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Abstract

This paper solves and estimates a stochastic model of optimal inter-temporal behavior to assess how changes in the design of the income protection and pension systems in Brazil could affect savings rates, the share of time that individuals spend outside of the formal sector, and retirement decisions. Dynamics depend on five main parameters: preferences regarding consumption and leisure, preferences regarding formal Vs. informal work, attitudes towards risks, the rate of time preference, and the distributions of two exogenous shocks that affect movements in and out of the social security system (independently of individual decisions). The yearly household survey is used to create a pseudo panel by age-cohorts and estimate the joint distribution of model parameters based on a generalized version of the Gibbs sampler. The model does a good job in replicating the distribution of the members of the cohort across states (in or out of the social security / active or retired). Because the parameters are related to individual preferences or exogenous shocks, the joint distribution is unlikely to change when the social insurance system changes. Thus, the model is used to explore how alternative policy interventions could affect behaviors and through this channel benefit levels and fiscal costs. The results from various simulations provide three main insights: (i) the Brazilian SI system today might generate unnecessary distortions (lower savings rates, less formal employment, and more early retirement) that increase the costs of the system and might generate regressive redistribution; (ii) there are important interactions between the income protection and pension systems, which calls for joint policy analysis when considering reforms; and (iii) current distortions could be reduced by creating an actuarial link between contributions and benefits and then giving matching contributions or matching capital to individuals with limited savings capacity, which requires having individual savings accounts that can be funded or notional.

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1. INTRODUCTION

Social insurance policies affect individual behaviors and can have non-trivial effects on labor markets (see Krueger and Mayer, 2002). The existence of mandatory pensions, for instance, affects retirement decisions. Often, benefit formulas and eligibility conditions in defined benefit plans induce early withdrawal form the labor force, which increases the cost of the pension system and can reduce human capital (see, for instance, Bodor et al. 2008; Blundell et al. 2002; Anderson et al. 1999; Gruber and Wise, 1998; Samwick, 1998; Lumsdain and Wise, 1994; and Fields and Mitchel, 1988). Unemployment insurance can also affect incentives to search for jobs, which can lead to longer spells and/or better matching (see Calmfors and Holmlund, 2000). In general, there is a positive correlation between the level of the benefit, its duration, and the length of the spell (see, for instance, Layard et al., 2006; Card and Levine, 2000; Anderson and Mayer, 1993; and Mayer 1991). Even funded mandatory unemployment savings accounts, under some circumstances, can have unintended consequences and induce more frequent separations and higher turn-over (see Vodopivec, 2004).

The standard analysis of the economic impacts of policy changes in the social insurance system, however, generally ignores these effects or simply makes assumptions about possible behavioral changes. One reason is that there are no econometric models linking the complex set of rules of a given system (say pensions) to behaviors (usually there is no enough variation in system parameters to estimate these models). The econometric models that we have, in general, tell us how the *presence* of the system affects a certain behavior but not what would happen if the rules of the system change – particularly if one is interest about interactions between systems. One can always recur to pilot ex-post impact evaluations to understand how a given change in policy would affect behaviors and ultimately welfare. But these exercises are costly and not very suitable to assess *possible scenarios* for reform. In this case, we argue, a second best is to rely on a behavioral model derived from first principles, try to estimate the joint distribution of parameters to maximize the likelihood that the model is consistent with available data, and then conduct simulations of the potential impacts of alternative policy interventions across the joint distribution.

This paper develops such a model and applies it to analyze the impact of pensions and income protection policies in Brazil, where the government is considering reforms in pensions and income protection systems to deal, in part, with incentive problems. The country spends around 12 percent of GDP in social insurance programs. The largest share (55 percent) goes to mandatory contributory pensions for private sector workers (RGPS), the unemployment insurance system (*Seguro Desemprego*), and mandatory unemployment individual savings accounts (FGTS). It has been shown that these programs, in addition to be fiscally unsustainable, provide incentives for retirement over work (see, for instance, Queiroz, 2005 and 2007; and Carvalho, 2002), encourage sparse contribution densities, and increase turn over (see Barros et al., 1999; Gonzaga, 2003; and World Bank 2002). Moreover, the complexity of the rules opens the door to abuse and makes redistribution highly non transparent and sometime regressive.

The model used here to analyze incentives is based on the classic inter-temporal utility maximization framework. Representative members of an age-sex cohort make decisions about savings, the level effort invested in finding and keeping formal sector jobs, and when to retire, taking into account the rules of the pensions and income protection systems. In our application to Brazil, these rules are quite complex. Thus, we solve the model using a dynamic programming algorithm. We also *sample* the joint distribution of the parameters that determine individual behaviors in order to reproduce the empirical distribution of the 1990 cohort for 25 years old males across three states: contributing to the social security; outside of the social security (i.e., informal sector); or retired. Given the joint distribution of model parameters it is then possible to explore a large number of possible behavioral responses to policy changes. Moreover, because all but one of the parameters of the model represent individual preferences, their joint distribution is unlikely to change when policy changes.

