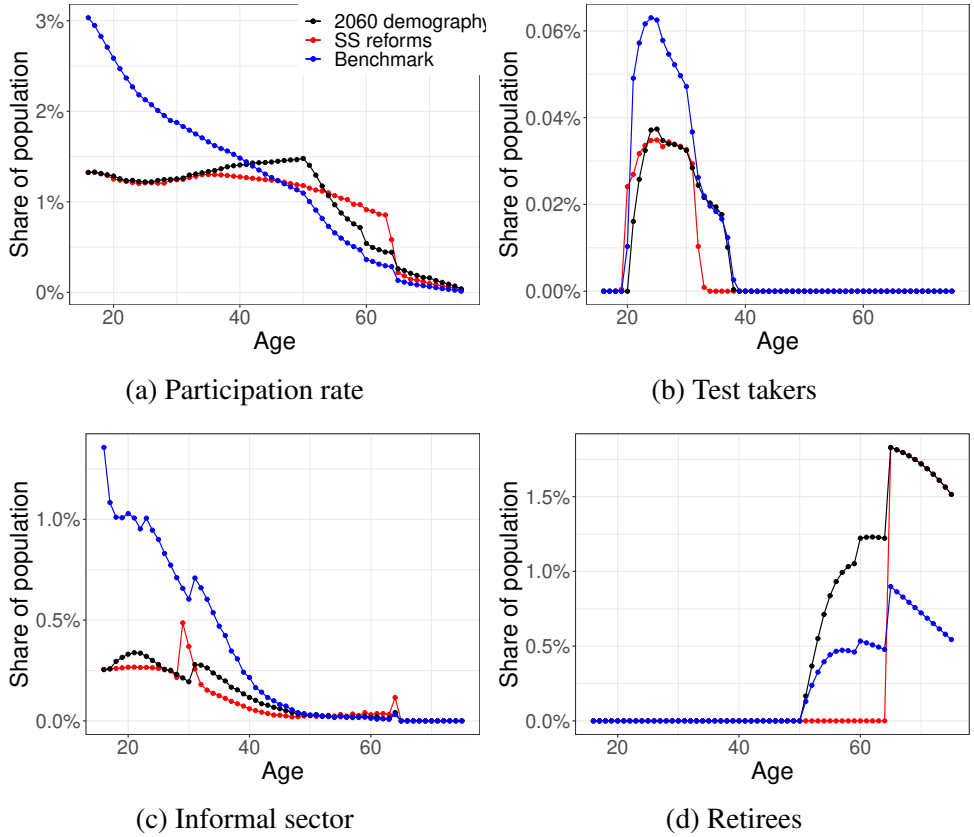
The benchmark reforms reduce the number of public sector applicants from 0.46% to 0.39% due to worsened public sector retirement conditions. The reforms also change the test-taking

[39]Table G.6 shows that virtually zero agents are moving from home to the informal sector.

behavior of agents over the life cycle, as we can see in Figure 8b. More individuals between 20 and 23 years old take the public exam, but fewer individuals between 31 and 40 years old take the exam. This reduces the average wage level at which individuals try to migrate from the private to the public sector. Moreover, as Figure 9 shows, this anticipation effect in the test-taking behavior happens mostly for highly skilled individuals working in the formal sector.

Population aging will reduce the size of the informal sector, as the 2060 economy will have fewer young individuals who rely on informality to avoid taxes and increase savings for later stages of their life cycles (Table 5). The benchmark reforms are not projected to impact significantly informality over the life cycle relative to a no-reform scenario (Figure 8c). The main difference is around 30 years of age, when agents try their chances in the public sector. To compensate for the fall in utility, they migrate to the informal sector, avoiding taxes and increasing their net income. Linked to the previous discussion on test-taking behavior, Figure 9 shows that these new informal workers are of medium-to-high productivity and would otherwise work in the formal sector.

Figure 8: The responses of participation rate, test taking behavior and informality



(a) Participation rate

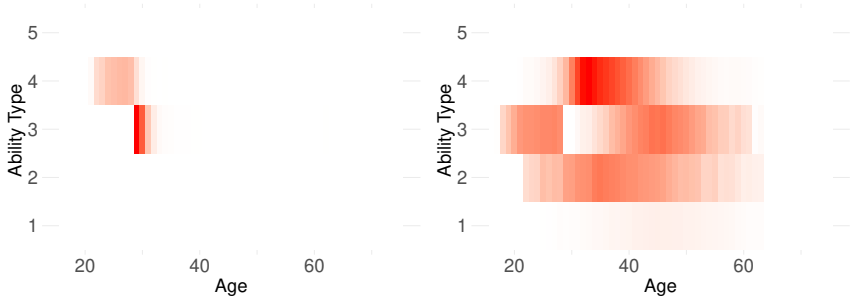
(b) Test takers

(c) Informal sector

(d) Retirees

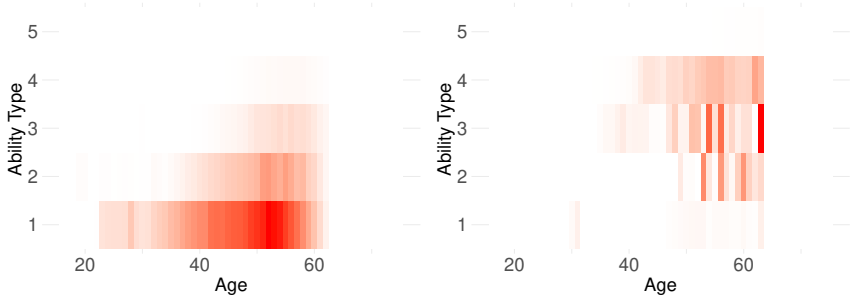
Notes: This figure shows, for each age, the fraction of the population participating in the labor markets (top left), taking the public exam (top right), working in the informal sector (bottom left), and retiring (bottom right). The results are presented for the (2013) calibrated model (blue), the 2060 demography (black), and the 2060 demography with both reforms (red).

Figure 9: Impact of Pension Reforms on Sector Mobility by Age and Ability



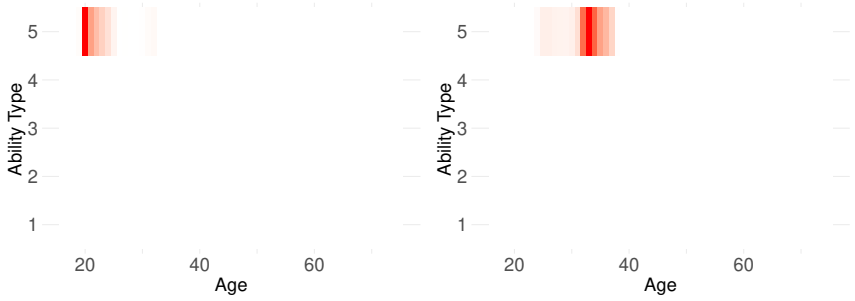
(a) Formal → Informal

(b) Informal → Formal



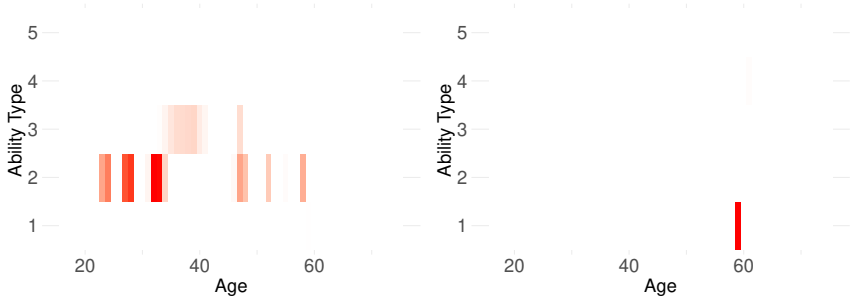
(c) Formal → Home

(d) Home → Formal



(e) Formal → Test takers

(f) Test takers → Formal



(g) Informal → Home

(h) Home → Informal

Notes: This figure illustrates the distribution of agents that switched sectors by ability (vertical axis) and age (horizontal axis) after the implementation of the benchmark reforms. Red color indicates a higher concentration of agents. Table G.6 in the Appendix shows the share of private agents in the new steady state that changed their occupational behavior.

Robustness checks. We perform a series of robustness checks on our results in the Appendix. Table H.7 shows that a reform in the pension system that equalizes all retirement conditions yields similar findings to the benchmark reforms that cap public benefits and impose a minimum retirement age. Table H.8 shows that the results are robust to separable preferences in consumption and leisure, as in McGrattan and Prescott (2017). Table H.9 highlights that general equilibrium interactions are key to our quantitative findings. Lastly, Table H.10 shows that our findings are robust to aging the population via a combination of different survival probabilities and population growth rates.

6.3 The Role of the Public Sector and Informality

This section performs four exercises to highlight the importance of the public and informal sectors when evaluating pension reforms. The public sector deserves careful consideration for at least two reasons. First, public employees often operate under distinct pension systems. Second, employment in the public sector is marked by higher job security and a non-negligible wage premium, which can distort agents' sectoral decisions. Addressing the informal sector is also crucial since workers in this sector typically do not contribute to pension systems, yet they might still be eligible for certain retirement benefits.