In this paper we use the model first to better understand the magnitude of the incentive problems that the social insurance system might be creating and the relative effect of each program. We then explore how the move to simple actuarially fair benefit formulas that attempt to be incentive neutral (see Whitehouse, 2008) and that are coupled with explicit subsidies for low-income groups, could affect contribution densities, savings (assets), retirement decisions, and ultimately the cost of the programs. The analysis, of

course, ignores the general equilibrium effects of these policies. In particular, we hold constant the current tax-wedge, wages, and labor demand.

The paper is organized as follows. Section 2 introduces the Brazilian social insurance system and discusses some key stylized facts about labor market dynamics. Section 3 introduces the model and explains the methods used to solve the inter-temporal optimization problem and perform simulations. Section 4 presents the strategy used to sample the posterior joint distribution of model parameters and assess convergence. Section 5 discusses the results of various policy simulations.   Finally, Section 6 summarizes the main insights and limitations from the analysis.

2. THE BRAZILIAN SOCIAL INSURANCE SYSTEM AND LABOR MARKET DYNAMICS

The Brazilian social insurance system provides comprehensive coverage of standard risks through the National Social Security Institute (INSS) and the unemployment benefits programs managed by the Ministry of Labor through the *Caixa Econômica Federal* (CEF). The INSS covers private sector workers and provides old-age, disability and survivorship pensions (RGPS benefits), insurance for work accidents, various transfers related to maternity and sickness leave, as well as non-contributory transfers to the poor elderly and disabled. The CEF manages the unemployment insurance system and the Length of Service Guarantee Fund (FGTS); the latter is a mandatory system of funded unemployment individual savings accounts. The RGPS is financed by pay-roll taxes (20% for most employers) and social security contributions (7.65% to 11% depending on the income level)[1]. The FGTS also uses a pay-roll tax of 8% and in addition a dismissal fine of 40% of accumulated assets that are paid directly to employees. Unemployment insurance benefits, on the other hand, are financed by 40% of the proceeds of a 0.65 tax on gross revenues (case of the services sector) and a 1.65% tax on value added (case of the industry sector).

The RGPS is considerably complex; there are in fact three regimes that depend on the retirement age and the vesting period: (i) retirement based on a minimum age (53M/48W) and a minimum number of years of contributions (30M/25W) that pays a so

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[1] Since January 2008, because there is no more CPMF, the smallest contribution rate is 8%.

called Proportional Length of Contribution (PLOC) Pension ; (ii) retirement based on a number of years of contributions (35M/30W) and no minimum age that pays a full Length of Contribution (LOC) Pension; and (iii) retirement based on age (65M/60W) and a minimum number of years of contributions (15M/15W) that pays an Aging Pension. In all cases, the pension system guarantees a top-up so that the minimum pension (*Piso Previdenciário*) is equal to the minimum wage. Pensions are indexed by inflation. The resulting replacement rates for the median and the average full-career workers are presented in the top-left panel of Figure 1.[2]

For the median worker and those with incomes below the median the system provides strong incentives for early retirement. Hence, the "implicit tax" resulting from delaying retirement by one year after eligibility to a pension is around 50% of earnings (see top-right panel of Figure 1). At the same time, for the median worker, flat Net Expected Life-time Earnings indicate that the system provides week incentives to contribute beyond the minimum necessary to be eligible for a pension (see bottom left panel Figure 1). This is in part because of the high level of the minimum pension and the fact that it is offered as a top-up (there is 100% marginal tax on each $R increase the contributory pension). On the other hand, for workers earning the average or more, the system provides implicit subsidies if they delay retirement. As a result, there is a large variation in the internal rates of return (IRR) on contributions that workers receive as a function of career histories and wage dynamics (see bottom-right panel in Figure 1). This implies considerable redistribution that is non-transparent. Also, in the majority of cases, IRRs are above sustainable levels. The system is thus accumulating unfunded liabilities that cannot be repaid out of future contributions and will require intergenerational transfers that can be regressive (see Robalino and Bodor 2008 for a discussion of the sustainable IRR of pay-as-you-go systems).