The first exercise, displayed in Table 6, freezes the sectoral status of public and informal workers while allowing the remaining agents to fully respond to the benchmark pension reforms. In a world where public and informal workers cannot move sectors, the public deficit would be 0.5 pp higher (10.7% versus 10.2%). An artificially high informal sector lowers the contributions to the pension system, increasing its deficit relative to GDP. This is shown in Column "Only public sector" of Table 6, where we also allow informal workers to reoptimize sectors, and the social security deficit decreases by 0.3 percentage points. Importantly, informal and public sector application decisions are responsible for 70%, 60% and 38% of the increases in GDP, consumption, and the capital stock, respectively, in response to the benchmark reforms. These findings highlight that endogenous sectoral choices are key in understanding the broad implications of the reforms.

In the second exercise, shown in Table 7, we shut down the public sector by artificially increasing the threshold score $\bar{q}$. We fix the remaining parameters according to Tables G.1 and G.2, and re-calculate the equilibrium in 2013 and 2060 with and without the benchmark reforms. The absence of a public sector substantially lowers the estimated social security deficit in 2013 and 2060 to 0.5% and 11.7%, respectively. Moreover, raising the retirement age—which corresponds to the benchmark reforms in the absence of a public sector—now has a modest impact on the pension deficit, which falls by 2.5 pp from 11.7 to 9.2% of GDP. The stark reduction in the consumption tax due to the absence of a public sector raises consumption,

Table 6: Decomposing the contribution of informality and public sector choices

	2060 demography	Benchmark reforms		
		Sectoral decisions fixed		Optimal decisions
		Informal and public sector	Only public sector	
SS deficit/GDP (%)	16.6	10.7	10.4	10.2
Public SS deficit/GDP (%)	5.2	1.54	1.49	1.4
Private SS deficit/GDP (%)	11.5	9.1	8.9	8.9
Consumption tax (%)	54.6	46.6	46.0	45.4
Avg. Consumption (C)	1.90	1.92	1.93	1.95
Avg. Capital (K)	7.22	7.63	7.75	7.88
Avg. Output (Y)	2.73	2.76	2.80	2.83
K/Y	2.65	2.76	2.77	2.78
Participation rate (%)	60.0	60.9	58.9	58.7
Fraction of retirees (%)	31.5	18.7	18.7	18.7

Notes: This table decomposes the results of Table 5 with 2060 demography. The "2060 demography" column considers the no-reform scenario with 2060 demography. "Optimal decisions" shows the results considering the benchmark reforms. The remaining columns consider the impact of the benchmark reforms while maintaining the sectoral decisions on informality and public sector application the same as in the no-reform 2060 economy. Avg. Consumption (C), Avg. Capital (K), and Avg. Output (Y) are expressed in 10,000 Brazilian reais (BRL) at 2013 prices. Participation rate and fraction of retirees are out of the total population. Informality is calculated out of the total workforce.

capital, and GDP in both 2013 and 2060 economies relative to their counterparts. However, reforming the pension system now lowers these aggregate variables as it reduces the aggregate participation rate by 1.9 pp.

Table 7: Analysing the pension reform in an economy without public workers

		2060 demography	
	New Benchmark	w/o reforms	Minimum age
SS deficit/GDP (%)	0.5	11.7	9.2
Public SS deficit/GDP (%)	0.0	0.0	0.0
Private SS deficit/GDP (%)	0.5	11.7	9.2
Consumption tax (%)	8.5	24.6	20.9
Avg. Consumption (C)	2.01	2.14	2.10
Avg. Capital (K)	7.99	8.56	8.44
Avg. Output (Y)	3.19	3.12	3.05
K/Y	2.51	2.74	2.77
Participation rate (%)	71.6	58.4	56.5
Fraction of retirees (%)	15.0	33.6	18.7

Notes: This table considers an economy without a public sector. In the first column, "New Benchmark (%)," we consider the new 2013 Benchmark where the parameters are the same as in the Benchmark, but the model does not have public workers. The second column, "w/o reforms," shows the results considering the 2060 demography. The third column considers both reforms with the 2060 demography. Avg. Consumption (C), Avg. Capital (K), and Avg. Output (Y) are expressed in 10,000 Brazilian reais (BRL) at 2013 prices.

The third exercise, displayed in Table 8, introduces two modifications to the model alongside the benchmark reforms. First, as shown in Column "No wage premium," we eliminate the public sector wage premium by setting $\theta = 0$. Second, displayed in Column "Higher SS contribution," we increase the rate of contribution to the social security system, τ_{ss}, from 0.11 to 0.2, so that the adjustment of the government budget is not done entirely via consumption taxes. Eliminating

the public sector wage premium has a modest impact on the economy, with a small reduction in the social security deficit of 0.05 pp. This is driven by a decrease in the public sector deficit, as lower wages and fewer civil servants lead to a reduction in pension obligations. The participation rate falls slightly, and informality increases, which may explain the slight fall in output and consumption. Increasing the contribution rate to 0.2 has a larger impact on the pension deficit, which falls by 0.77 pp. Once again, this is due to the reduction of the public pension deficit, which falls from 1.4 to 0.58 percent of GDP. Apart from the impact on the pension deficit and on public sector workers and applicants, the economic effects of higher contribution rates on other aggregate variables are limited.

Table 8: Additional reforms in the public sector with 2060 demography

2060 Demography with additional reforms			
	Both reforms	**No wage premium**	**Higher SS contribution**
SS deficit/GDP (%)	10.24	10.19	9.47
Public SS deficit/GDP (%)	1.4	1.28	0.58
Private SS deficit/GDP (%)	8.90	8.91	8.89
Consumption tax (%)	45.4	43.18	44.34
Avg. Consumption (C)	1.95	1.947	1.949
Avg. Capital (K)	7.88	7.82	7.87
Avg. Output (Y)	2.829	2.820	2.828
K/Y	2.78	2.77	2.78
Participation rate (%)	58.71	58.61	58.64
Fraction of retirees (%)	18.71	18.71	18.71
Informality (%)	6.29	6.58	6.37
Public sector applicants (%)	0.39	0.35	0.35

Notes: This table shows the effects of different social security reforms focused on the public sector. No wage premium means that $\theta = 0$; Higher contribution to S.S. means that public workers will have a higher tax related to their pension contribution (20% now versus 11% before). Avg. Consumption (C), Avg. Capital (K), and Avg. Output (Y) are expressed in 10,000 Brazilian reais (BRL) at 2013 prices. Participation rate and fraction of retirees are out of the total population. Informality is calculated out of the total workforce.

In the fourth exercise, we double the number of public sector workers in the 2013 economy. We then recalculate the equilibrium in 2060 and simulate the impacts of the benchmark social security reforms. Table 9 summarizes the main findings. The "2013 demography" column presents the equilibrium for this artificial economy with twice as many civil servants in that year. As expected, total and public social security deficits are larger than their counterparts in Table 5, with the latter roughly doubling. The consumption tax that clears the government budget is also very high (67% vs. 35% in Table 5), increasing the informal share of workers from 19% to 44% as agents avoid labor taxes to smooth consumption. This, along with the larger public sector, results in a participation rate of 81% in equilibrium.

When the economy is simulated with the 2060 demography—a much older population— and no reforms, the social security deficit increases to 22.6% of GDP, with the public sector pension deficit alone reaching 11.3% of GDP. The impact of population aging on consumption, capital,

and output is similar to that in Table 5, although informality and participation rates remain relatively high, and the share of retirees is relatively small. At the same time, the benchmark reforms significantly reduce the pension deficit, cutting it by nearly half as a share of GDP. The fall in the public sector pension deficit is also significant. Consequently, the consumption tax falls from 92% to 75%, raising aggregate output, capital, and consumption. Moreover, under the benchmark reforms, the public sector loses attractiveness, and the share of applicants to a public job falls by 50%.

Taken together, these exercises highlight that the savings from pension reforms increase with the size of the public sector. Namely, the benchmark reforms lower the pension deficit over GDP by 2.5 pp (11.7 to 9.2%) in an economy with no public sector, by 6.4 pp (16.6 to 10.2%) in the calibrated model, and by 11 pp (22.6 to 11.6%) in an economy with twice the amount of public workers. Hence, failing to account for endogenous public and informal sector decisions, or incorrectly sizing these sectors, may lead to substantial biases in estimating the long-run impacts of pension reforms.

Table 9: Social security reforms and the size of public sector

An economy with twice as many public sector workers			
	2013 demography	**2060 demography**	
		w/o reforms	**Both reforms**
SS deficit/GDP (%)	3.4	22.6	11.6
Public SS deficit/GDP (%)	2.6	11.28	3.1
Private SS deficit/GDP (%)	0.8	11.3	8.5
Consumption tax (%)	67.1	92.0	75
Avg. Consumption (C)	1.57	1.67	1.79
Avg. Capital (K)	5.63	6.21	7.48
Avg. Output (Y)	2.40	2.39	2.63
K/Y	2.35	2.60	2.85
Participation rate (%)	80.8	92.1	58.7
Fraction of retirees (%)	12.0	14.0	18.7
Informality (%)	44.0	42.5	4.1
Public sector applicants (%)	1.2	0.8	0.4

Notes:The second column of the table reproduces the 2013 benchmark result, but with twice as many public sector workers. The third and fourth columns show results for an economy with the 2060 demographic structure and twice the number of public sector workers, with and without the reforms, respectively. Avg. Consumption (C), Avg. Capital (K), and Avg. Output (Y) are expressed in 10,000 Brazilian reais (BRL) at 2013 prices. Participation rate and fraction of retirees are out of the total population. Informality is calculated out of the total workforce.

7 Transition Dynamics

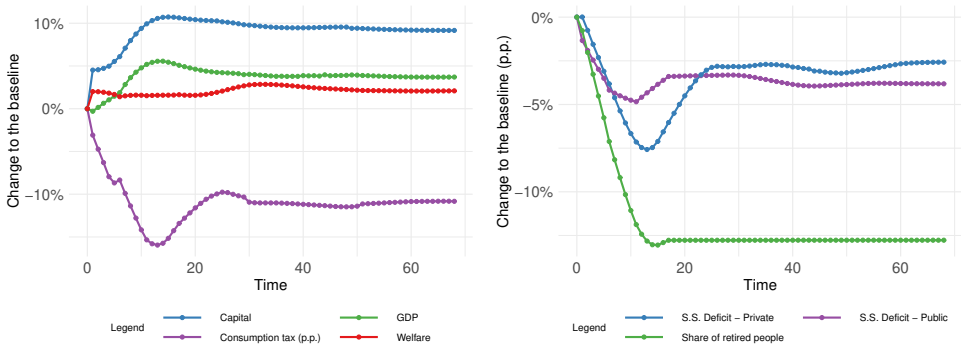
The previous section's long-run analysis does not account for important short-run and transitional dynamics. This section addresses these factors by exploring how the economy evolves from its initial equilibrium to the long-run counterfactual steady states after implementing the minimum

retirement age and unification reforms. We assume that the economy starts in a stationary equilibrium, that the policy is unexpectedly introduced, and that the economy then converges to a new steady state. Agents are presumed to fully anticipate the effects of the reforms, adjusting their expectations and decisions accordingly.[40]

7.1 Macroeconomic Aggregates

We start by discussing the evolution of macroeconomic aggregates such as capital, GDP, and the social security deficit. Figure 10a shows that capital and GDP reach their peak increases after 14 years, with GDP rising by over 5% and capital surging by more than 10%. Over time, both variables gradually stabilize at equilibrium levels above their initial values. This growth is primarily driven by a reduced consumption tax, resulting from a declining social security deficit, and a substantial rise in public employees' savings. In the short run, the consumption tax drops by approximately 16 pp before stabilizing at a long-run level that is 11 pp lower than its initial value.

Figure 10: Aggregate variables along the transition path



(a) Aggregate variables (b) Social security variables

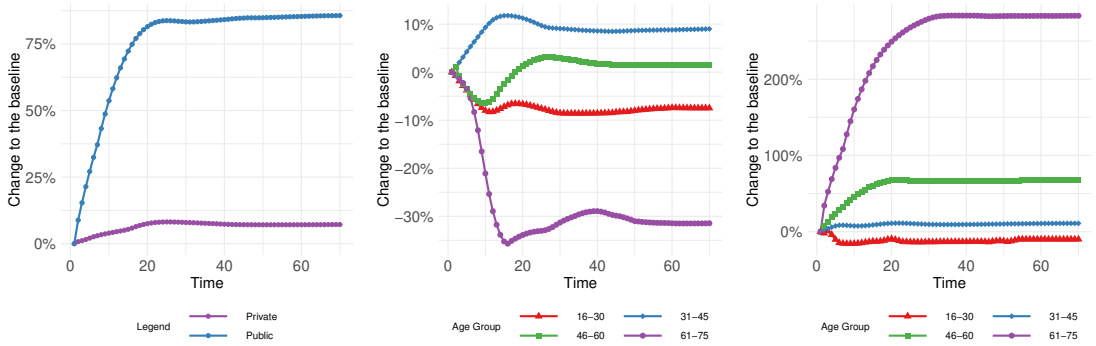
Notes: This figure shows transition dynamics after implementing both reforms (minimum retirement age and unification reform). Values are in percent changes compared to the baseline (initial period). Figure 10a presents capital, GDP, consumption tax, and aggregate welfare. Figure 10b presents social security deficit for public and private workers and the share of retired workers.

The transition dynamics of the social security deficit in the public and private sectors are displayed in Figure 10b. Initially, the public sector experiences a sharper decline in its deficit, largely due to the introduction of a pension ceiling. Over the first 14 years, the proportion of retiring workers falls, with a more pronounced effect in the private sector. This reflects the historical prevalence of early retirement among private-sector workers, whereas public employees were required to retire no earlier than 60. However, once this extensive margin effect fades, the private-sector deficit rises, driven by an increasing number of retirees receiving higher

[40] See Appendix E for details on the transition algorithm.

pensions tied to rising wage levels. In the long run, both sectors see a substantial reduction in their deficits, with the decline more pronounced in the public sector, reflecting the lasting effects of the pension ceiling and structural shifts in retirement patterns.

Figure 11: The response of savings to the benchmark reforms



(a) Savings by sector (b) Private savings by age (c) Public savings by age

Notes: This figure shows transition dynamics of savings under the benchmark reforms. Values are in percent changes compared to the baseline (initial period). Figure 11a presents the savings evaluation from public and private workers. Figures 11b and 11c present the savings by age groups for private and public workers, respectively.

Figure 11a shows that public workers' savings increased by approximately 86%, induced largely by the reduction of their benefits. Figure 11 further breaks down the effects of the reform on savings across different age groups and sectors. For private-sector workers, older individuals (ages 61–75) experience a savings decline of approximately 30%. This is primarily because they are the most affected group by the minimum retirement age: their need for precautionary savings diminishes with fewer years spent in retirement. In contrast, public-sector workers exhibit a different pattern, as they previously did not have widespread early retirement. Instead, their savings behavior changes due to significantly lower retirement benefits following the unification reform. In both sectors, younger workers reduce their savings, driven by the lower consumption tax and higher expected future wages, which create incentives to save later. Additionally, we observe increased savings among workers aged 31–45 and 45–60 in both sectors. However, for private-sector workers between 45 and 60, savings initially decline in the short run, as many who had planned for early retirement must now continue working until age 65.

7.2 Welfare Analysis

We now turn to the welfare implications of the social security reforms. Welfare is assessed using the consumption equivalent welfare gains, defined as the constant proportional change in an individual's consumption that would make them indifferent between the no-reform and reform

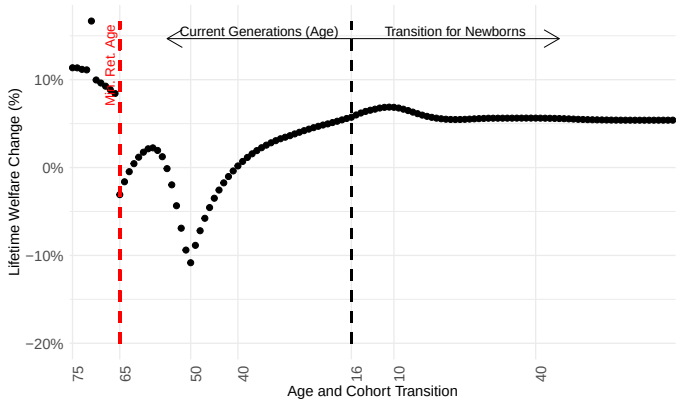
scenarios. We derive it from Equation (1) as:

$$\Delta(t,j,s) = 1 - \left[\frac{V^{\text{No Reform}}(t,j,s)}{V^{\text{Reform}}(t,j,s)}\right]^{\frac{1}{\gamma(1-\sigma)}} \tag{25}$$

This measure is computed for each transition period, $t = 1,...,T$, age $j = 1,...,J$ and remaining state variables summarized by s.[41] A positive value means individuals would be willing to decrease consumption by $\Delta\%$ in the new steady state to be in the old steady state. We aggregate welfare gains using the respective equilibrium distribution of agents along the transition path.

The red curve in Figure 10a, Panel (a), displays the aggregate welfare gains from the benchmark reforms along the transition path. Welfare gains are positive throughout all periods, fluctuating between 1.4 and 2.85% of consumption. Despite fluctuations along the transition path and the distributional aspects discussed below, aggregate welfare gains between the short and long run are not substantially different (around 2%).

Figure 12: Welfare by cohorts



Notes: This figure follows McGrattan and Prescott (2017) and shows the percentage welfare gains for different cohorts. To the left of the vertical black line, we plot welfare changes for current generations in the first period of the policy implementation. To the right of the vertical black line, we display the welfare gains for agents born ($j = 1$) in each period along the economy's transition to the new steady state. We measure welfare as the proportional change in consumption that equalizes agents' lifetime utility between pre- and post-reform at each point during the transition path.