In terms of income protection, formal sector workers who loose their jobs after a certain number of months of contributions become eligible for an unemployment insurance benefit and a lump sump payment from their individual savings accounts. To be eligible for unemployment insurance workers need to have held a formal sector job (*trabalho with carteira*) for at least 6 months in the previous 36 month period to the start

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[2] See Annex 1 for a description of benefit formulas for both pensions and UI – use mathematical formulas.

of the unemployment spell. The duration of the benefit ranges between 3 and 5 months depending on the contribution period. With 6 to 11 months workers receive 3 months of benefits, with 12 to 23 they receive 4 months, and with 24 to 36 they receive 5 months. The benefit itself depends on earnings and ranges between R$350 in 2006 (or around 40% of average earnings) and R$ 654, 85. At the same time, workers receive a lump sum equal to the balance accumulated in their FGTS accounts while working in their last job *plus* a dismissal fine equal to 40% of corresponding accumulated assets. As previously mentioned the accumulations are financed with an 8% contribution rate that over a 12 months period yields a capital more or less equal to one month of salary.

Figure 1: Replacement Rates, Incentives and Redistribution in the RGPS
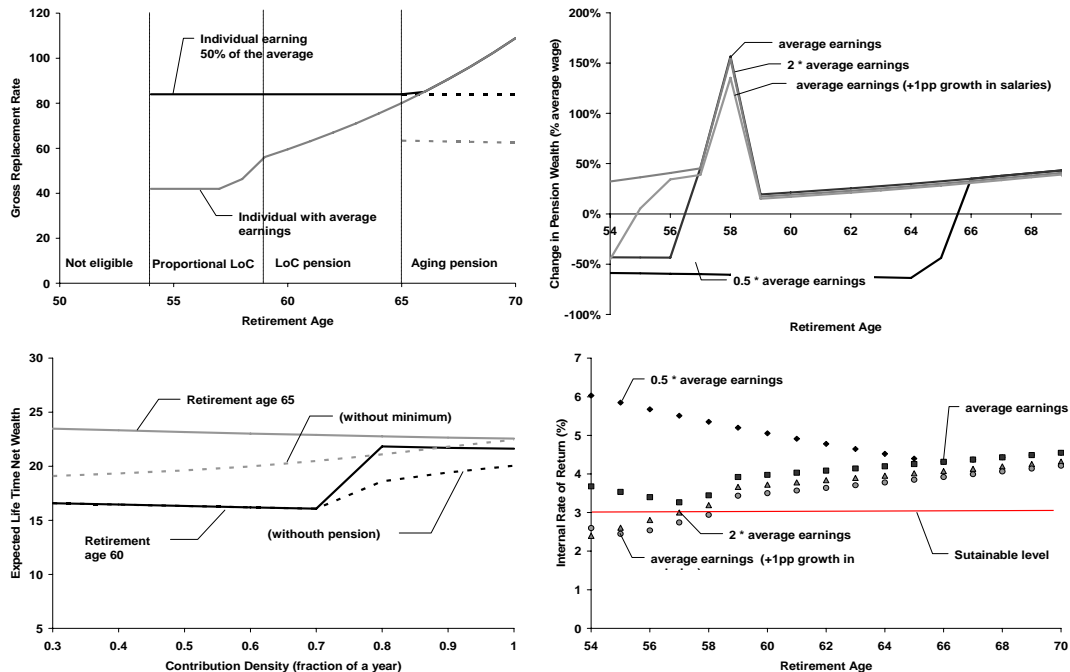
Source. Authors' calculations based on current legislation.

Overall, the replacement rates offered by the UI system range between 40 and 100 percent depending on the level of income. The benefit formula ensures that replacement rates are higher for low than for high income workers (see top-left panel of Figure 2). The duration of benefits is also higher for the median worker and below. Taking both UI and FGTS together, the median worker can finance between 3.5 and 8 months of salaries depending on the number of months of contributions (see top-right panel of Figure 2).

Still, redistribution within the system seems to be regressive as low income workers have lower take-up rates and lower average benefits (see bottom panels of Figure 2).

Figure 2: Mandate of the Income Protection System and Redistribution
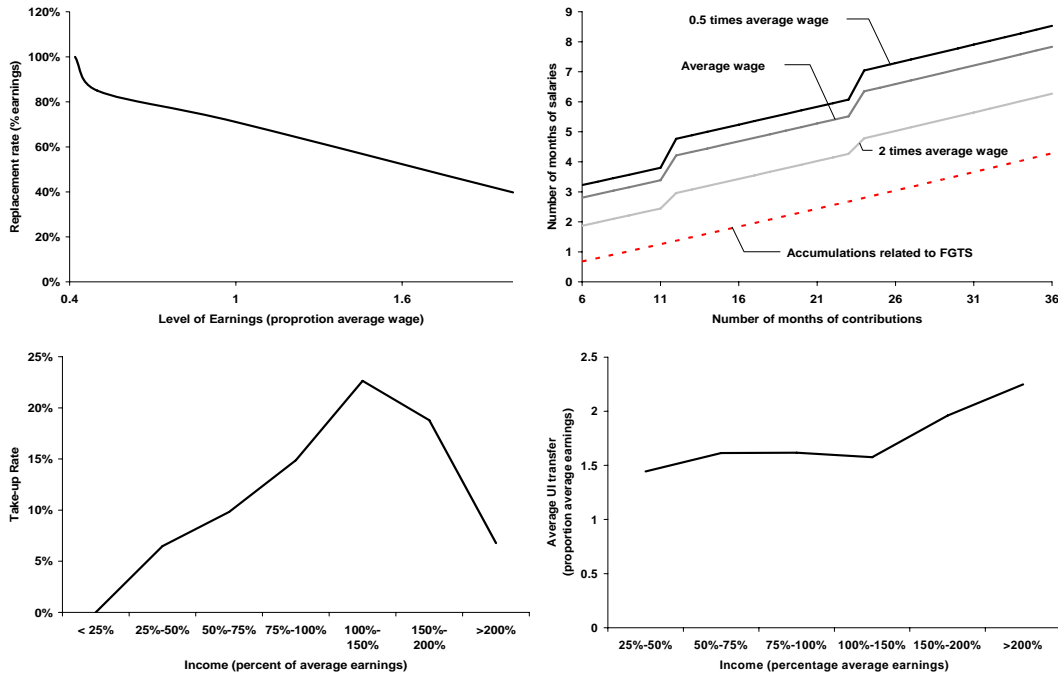
In terms of incentives the evidence is somewhat mixed. The most recent analysis suggests that UI does not have a major impact on the duration of unemployment spells and, if anything, it is allowing workers to find better jobs (Margolis, 2008). At the same time, there is evidence of considerable labor mobility in Brazil and the existence of a labor market that is not fully segmented. The average duration of formal sector jobs is around 4.5 years, while the duration of self-employment and informal sectors jobs is respectively 2.3 years and a little less than one year (see Bosh and Maloney, 2007). Around 46 percent of informal sector workers would transit to formal sector jobs in the course of the year; among individuals who leave formal sector jobs, around 30 percent would become wage earners in the informal sector and 16.7 percent self-employed (see Bosh and Maloney, 2007; and World Bank, 2002).[3] But the probabilities of re-entering

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[3] In Brazil informal sector jobs are mainly referred to jobs without social security coverage. Workers in the informal sector are thus workers *Sem Carteira,* a card that is issued by the Ministry of Labor.

formal sector jobs are lower than for informal sector jobs, particularly for low-income workers (see Figure 3). They also face higher unemployment risks, particularly in the informal sector.

High turnover is attributed in part to the FGTS as workers attempt to cash-out their unemployment savings accounts and/or employers prefer short-term contracts to avoid paying the dismissal fine (see Barros et al., 1999; and Gonzaga, 2003). Here we are more interested with the former phenomena that could take place if the rates of return on FGTS savings are consistently below market and if the mandate for precautionary savings is too high and/or there are credit constraints that impede dis-savings. In our model below we take into account the last two.

Figure 3: Probability of Exiting and Entering Formal and Informal Employment
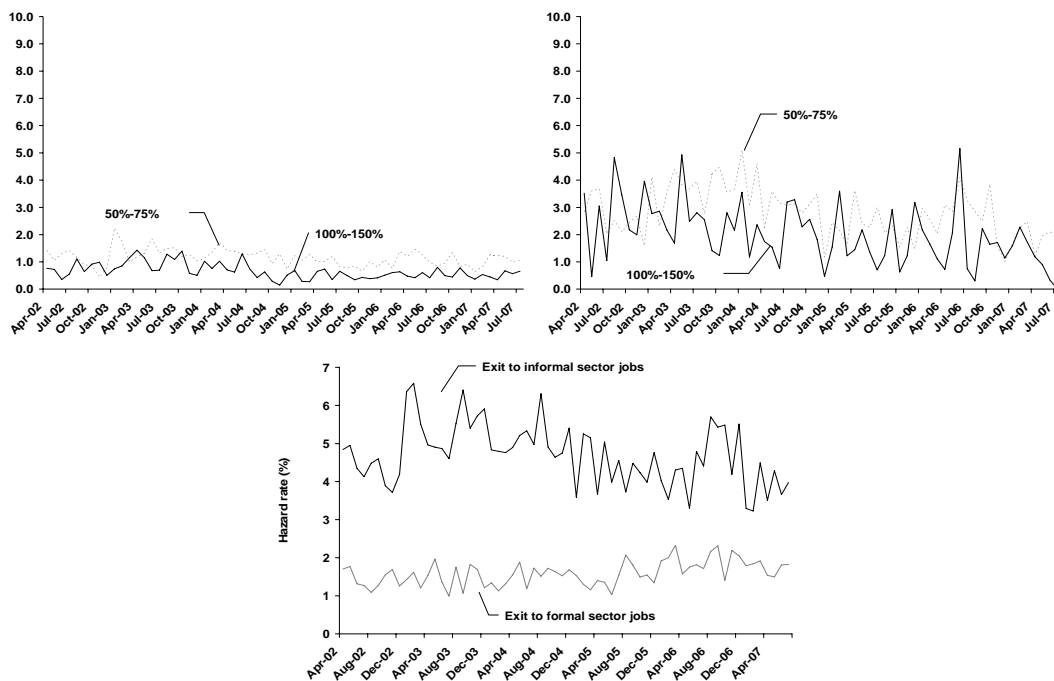
Source. Authors' calculations based on PME (Panel Survey of Workers in Metropolitan Areas).