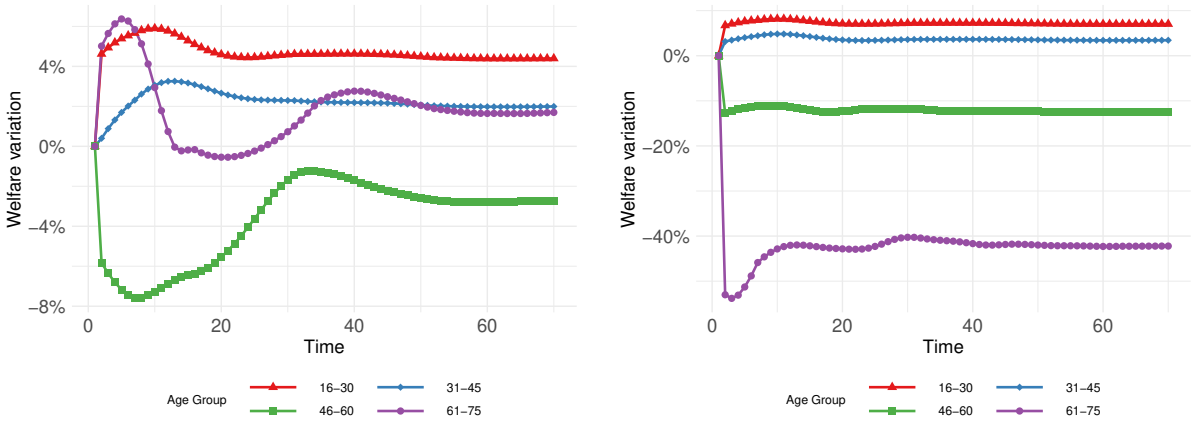
Figure 12 presents the lifetime welfare changes of different cohorts alive in $t = 1$ and future generations born along the transition path. Four key results stand out. First, all newborn agents are better off in a world where the benchmark reforms were implemented. Still, there is variation along the transition, with agents born during periods of low consumption tax rates benefiting the most. Second, individuals younger than 40 years old at $t = 1$ benefit from the instantaneous reduction in consumption taxes despite worsened retirement conditions in future dates. Third, individuals close to retirement are the ones who are worse off. These are depicted by the kinks in the graph. For example, individuals who used to claim early retirement at 50 years old now

[41] These depend on the sector of the agent, as discussed in Section 3, and are omitted for brevity.

have to postpone their plans until they turn 65. Fourth, agents already claiming their retirement benefits are better off due to lower consumption taxes in the aftermath of the benchmark reforms. Overall, this analysis highlights the winners and losers of the benchmark reforms, shedding light on potential ways for governments to design transition rules for the existing workforce.

Figures 13a and 13b further break down the dynamic welfare consequences of the benchmark reforms across different age groups and sectors. Younger workers between 16 and 45 in both the public and private sectors experience substantial welfare improvements driven by changes in general equilibrium variables, particularly the lower consumption tax and higher wages. In contrast, older generations, especially public-sector employees, face the most significant welfare losses due to the imposition of the social security ceiling, capping their pension benefits. For older private sector workers, welfare initially increases in the short run, as those who had not planned for early retirement benefit from favorable equilibrium effects. However, over time, as new cohorts reach the age at which they would have retired under the previous system but are now required to continue working, the negative impact of the reform outweighs these initial gains.

Figure 13: Welfare by age group and sector



(a) Private workers

(b) Public workers

Notes: This figure shows the transition dynamics of welfare after implementing both reforms (minimum retirement age and unification reform). Values are in percent changes compared to the baseline (initial period). Welfare is measured as the proportional change in consumption that equalizes agents' instantaneous utility between pre- and post-reform.

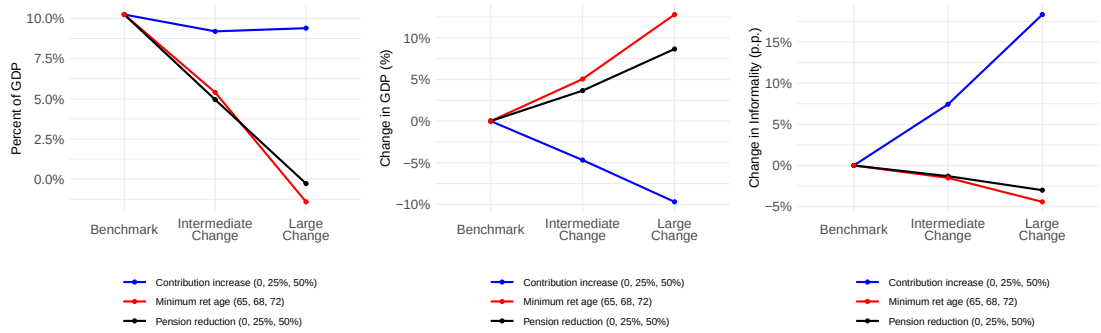
In summary, the analysis of transition dynamics highlights significant short-run effects that a purely long-run perspective would miss. Capital and GDP grow significantly in the first years of the transition, driven by lower consumption taxes and increased public-sector savings. The public sector sees an immediate reduction in its pension deficit due to benefit ceilings, while the private sector pension deficit experiences a delayed but eventual decline. Savings behavior differs across sectors: public employees save more due to pension cuts, while private workers

adjust based on the new retirement age. Welfare gains are concentrated among younger workers, while older generations—especially in the public sector or those planning to engage in early retirement—lose from the benchmark reforms.

8 Zero-Deficit Policies

Demographic changes will put increasing pressure on the social security deficit, and our simulations suggest that the benchmark reforms will not fully offset these pressures. This section studies how the government could eliminate the pension deficit in the long run. Specifically, we evaluate three policies: (i) further increasing the minimum retirement age; (ii) further reducing the replacement rate of pensions; and (iii) further raising the contribution rates paid by formal sector workers to the pension system.[42]

Figure 14: Policies to eliminate the pension deficit



(a) S.S. deficit (b) GDP (c) Informality

Notes: This figure shows the long-run effects of three policies: (i) increasing the social security contribution rates by 25% and 50% (blue); (ii) reducing pension replacement rates by 25% and 50% (red); and (iii) increasing minimum retirement age to 68 and 72 years old (black). Figure 14a, 14b, and 14c present the results for pension deficit over GDP, GDP, and informality, respectively. Only one policy tool is changed at a time, together with the benchmark reforms.

Figure 14 shows the effects of these policy tools on the pension deficit, GDP, and informality. Eliminating Brazil's pension deficit by 2060 would require raising the minimum retirement age to above 71 or cutting retirement benefits by about 50% (Figure 14, left panel). The need for a higher minimum retirement age is not unique to Brazil. In 2020, men who entered the labor market at age 22 retired at an average age of 64.2 in OECD countries, with Iceland, Norway, and Israel setting a normal retirement age of 67 (OECD, 2021). France, for instance, raised its retirement age from 62 to 64 in 2023. Our model highlights that for Brazil, a country younger

[42]The minimum retirement age in Brazil is lower than other OECD countries (Section 2). Contribution rates in Brazil are between 8-11% of formal earnings, similar to the 8.2% OECD average. Lastly, the pension replacement rate in Brazil is around 88%, above the OECD average of 63.8% (OECD, 2023).

than these European counterparts, eliminating the social security deficit would require imposing a minimum retirement age substantially above those figures.

The middle and right panels of Figure 14 show the effects of these different policies on GDP and informality, respectively. Increasing the minimum retirement age or reducing pension benefits in the *Large Change* policy are estimated to increase long-run GDP by between 7.5 and 12.5%. Stricter retirement conditions encourage individuals to work and save for longer, raising aggregate savings and boosting the capital stock. Higher capital lowers the interest rate, increasing formal firms' demand for labor. As a result, formal wages rise, and the size of the informal sector falls by between 2.5 and 5 percentage points. As people work longer, they contribute more to the economy through taxes and production, increasing government revenues and reducing retirement expenses and the equilibrium consumption tax.

By contrast, the blue lines in Figure 14 show that raising contribution rates is less effective in eliminating the pension deficit. In our model, higher taxes push more workers into the informal sector to avoid contributions. For instance, a 50% increase in contribution rates raises informality by nearly 20 percentage points, shrinking the tax base and offsetting most of the expected direct fiscal gains. The rise in informality also leads to a 10% fall in GDP, further limiting deficit reduction via a lower denominator. These findings highlight that in economies with high levels of informality, governments face tighter constraints in using tax-based measures to address pension deficits.

9 Conclusion

This paper develops a general equilibrium life-cycle model with endogenous sectoral and retirement decisions to quantify the effects of social security reforms in economies with segmented pension systems and large informal sectors. By calibrating the model to Brazil, we find that unifying public and private pension systems and raising the minimum retirement age generate sizable gains in output, capital accumulation, and aggregate welfare. These reforms also contribute to a substantial reduction in the social security deficit. A key mechanism driving these results is the reallocation of labor across formal, informal, and public sectors, which acts as a central channel through which reforms shape macroeconomic outcomes. Neglecting the interaction between pension rules and sector choices can potentially lead to a significant underestimation of reform impacts.