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3. THE DYNAMIC STOCHASTIC BEHAVIORAL MODEL

We are interested in formalizing the effect of the social insurance system in three types of economic decisions: (i) the level of savings; (ii) efforts to preserve/find jobs in the "formal sector" (defined by access to social security); and (iii) retirement decisions. We thus use as our starting point the standard life-cycle utility maximization framework and introduce uncertainty in employment status and life expectancy. Many have criticized some of the assumptions of this framework, in particular, whether it is a fair representation of how individuals make decisions in practice – which would imply unbounded rationality and perfect foresight. Few, including the authors of this paper, would claim that individual's base their decisions on the solutions to models of the sort presented here. However, the test is not whether the model is a fair representation of the mental decision-making process, but whether the mathematical formalisms are able to *simulate* how individuals react to alternative incentives: if a pension system pays a very high pension individuals are less likely to save on their own; if the government offers long periods of unemployment assistance individuals are less likely to look for jobs. Thus, in the absence of empirical information linking system parameters to behaviors, the model is a useful benchmark that we use to explore a large range of possible behavioral responses to policy changes. Behaviors that are more like to have generated actual observations receive a higher weight. In essence, we use the model as a data generation mechanism and from this point of view it is not very different from linear single-equation econometric models.

The dynamic stochastic problem that representative agents are assumed to solve is formally given by:

$$\underset{c^*,q^*,R^*}{Max} : \sum_{t=a}^{R^*} U\!\left(c_t^*, \hat{l}_t \; ; q_t^*\right) v_t \rho^t + \sum_{t=R^*+1}^{X} U\!\left(c_t^*, h\right) v_t \rho^t$$

$$s.t. \quad k_t = k_{t-1}*(1+r_t) + y_t - c_t^*$$

$$y_t = w_t\!\left(h - \hat{l}_t\right)(1-\beta)e_t + \left[\delta_u w_t\!\left(h - l_t^*\right)\eta_u + S_u\!\left(\{\mathbf{Z}\}_a^{t-1}, e_{t-1}; \mathbf{\psi}_u\right)\right](1-e_t) \; if \quad t \le R^* \; , \; (1)$$

$$y_t = S_p\!\left(\{\mathbf{Z}\}_a^{t-1}; \mathbf{\psi}_u\right) + \delta_p w_t\!\left(h - l_t^*\right)\eta_p \quad if \quad t > R^*$$

$$P\!\left(e_t = 1 \,|\, e_{t-1} = j\right) = 1 - \exp\!\left(-\varphi_j q_t^*\right); \quad j \in \{0,1\}; \quad q \in [0,1]$$

$$k_X = 0$$

where U(.) is a standard utility function capturing the trade-off between consumption (c) and leisure (l); v_t is the probability of survival to age t; ρ is the rate of time preference; y is income; w labor productivity; r the real interest rate; h the total available working time during period t; e is equal to one if the individual is employed in a "formal sector job" and zero otherwise; β is the social security contribution rate (paid by the employee); R is the retirement age; X is the maximum number of years a human being can live; a is the entry age to the labor market, and $Z_t = \{w_t, e_t, r_t\}$. The function S_p (.) gives the value of retirement income that depends on past wages, interest rates, career histories, as well as the parameters $\mathbf{\psi}_p$ of the pension system.

The model allows for work after retirement from the mandatory system. Thus, with probability η_p individuals who retire work in the informal sector at a fraction δ_p of the formal sector wage. Similar to pension benefits, the function S_u (.) gives the value of unemployment benefits which also depend on past values of Z and policy parameters $\mathbf{\psi}_u$.

One innovation in this model is that it allows for the transitions in and out of the social security to depend, in part, on individual decisions. It is assumed that these transitions can be modeled by a Markov-type stochastic process that depends on factors which are exogenous to the worker (i.e., that the worker cannot control or change at least in the short term) and factors that are endogenous (i.e., that the worker controls). Exogenous factors refer, for instance, to the economic environment that makes more or less easier finding and keeping jobs (e.g., economic growth, firms turnover rates), as well as workers characteristics (e.g., level of education, sector/region where the individual works). These exogenous factors are captured by the parameters φ_0 and φ_1 which give respectively the probabilities of finding a job that is covered by the social security if one

is outside (j=0) or keeping a job covered by the social security (j=1) if one is inside. The endogenous factors are captured by the variable q which represents the "level of effort" that individuals invest in finding or keeping jobs. As shown in (1), q affects directly the transition probabilities in and out of the social security. We also assume that effort is "costly" and thus utility goes down when q increases (dU/dq<0).