While the reforms yield positive aggregate welfare gains, they also entail distributional effects across age groups and sectors, highlighting the political challenges of implementing ambitious adjustments. They also lead to significant sector migration. Our findings also underscore how informality can amplify the fiscal costs of pension systems in emerging markets. We show that raising minimum retirement ages or lowering replacement rates are more effective policy options

for eliminating pension deficits than increasing contribution rates. Overall, our findings indicate that well-designed, comprehensive pension reforms that account for sectoral reallocations are crucial to strengthening fiscal sustainability and economic performance in aging emerging economies.

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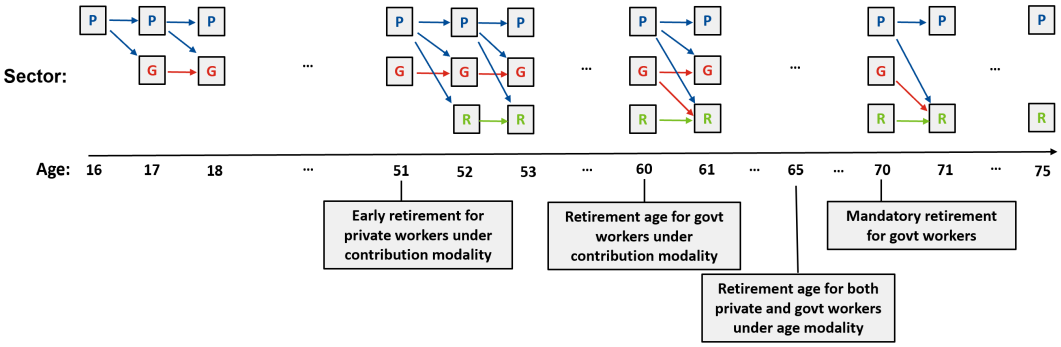
Appendix A Private Agents' Timeline and Decision Tree

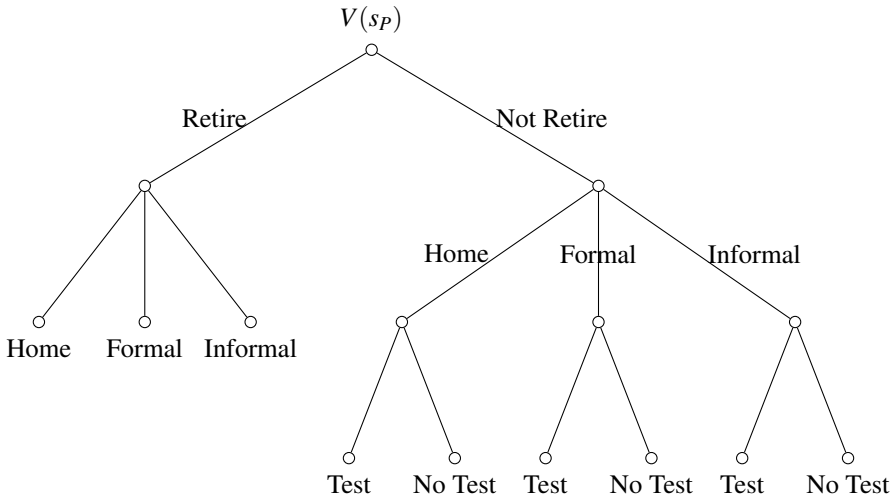
This appendix contains the timeline of the representative agent (Figure A.1) and the decision tree summarizing the main sectoral choices of a private agent in the model (Figure A.2). First, they decide whether to enter the retirement sector. Then, they choose whether to work formally, informally, or stay home. Lastly, for those agents who are not yet retired, they decide whether to take the public exam or not. Taking the public exam entails a time cost, discounted from hours of work or leisure.

Figure A.1: Timeline of a Representative Agent.



Notes: Timeline from birth to death of a representative agent. The three main economic states are the private sector, the government sector, and retirement. Transitions between states are endogenous and have eligibility requirements. Private sector agents must pass the public exam to enter government, and retirement conditions must be met for agents to start collecting pensions (see Section 4 for more details).

Figure A.2: Decision Tree of Agents in the Private Sector



Notes: This diagram depicts all possible discrete choices a private agent has within a period in our model.

Appendix B Agents' Stationary Distribution

In this appendix, we formally derive the stationary distribution for the agents in the economy. Given the assumptions on the entrants detailed in the main text, we have:

$$\mu_P(s_P) = \begin{cases} \varphi_1 \bar{\Gamma}(z), \text{ if } s_p = (1,0,z,0,0) \\ 0, \text{ for all other } s_p = (1,a,z,x,t_C)\} \end{cases}$$

and $\mu_m(s_m) = 0$ for all other sectors $m = \{R,G\}$ at $j = 1$, where $\bar{\Gamma}$ represents the stationary distribution for the Markov process $\{z\}$. We now detail the construction of the measures of agents in all sectors when $j > 1$.

The measure of each private agent in the economy, (j,a',z',x',t'_C), can be written as the sum of two terms. The first one considers the mass of all agents in the private sector who voluntarily remained there. The second term considers the private workers who applied to the public sector and failed to get in. Both terms take into account the measure $\mu_P(j-1,a,z,x,t_C)$. Within each term, we consider the transition probability of the idiosyncratic productivity, the optimal amount saved by the agents, the updated average past earnings and updated time of contribution conditional on optimal labor and informality choices, retirement decisions, the public sector application decision, and the probability of succeeding in the public sector exam.

The distribution for the formal private sector workers across ages $j = \{2,...,J\}$ is recursively given by:

$$\mu_P(j,a',z',x',t'_C) = \frac{\psi_{j-1}}{1+g_n} \cdot \Bigg\{ \sum_{s_P|j-1} \Pi(z,z') \mathbb{I}_{\{d^a(s_P)=a'\}} \mathbb{I}_{\{\tilde{x}'=x'\}} \mathbb{I}_{\{\tilde{t}'_C=t'_C\}} (1-d^p(s_P))(1-d^r(s_P)) \cdot \mu_P(s_P) + \sum_{s_P|j-1} \Pi(z,z') \mathbb{I}_{\{d^a(s_P)=a'\}} \mathbb{I}_{\{\tilde{x}'=x'\}} \mathbb{I}_{\{\tilde{t}'_C=t'_C\}} d^p(s_P)(1-q_p) \cdot \mu_P(s_P) \Bigg\}$$

where the updated average past earnings and length of contribution to the social security system can be written as a function of the optimal labor decision $d^h(s_P)$, informality decision $d^i(s_P)$ and application to the public sector decision, $d^p(s_P)$:

$$(\tilde{x}',\tilde{t}'_C) = \begin{cases} \left(\frac{x(t_C-2)+min\{y_{j-1}(w_f,P),y_{\max}\}}{t_C-1}, t_C+1 \right) & \text{if works formally} \\ (x,t_C) & \text{otherwise} \end{cases}$$

The distribution of the public servants has two components. The first one takes into account the private workers who took the test and succeeded. The second considers the decision of public workers who did not ask for retirement:

$$\mu_G(j,a',z',t'_C,t'_G) = \frac{\psi_{j-1}}{1+g_n} \cdot \Bigg\{ \sum_{s_P|j-1} \mathbb{I}_{\{z=z'\}} \mathbb{I}_{\{d^a(s_P)=a'\}} \mathbb{I}_{\{\tilde{x}'=x'\}} \mathbb{I}_{\{\tilde{t}'_C=t'_C\}} d^p(s_P) q_p \cdot \mu_P(s_P) + \sum_{s_G|j-1} \mathbb{I}_{\{z=z'\}} \mathbb{I}_{\{d^a(s_G)=a'\}} \mathbb{I}_{\{t_C+1=t'_C\}} \mathbb{I}_{\{t_G+1=t'_G\}} (1-d^r(s_G)) \cdot \mu_G(s_G) \Bigg\}$$

where $\tilde{x}'$ and $\tilde{t}'_C$ have the same definition as before.

The distribution of the retirees is also composed of two parts. First, we have agents who

have already retired from the labor force. Second, we account for the ones who recently asked for retirement:[43]

$$\mu_{RP}(j,a',z',b') = \frac{\psi_{j-1}}{1+g_n} \cdot \left\{ \sum_{s_R|j-1} \Pi(z,z') \mathbb{I}_{\{d^a(s_R)=a'\}} \mathbb{I}_{\{b'=b\}} \cdot \mu_{RP}(s_R) + \sum_{s_P|j-1} \alpha_b \cdot \Pi(z,z') \mathbb{I}_{\{d^a(s_P)=a'\}} d^r(s_P) \cdot \mu_P(s_P) \right\}$$

where α_b is the interpolation coefficient of the function $b(\cdot)$ on the grid $\mathscr{B}$. A similar equation applies to compute the distribution of the retirees in the public sector; therefore, we will omit it, for brevity.

Appendix C Defining the Stationary Competitive Equilibrium

In this appendix, we define the recursive stationary equilibrium of the model. A *recursive competitive equilibrium* consists of value functions $V : S_m \to \mathbb{R}$ for all $m \in \{P,G,R\}$, policy functions: (i) $d^h : S_m \to \{0,H\}$, for the optimal labor decision for all $m \in \{P,G,R\}$; (ii) asset holdings $d^a : S_m \to \mathbb{R}_+$ for all $m \in \{P,G,R\}$; (iii) consumption $d^c : S_m \to \mathbb{R}_{++}$ for all $m \in \{P,G,R\}$; (iv) $d^r : S_m \to \{0,1\}$ retirement decisions for $m \in \{P,G\}$; (v) $d^i : S_m \to \{0,1\}$, $m \in \{P,R\}$ for the optimal decision of working for the informal sector; (vi) $d^p : S_P \to \{0,1\}$ for the optimal decision of application to the public sector; competitive prices $\{r, w_f, w_i\}$, age dependent but time invariant measures of agents $\mu_m(s_m)$, government transfers ζ, taxes, an amount of public good, Y_G, and a threshold score $\bar{q}$ such that:

(1) The value and policy functions solve the problem of the agents;

(2) Formal private firms maximize profits given $\{r, w_f\}$ and informal wages are given by $w_i = A_i$;

(3) The individual and aggregate behavior are consistent:

$$K' = \sum_{m\in\{P,G,R\}} \sum_{s_m} d^a(s_m)\mu_m(s_m)$$

$$K = \frac{K'}{1+g_n}$$

$$N_f = \sum_{m\in\{P,R\}} \sum_{s_m} e^{z+\eta_j}(1-d^i(s_m))d^h(s_m)\mu_m(s_m)$$

$$N_i = \sum_{m\in\{P,R\}} \sum_{s_m} e^{z+\eta_j} d^i(s_m)d^h(s_m)\mu_m(s_m)$$

[43] When solving the model, we divide the retirees between private (*RP*) and public (*RG*) retirees. The stationary distributions of the retirees are similar, therefore, we will only derive for *RP*.

(4) The government chooses $\bar{q}$ in order to balance people coming in and out:

$$\bar{N}_G = \sum_{s_G} \mu_G(s_G)$$

(5) Public goods' consistency:

$$Y_G = \sum_{s_G} \mu_G(s_G) e^{z_G + \eta_j} \cdot H$$

(6) Final good market clears:

$$\sum_{m \in \{P,G,R\}} \sum_{s_m} d^c(s_m)\mu_m(s_m) + K' + C_g = Y_f + Y_i + (1-\delta)K$$

(7) τ_C balances the government budget constraint:

$$\begin{aligned}
&\sum_{m,s_m} \tau_C \cdot d^c(s_m)\mu_s(s_m) + \sum_{m,s_m} \tau_K \cdot d^a(s_m)\mu_s(s_m) + (\tau_y(P) + \tau_w) w_f N_f + \\
&\tau_{ss}(P) \sum_{s_P} (1 - d^i(s_P)) \min\{w_f e^{z+\eta_j} \cdot d^h(s_P), y_{max}\} \mu_P(s_P) = \\
&\sum_{s_G} (1 - \tau_y(G) - \tau_{ss}(G))(1+\theta) w_f e^{z_G+\eta_j} \cdot H \mu_G(s_G) + \sum_{s_R} (1-\tau_b) b \cdot \mu_R(s_R) + C_g
\end{aligned}$$

(8) Bequests are rebated to the living ones:

$$\zeta = \frac{1+r}{1+g_n} \sum_{m,s_m} d^a(s_m)(1-\psi_j)\mu_m(s_m)$$

Appendix D Computing the Stationary Competitive Equilibrium

In this appendix, we detail the computational methods used to quantitatively assess the macroeconomic consequences of social security reforms. We numerically solved the model in Fortran 90. To do so, we discretized the asset space, the average past earnings space, the income process space, and the social security benefits space. We did so in 52, 10, 5, and 42 points, respectively.

The grid on assets goes from $R\$0$ to $R\$3,790,202$, with its points concentrated over the lower bound.[44] The grid for x is equally spaced between 0 and y_{max}. The grid for b is linearly spaced between[45] $R\$0$ and $R\$100,000$. The algorithm to find the general equilibrium was an adaptation from the algorithm commonly used in the literature,[46] including a fixed point over $\bar{q}$ to match $\bar{N_G}$. The steps used to compute the stationary equilibrium are:

[44] We chose the upper bound as the smallest value such that no agent in any state chooses optimally this upper bound. The concentration in the grid follows a cubic polynomial.

[45] We chose a value for the upper bound large enough such that more than 99% of the benefits distributed in equilibrium are lower than that value.

[46] See Chen (2010) for an example.

1. Guess initial values for $\Theta \equiv (r, Y_G, \zeta, \tau_c, \bar{q})$;
2. Use the formal firm first-order conditions to obtain w_f ;
3. Solve the agents' problems backwards and find the respective policy functions;
4. Use the policy functions to compute the associated stationary distribution of households by forward induction;
5. Aggregate the individual decisions and find $\tilde{\bar{q}}$ such that $\bar{N}_G$ of the population is working as public servants;
6. Use individual decisions to calculate the implicit remaining variables $\tilde{\Theta} \equiv (\tilde{r}, \tilde{Y}_G, \tilde{\zeta}, \tilde{\tau}_c)$;
7. Check whether $||\tilde{\Theta} - \Theta|| < \varepsilon$. If not, update Θ, return to item 2 and iterate until convergence.

Appendix E Transition Dynamics

In this appendix, we lay out the algorithm to calculate the transition dynamics between two steady states. We assume the economy starts in the no-reform 2060 steady state at $t = 1$. We also assume that the transition to the new steady state with the benchmark reforms will take place in $T = 80$ years. The reforms are unexpectedly introduced and agents are presumed to fully anticipate its effects after the announcement, adjusting their expectations and decisions accordingly.

The algorithm to calculate the transition path between steady states is described below. We use it to find transition values for the policy functions, value functions, and distribution of agents, respectively denoted by $d(s,t)$, $V(s,t)$ and $\mu(s,t)$ for all state variables s and transition period t.

1. Guess a path for equilibrium variables $\{r_t^0, w_t^0, \bar{q}_t^0, tr_t^0, \tau_t^{c,0}\}$ for all $t = 1, ..., T$
2. Assume that agents arrive in the new steady state at $t = T$: $V(s,T) = V^{\text{New}}(s)$ where $V^{\text{new}}(s)$ represents the value function in the steady state *with* the benchmark reforms
3. Backward calculation of the value functions described in Section 3 from $t = T-1, ..., 1$. These are summarized by the following operation:

$$V(s,t) = \max\{u(c,l) + \beta\psi\mathbb{E}[V(s',t+1)]\}$$

4. Save respective policy functions along the transition path $t = 1, ..., T$: $d(s,t)$
5. Assume that the initial distribution of agents is the one in the steady state *without* the reforms: $\mu(s,1) = \mu^{\text{old}}(s)$
6. Calculate the model-implied distribution of agents for all $t = 2, ..., T$ using the policy functions following Appendix B. This is summarized by the following operation:

$$\mu(s',t) = \sum_s d(s \to s', t-1) \cdot \mu(s, t-1)$$

7. Use the distribution of agents along the transition to calculate model-implied equilibrium variables for all $t = 1, ..., T$:

   - $\{r_t^1, w_t^1, tr_t^1, \tau_t^{c,1}\}$ are obtained via aggregating individual decisions with respective masses
   - We assume $\bar{q}_t^1$ converges to the new steady state $\bar{q}^{new}$ and allow for the size of the public sector to vary along the transition path

8. Update equilibrium variables and iterate steps 2-7 until convergence

Appendix F Data Sources

This appendix presents the data sources used in the paper. At the aggregate level, we draw on data from the 2013 Brazilian National Accounts to calculate the share of GDP consumed by the government; the 2013 Social Security Annual Report to estimate the social security deficit and public versus private retirement statistics; and the 2013 IBGE mortality tables to obtain survival probabilities.

At the micro level, we use two data sets provided by the IBGE. The first is the 2013 PNAD, a cross-sectional household survey that is representative at the national level. We use this dataset to calculate the distribution of agents across the three main sectors in the model (private, public, and retirees) as well as the distributions of economic participation, test takers, and statistics on retirees by age.

The second data set, used for estimating the income process, the age-efficiency profile, and the public sector wage premium, is the 2012-2018 PNADC. This survey is a quarterly rotating panel with information on labor market outcomes for a nationally representative sample. Its main goal is to produce indicators that monitor quarterly fluctuations in the workforce. The survey follows a rotation scheme in which each household is visited five times over five consecutive quarters, allowing us to construct a one-year panel of individuals.