That some workers consciously make the decision to quit formal sector jobs might sound counterintuitive to some, but it is nonetheless a relevant issue in the case of Brazil, where turnover rates are considerably high (see Section 2). Again, depending on preferences, many workers might not want to risk formal sector jobs under any circumstance. Others are more likely to weight the pros and cons and "reduce efforts to stay," for instance, when unemployment benefits are high, or when they have access to a relatively high balance in their unemployment savings accounts, or when they can save a contribution rate that does not add to their pension.

The formulation that we use to model transitions in and out of the social security is similar to that of Hopenhayn and Nicolini (1997), although they focus on employment/unemployment transitions. Here, in order to speed-up the algorithm that solves the model, we assume that q is bounded: 0<q<1. When q=1 (maximum effort) the Markov transition matrix regulating movements in and out of the social security system is characterized by $\varphi 0$ and $\varphi 1$. When q=0 individuals either do not find jobs or loose jobs with probability 1.

Workers who are not covered by the social security can be working in the informal sector or unemployed. But we assume that in both cases individuals can cash their unemployment benefits. Indeed, in practice, it is very difficult to enforce that individuals receiving unemployment benefits do not work in the informal sector. Moreover, as discussed in Section 2, transitions in and out of the social security are likely to go through periods of unemployment. Here we assume that with a certain probability η_u, individuals who exit the social security system find jobs in the informal sector. The wage premium of a formal sector job is given by $(1/\delta_u)$.

For the empirical work we use the standard constant risk aversion utility function that has been adapted to take into account the level of effort put into preserving and/or finding a job. We have:

$$U(c,l,q) = \left[\left(c^{\alpha_1}l^{1-\alpha}\right)^{1-\lambda}/(1-\lambda)\right]\!(1-\alpha_2 q) \qquad , (2)$$

where the standard parameters α_1 and λ capture respectively relative preferences for consumption and leisure and the level of risk aversion. The new parameter is α_2 which can be taught to capture individual attitudes towards formal sector work. A high/low α_2 would indicate that workers have low/strong preferences for formal sector jobs. The formulation was mainly chosen for transparency. Thus, equation (2) implies that when q increases from 0 to 1, utility is reduced by α_2*100 percent.

So up to here the dynamics of the model depend on the vector of parameters $\theta=\{\alpha_1,\alpha_2,\lambda,\varphi_0,\varphi_1,\rho,\ \delta'=\ \delta_p*\eta_p\ \}$ that needs to be estimated; four exogenous parameters/sequences (δ_u, η_u, $\{w_t\}$ and $\{r_t\}$); and the rules of the Brazilian social insurance system. We set $w_t=\xi.W_0*(1+g)^t$, where W represents economy wide average earnings in the based year. Then across simulations we have g=3%. r=4%, δ_u=0.3 and η_u= 0.6. Thus, for a given θ and ξ (which captures the level of income of the representative individuals in the cohort) we solve the model using a dynamic programming algorithm and generate a "behaviors vector" $M_d(a,e,k,v,R|\theta,\xi)$ that gives the optimal rule for decision $d=\{q^*,c^*,R^*\}$ as a function of the age a of the individual, his/her state e, the level of assets he/she holds, the vesting period v (that is the number of years the individual has contributed to the social security), and the retirement age R (if retired). The vesting period is important because benefit formulas in the pension system.

In the dynamic programming algorithm the vector M_d has the following dimensions: 80 ages, 4 states, 250 levels of capital, 45 vesting periods, and up to 20 retirement ages. The optimal level of the control variables d is computed recursively at every point in this space taking as given the dynamics of wages, the interest rate, the benefits provided by the social insurance system, the probabilities of being alive, and the probabilities of loosing/finding a formal sector job *given* the level of effort. The four

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states for e are: (1) out of the social security without unemployment benefits; (2) out of the social security receiving benefits; (3) contributing to the social security; and (4) retired. We track separately being out of the social security with or without unemployment benefits to control for the fact that individuals cannot receive benefits in two consecutive periods. As for the capital "grid," 250 points give a reasonable resolution for a maximum capital equivalent to 25 times initial average earnings, so that each grid point is equivalent to 10% of average earnings. Still, the numerical approximation results in somewhat jittery optional savings and levels of effort as a function of capital. Thus, we also use a fourth degree polynomial to smooth the optimal values in M_d.