Even though they are similar, the PNAD has better information on both demographics and individuals out of the labor force, as the main purpose of the PNADC is to generate labor force statistics. In both data sets we focus the analysis on men between 16 and 75 years old.[47] We define an informal worker as a worker who does not have a legal working contract (*carteira de trabalho*), hence is not covered by the social security system and does not pay income taxes. A government agent is a statutory government employee, as these are subject to the segregated retirement scheme.[48]

Appendix G Additional Figures and Tables

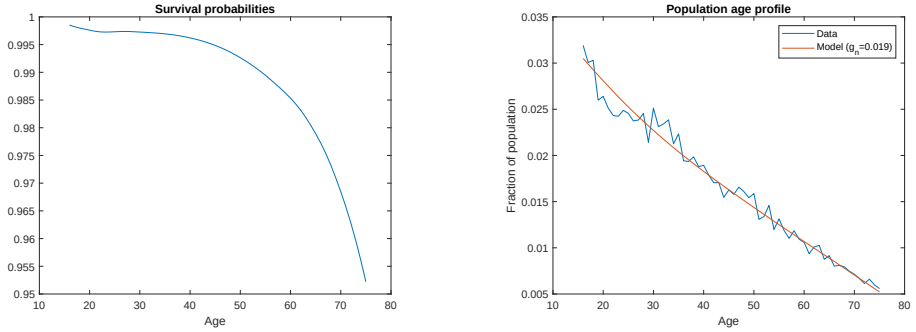
This appendix contains additional figures and tables referenced in the main text.

[47] We do so for simplicity, to refrain from modeling household-level choices (e.g., fertility decisions) that could impact both labor force participation and retirement decisions.

[48] Politicians, Central Bank workers, and admin/clerical jobs in the government are examples of statutory workers. Public enterprises' employees are not considered statutory public servants.

G.1 Calibration

Figure G.1: Calibrated Survival Probabilities and Age Profile



Notes: This figure shows the survival probabilities (left) and the population age profile (right), comparing the model-implied profile (red) with the data (blue). The population age profile is normalized to 1. Sources: 2013 IBGE Mortality Tables and 2013 PNAD.

Table G.1: Internal calibration

Parameter	Target	Model	Data
$\beta = 0.96$	K/Y	2.4	2.5
$\gamma = 0.248$	Participation Rate	73%	72.3%
$A_f = 2.194$	GDP per capita	R$ 27,468	R$ 26,520
$A_i = 3.03$	Informal sector size	19.5%	18.9%
$\alpha_0^p = 266$			
$\alpha_1^p = -80$	Test takers age profile	(Figure 5)	
$\alpha_2^p = 6$			
$\tau_w = 0.085$	Private SS deficit/GDP	0.8%	0.9%

Notes: This table shows the internal calibration results. The participation rate is calculated out of the total population. The informal sector is calculated out of the total employed population. The numerical implementation of the model is discussed in Appendix D.

Table G.2: External calibration

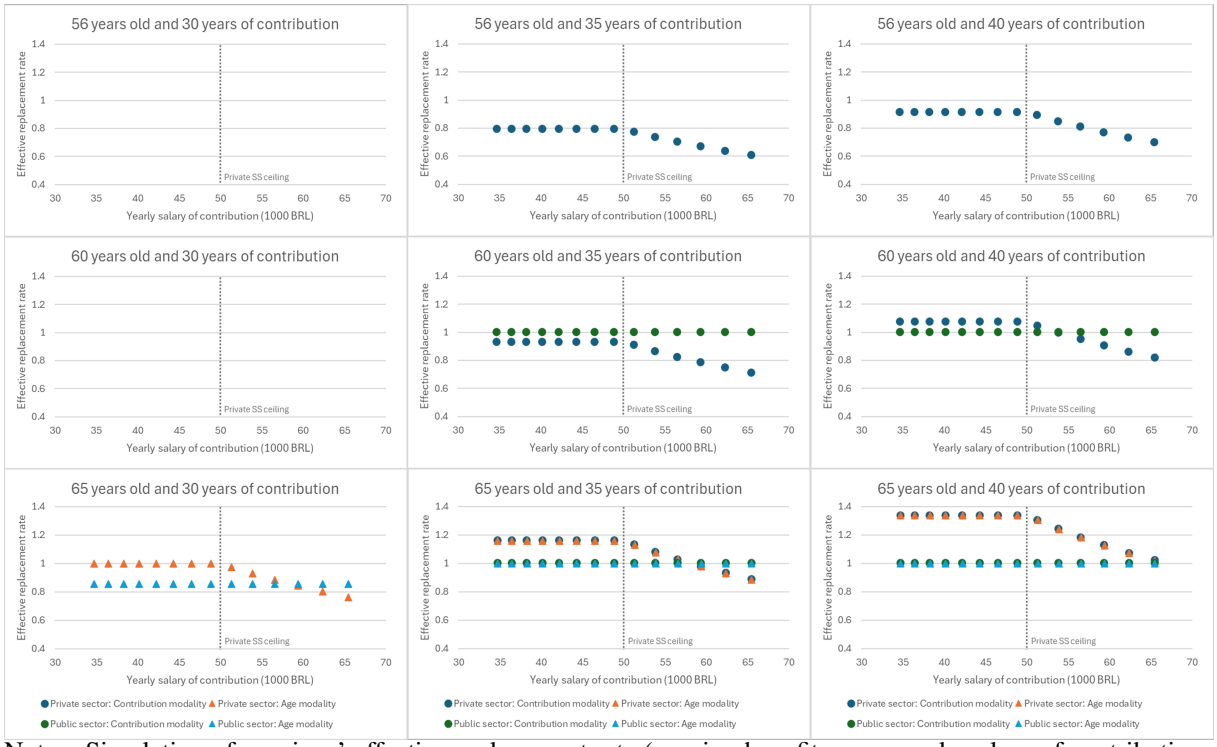
Parameter	Description	Value	Source
J	Maximum age	60	Agents live from 16-75
$\{\psi_j\}$	Survival probabilities	Figure G.1	IBGE
g_n	Population growth rate	1.9%	IBGE
$\bar{H}$	Time endowment	8,760 hours	24 hours/day x 365 days/year
H	Working hours	2,016 hours	8 hours/day x 52 weeks/year
σ	Risk aversion	2.5	Attanasio (1999)
ε	Public good coef.	0.5	Ferreira and Nascimento (2005)
α	Capital share in output	0.4	Standard value
δ	Depreciation rate	0.06	Parente and Prescott (2002)
$\mathscr{Z}$	Productivity space	Table G.4	PNADC
$\Pi(z,z')$	Transition probabilities	Table G.4	PNADC
$\{\eta_j\}$	Age-efficiency profile	Figure G.2	PNADC
θ	Public sector wage premium	9.8%	PNADC
$b(.)$	Benefits function	Section 4.4	2013 rules
$\tau_y(P)$	Private sector's income tax	18%	Literature
$\tau_y(G)$	Public sector's income tax	9%	$\tau_y(P)$−FGTS/union contrib
τ_k	Capital tax	15.5%	Literature
$\tau_{SS}(G)$	G worker SS contribution	11%	2013 tax rates
$\tau_{SS}(P)$	P worker SS contribution	Equation (22)	2013 tax rates
τ_b	G retiree benefit tax	11%	2013 tax rates
α_G	$\frac{\text{Govt. Consumpt.}}{\text{GDP}}$	18.9%	National Accounts
$\bar{N}_G$	Size of the government	5%	2005-2013 PNAD
y_{max}	Private SS ceiling	R$ 50,000	2013 rules

Notes: This table summarizes the externally calibrated parameters, discussed throughout Section 4.

Figure G.2: Estimated age-efficiency profile

Notes: This figure plots the age-efficiency profile, $\hat{\alpha}_1^{\eta} j + \hat{\alpha}_2^{\eta} j^2$, implied by the age coefficients estimated in column (4), Table G.3. Sources: 2012-2018 PNADC.

Figure G.3: Pension benefits



Notes: Simulation of pensions' effective replacement rate (pension benefits over yearly salary of contribution; y-axis) as a function of retirement age (rows), years of contribution (columns), and yearly salary of contribution (x-axis). Dark-blue dots represent private retirement under the contribution modality, orange triangles represent private retirement under the age modality, green dots represent public retirement under the contribution modality, and light-blue triangles denote public retirement under the age modality.

Table G.3: Estimation of the income process variables

	(1)	(2)	(3)	(4)
Public servant		0.169*	0.094*	0.090*
		(0.004)	(0.005)	(0.006)
Informal worker		-0.188*	-0.056*	-0.053*
		(0.002)	(0.002)	(0.003)
Age	0.061*	0.032*	0.031*	0.029*
	(0.000)	(0.000)	(0.001)	(0.003)
Age^2	-0.00063*	-0.00028*	-0.00033*	-0.00031*
	(0.000)	(0.000)	(0.000)	(0.000)
Individual FE			✓	✓
Controls		✓	✓	✓
Time FE	✓	✓	✓	✓
Sample	Private	All	All	25-55
N	1,832,912	2,053,458	1,773,520	1,270,749
R^2	0.196	0.615	0.899	0.898

Notes: This table shows the main coefficients of Regression (16). We use the PNADC data from 2012q1-2018q4, focusing on men between 16 and 75 years old. Column (1) focuses on individuals in the private sector, columns (2) and (3) consider the whole sample, and column (4) restricts the sample to individuals aged 25-55 years old. Control variables are: tenure, race (when there are no individual fixed effects), occupation, sector, and education fixed effects. Robust standard errors in parentheses. $*p < 0.001$.