The vector M_d is then used to simulate the behaviors of the representative individual across m future states of the world. Thus, we generate a new vector $C_b(a, m | M_d(. | \theta, \xi), \mathbf{E})$ where $\mathbf{b} = \{e, q^*, c^*, k\}$ and $\mathbf{E}$ is an m by a vector of uniformly distributed random numbers that determine the realizations of the shocks that move individuals in and out of the social security ($\mathbf{E}$ is fix across simulations). The vector C_b can then be used to compute the probability that at age a, an individual characterized by $M_d(. | \theta, \xi)$ would be in a given state e. From C_b one can also derive the distribution of output variables of interest. We focus on six: (i) the present value of capital accumulations at age 55; (ii) contribution densities; (iii) the present value of contributory pensions paid; (iv) the present value of explicit subsidies paid through the pension system; (v) the present value of unemployment insurance benefits; and (vi) the present value of FGTS payments.

4. STRATEGY TO SAMPLE THE JOINT DISTRIBUTION OF MODEL PARAMETERS

There are various ways to estimate the joint distribution of model parameters, which as usual are constrained by the type of data available and computational power. The ideal, in terms of data, would be to use individual records on career histories (see, for instance, Jimenez-Martin and Sanchez, 2003). For each individual in the sample (which determines ξ) and for a given θ, $C_b(a, m | M_d(. | \theta, \xi), \mathbf{E})$ could be used to calculate the likelihood of observing his/her career path (taking wages as given) and the distribution of

assets at a given age(s). Then θ would be estimated to maximize this likelihood. The vector θ could also be estimated for different subgroups characterized, for instance, by level of education and gender. Unfortunately, at the time of writing, individual records are still not available. But regardless of the data, estimating in this way would be computationally very intensive. When all the policies are "on" solving the model for a given θ and ξ takes around 2.5 hours.[4] The other issue is that we are not interested in a "point estimate" of θ but rather on a joint distribution that allows us to explore policy impacts across a large range of possible behaviors. Otherwise, one would be assuming that preferences are more or less the same across individuals (and that preferences on various dimensions are independent) and then addressing a limited range of uncertainty (on this point see Pizer, 1996).

In this first application we have opted instead for a Bayesian method to sample the ex-post distribution of model parameters. In the absence of individual records we use a pseudo panel of age-cohorts derived from the household survey to construct a targeted distribution by state (contributing to the social security; outside of the social security; unemployed; and retired) for the cohort of 25 year old males who enter the labor market in year 1990. The distribution is presented in Figure 1. We focus only on urban areas and control for three levels of income: less than 50% of average earnings, between 50 and 75% of average earnings; and more than 75%.

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[4] We work with a server with 8 processors that operate in parallel. So, individuals could be arranged in 8 groups according to their life-time earnings (which is capture by ξ). In this case, each iteration would take around 2.5 hours.

Figure 4: Targeted Distribution for Cohort of 25 Year-Old Males in Urban Region

Income <50% of average **Income 50% to 75% of average**

Income > 75% of average
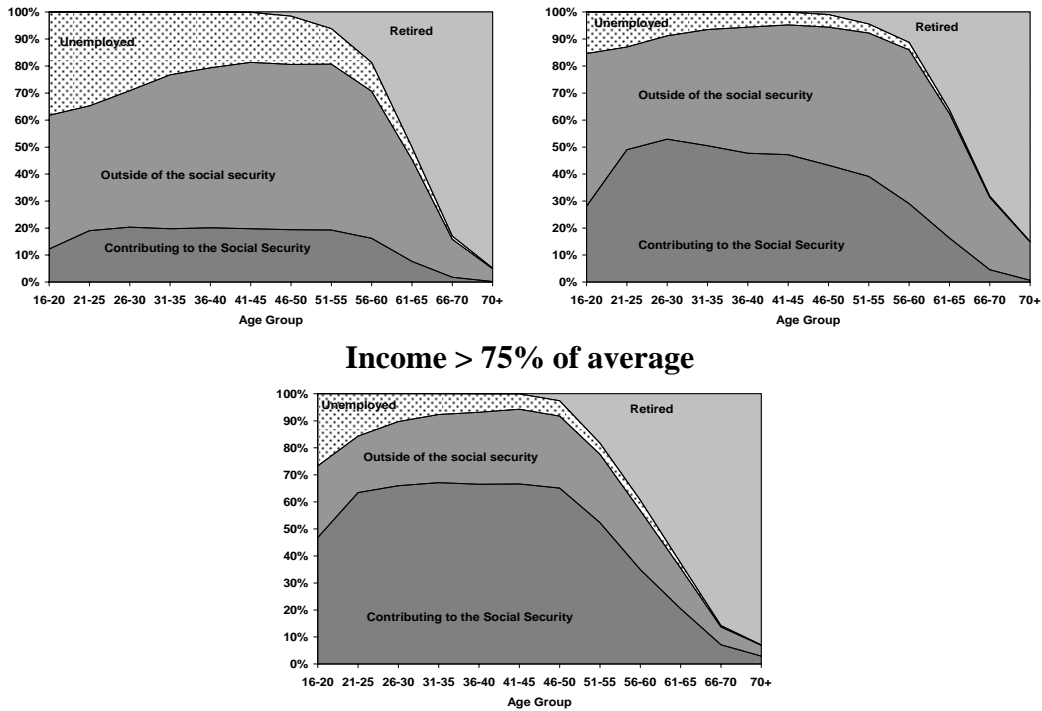
Source. Household surveys 1990-2006 PNAD. The methodology to input values for ages not observed is presented in the Appendix.