Table G.4: Idiosyncratic productivity process

Transition matrix: $\Pi(z,z')$		z_1	z_2	z_3	z_4	z_5
	z_1	0.659	0.220	0.089	0.029	0.003
	z_2	0.220	0.473	0.233	0.070	0.004
	z_3	0.082	0.246	0.479	0.183	0.009
	z_4	0.038	0.090	0.248	0.573	0.051
	z_5	0.022	0.030	0.055	0.252	0.642
State space: $\mathscr{Z}$		-0.715	-0.249	0.074	0.548	1.542

Notes: This table shows the results for the estimation of the idiosyncratic labor income process. The first five rows display transition probabilities between every two periods. Rows represent productivities at t and columns at $t+1$. The last row shows the elements in the discretized state space.

Table G.5: Summary of Pension Rules: Private vs. Public Sector

Feature	**Private Sector**	**Public Sector**
Retirement Modalities	Age (65+ and 15 years of contributions), Contribution (35 years of contributions)	Age (65+), Contribution (60+ and 35 years of contributions)
Benefit Base	Average past earnings (capped at social security ceiling)	Last wage (based on 80% highest wages, uncapped)
Replacement Rate	Depends on retirement age, contribution history, and social security factor	100% of last wage (Contribution modality); Proportional to years of service (Age modality)
Contribution Rates	8–11% of labor income (progressive, up to ceiling)	Flat 11% of income
Pension Taxation	No tax on benefits	11% tax on pension amounts exceeding private ceiling
Mandatory Retirement	No mandatory retirement age	Mandatory retirement at age 70
Minimum Pension	Minimum wage for low-income elderly	Not applicable

G.2 Sectoral changes

Table G.6: Sectoral changes in response to baseline social security reforms

↓ Old SS \ New SS →	Formal	Informal	Home	Public exam
Formal	38.2%	1.22%	3.81%	0.06%
Informal	7.62%	5.07%	0.13%	0.00%
Home	1.45%	0.00%	37.0%	0.00%
Public exam	0.14%	0.00%	0.00%	0.34%
Total in new SS	47.4%	6.29%	40.9%	0.39%

Notes: This table shows the change in the distribution of private sector agents between the old (rows) and new (rows) steady states. The last row depicts the share of the population in the new steady state in each sectoral choice. Old steady state denotes the 2060 demography with no reforms. The new steady state denotes the 2060 demography with benchmark reforms.

Appendix H Robustness checks

In this section, we present a series of robustness checks that provide a detailed analysis of the effects of social security reforms under different scenarios.

Table H.7 compares two scenarios: one where only the ceiling on public sector pension benefits is adjusted (main counterfactual), and another where the public and private sector pension systems are fully aligned. The results, displayed in Table H.7, show that the imposition of a cap on public pensions is quantitatively the most important component to be tackled in counterfactual pension reforms, hence the focus of our paper.

Table H.8 explores the robustness of our findings by testing an alternative utility function. Indeed, we recalibrated the model with a utility function separable in consumption and leisure as in McGrattan and Prescott (2017): $u(c,l) = log(c) + \sigma log(\bar{L} - l)$. We set $\sigma = 3.185$ to match the baseline 2013 participation rate. Table H.8 shows that the effects of the benchmark reforms on the macroeconomy are qualitatively similar.

In Table H.9, we look at the difference between partial and general equilibrium effects of the social security reforms. This distinction helps us understand not only the direct impact of the reforms but also how the entire economy adjusts in response, offering a more complete picture of their implications. Without the positive impact on the wage rate, informality would increase significantly rather than decline, leading to a larger deficit than the full exercise. Therefore, accounting for the effects of the informal sector and general equilibrium movements in factor prices is essential to fully understand the implications of this reform.

Finally, Table H.10 provides a robustness check under an alternative demographic scenario for 2060, where we adjust survival probabilities and population growth rates. We first plug in the IBGE projected survival probabilities for 2060, then we adjust the growth rate to match the age profile of Brazil in 2060. This results in an alternative calibrated 2060 growth rate of -0.0089. The effects of the benchmark reforms are quantitatively and qualitatively similar to those of the baseline analysis.

Table H.7: Full alignment of public and private sector pension systems

	Both reforms	
	Only the ceiling	**Full alignment**
SS deficit/GDP (%)	10.2	10.3
Public SS deficit/GDP (%)	1.40	1.45
Private SS deficit/GDP (%)	8.9	8.9
Consumption tax (%)	45.4	45.6
Avg. Consumption (C)	1.95	1.95
Avg. Capital (K)	7.88	7.87
Avg. Output (Y)	2.83	2.83
K/Y	2.8	2.8
Participation rate (%)	58.7	58.7
Fraction of retirees (%)	18.7	18.9
Informality (%)	6.3	6.3
Public sector applicants (%)	0.39	0.40

Notes: This table shows the effects of both social security reforms considering only the ceiling on the benefits of public employees (Only the ceiling) and a reform in the public sector that considers a full alignment with the private sector (Full alignment). Avg. Consumption (C), Avg. Capital (K), and Avg. Output (Y) are expressed in 10,000 Brazilian reais (BRL) at 2013 prices. Participation rate and fraction of retirees are out of the total population. Informality is calculated out of the total workforce.

Table H.8: Robustness check: Alternative utility function

	Benchmark utility		New utility	
	w/o reform	**Both Reforms**	**w/o reform**	**Both Reforms**
SS deficit/GDP (%)	16.6	10.2	17.0	9.9
Public SS deficit/GDP (%)	5.2	1.4	5.2	1.3
Private SS deficit/GDP (%)	11.5	8.9	11.8	8.6
Consumption tax (%)	54.6	45.4	56.6	46.2
Avg. Consumption (C)	1.90	1.95	1.96	2.00
Avg. Capital (K)	7.22	7.88	8.41	9.12
Avg. Output (Y)	2.73	2.83	2.91	3.00
K/Y	2.65	2.78	2.9	3.05
Participation rate (%)	60.0	58.7	59.0	55.9
Fraction of retirees (%)	31.5	18.7	33.2	18.7
Informality (%)	7.1	6.3	0.8	0.1
Public sector applicants (%)	0.5	0.4	0.6	0.5
Interest rate (%)	8.5	7.6	7.8	7.1
Wage	4.03	4.19	4.17	4.30

Notes: This table shows the effects of both social security reforms considering preferences that are separable in consumption and leisure as in McGrattan and Prescott (2017). Avg. Consumption (C), Avg. Capital (K), and Avg. Output (Y) are expressed in 10,000 Brazilian reais (BRL) at 2013 prices. Participation rate and fraction of retirees are out of the total population. Informality is calculated out of the total workforce.

Table H.9: Disentangling partial and general equilibrium effects

	Both reforms	
	G.E. effects	**Partial Equilibrium**
SS deficit/GDP (%)	10.2	12.0
Public SS deficit/GDP (%)	1.4	1.3
Private SS deficit/GDP (%)	8.9	10.7
Consumption tax (%)	45.4	54.6
Avg. Consumption (C)	1.95	1.85
Avg. Capital (K)	7.88	7.22
Avg. Output (Y)	2.83	2.80
K/Y	2.78	2.58
Participation rate (%)	58.7	57.6
Fraction of retirees (%)	18.7	18.7
Informality (%)	6.3	25.7
Public sector applicants (%)	0.4	0.35
Interest rate (%)	7.6	8.47
Wage	4.19	4.03

Notes: This table shows the partial and general equilibrium effects of the benchmark social security reforms. Avg. Consumption (C), Avg. Capital (K), and Avg. Output (Y) are expressed in 10,000 Brazilian reais (BRL) at 2013 prices. Participation rate and fraction of retirees are out of the total population. Informality is calculated out of the total workforce.

Table H.10: Robustness check: Alternative demography

	2060 new demography		2060 main demography	
	w/o reforms	**Reforms**	**w/o reforms**	**Reforms**
SS deficit/GDP (%)	16.6	10.4	16.6	10.2
Public SS deficit/GDP (%)	5.2	1.4	5.2	1.4
Private SS deficit/GDP %)	11.4	9.0	11.5	8.9
Consumption tax (%)	55.5	46.5	54.6	45.4
Avg. Consumption (C)	1.91	1.95	1.90	1.95
Avg. Capital (K)	7.59	8.26	7.22	7.88
Avg. Output (Y)	2.80	2.91	2.73	2.83
K/Y	2.7	2.8	2.65	2.78
Participation rate (%)	60.8	59.3	60.0	58.7
Fraction of retirees (%)	33.1	18.9	31.5	18.7
Informality (%)	5.0	4.4	7.1	6.3
Public sector applicants (%)	0.48	0.41	0.46	0.39

Notes: This table shows the effects of social security reform considering an alternative demography, where we change both the survival probabilities and the population growth rate. Namely, we first plug in the IBGE projected survival probabilities for 2060, then we adjust the growth rate to match the age profile of Brazil in 2060. This results in an alternative calibrated 2060 growth rate of -0.0089. Changing the survival probabilities alone while keeping the population growth rate constant at their 2013 calibrated levels cannot replicate the 2060 demographic profile from IBGE. Avg. Consumption (C), Avg. Capital (K), and Avg. Output (Y) are expressed in 10,000 Brazilian reais (BRL) at 2013 prices.