The idea is that the aggregate distributions that we observe are the result of millions of individuals making decisions and transiting between formal and informal sector jobs and periods of unemployment (see Section 2). Some individuals are such that they always stay in the informal or formal sectors. Others move in and out with more or less frequency. These various types are determined by the vector $\boldsymbol{\theta}$. So the question is, what is the probability of observing a given $\boldsymbol{\theta}$ given the aggregate distribution? And we know from Bayes rule that this probability is proportional to the probability of observing the data given $\boldsymbol{\theta}$. So we have:

$$P(\boldsymbol{\theta} \mid \mathbf{Y}_C) \propto L(Y \mid \boldsymbol{\theta}) f(\boldsymbol{\theta}), \tag{3}$$

The goal is then to sample points from the distribution of $\boldsymbol{\theta}$ in order to maximize the likelihood of the data. Given the complexity of the model, however, we cannot sample directly from the posterior distribution. We do not have marginal distributions

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either that would allow us to use the Gibbs sampler (see Cassella and George, 1992). Hence, we recur instead to a more general method, the Metropolis-Hastings (MH) algorithm of which the Gibbs sampler is a particular case (see MacKay, 2003 for a presentation).

In the MH algorithm we need to assume a prior distribution for each element of θ but the shape of this distribution does not affect the convergence properties of the algorithm, which are discussed in (Gourieroux and Monfort, 1996). Given this distribution the algorithm proceeds as follows:

1. Define $\theta_{s=0}$, basically our priors of the means.

2. Sample a new θ' from a density $f\left(\theta';\theta_s\right)$

3. Calculate $d = L(\mathbf{Y}\,|\,\theta')f\left(\theta_s,\theta'\right)/\,L(\mathbf{Y}\,|\,\theta_s)f\left(\theta',\theta_s\right)$

4. If d>1 then $\theta_{s+1} = \theta'$

5. Otherwise, $\theta_{s+1} = \theta'$ with probability d.

6. Goto 2.

The intuition is that the means of the densities from which we sample θ will be updated each time the likelihood of observing the data given the parameters improves. When there is no improvement (d<1) the mean can still be updated but with a probability that is proportional to d. If d is very low the probability that the mean is updated is also very low. We also notice that the improvement in the likelihood of observing the data is corrected by the odds of having sampled the parameters in the first place given the means of the distributions. In a symmetrical distribution such as the normal $f\left(\theta_s,\theta'\right)/\,f\left(\theta',\theta_s,\right)$ is always equal to one. But when censoring is introduced in the distribution of certain parameters, which is our case, the correction is needed.

In our application we use independent prior normal distributions for each of the parameters with height different initial means – hence the final distribution is based on 8 independent sequences of sampled parameters. For the parameters risk aversion (λ) and the time preference (ρ) we fix the means based on references from the literature. For

preferences for consumption over leisure (α_1) and formal Vs. informal sector work (α_2) we allow for a more or less arbitrary initial range of variation. For the parameters that determine transitions in and out of the social security we did some simulations to understand their influence on the steady state distribution of the cohort. On this basis we defined initial values and also imposed the constraint $\varphi_0<\varphi_1$ so that the probability of keeping a job is always higher than the probability of finding one (which is consistent with the data reviewed in Section 2). Finally, for the probability of working when retired we use as a starting reference the average derived from the household survey. For some of the parameters the economic model puts restrictions on their range of variation, hence we apply left or right censoring. In all cases, judgment is involved in setting the variances of the distributions so that there is enough variation to explore larger regions of the parameter space, but not too much that it would delay convergence (see MacKay, 2003). The initial distributions of the model parameters for the 8 sequences are presented in Table 1.

Table 1: Initial Distributions for the Eight Independent Samples of Model Parameters

	Risk Aversion	Time preference	Alfa 1	Alfa 2	Prob. Keep Formal Job	Prob. Work when Retired
Mean 1	1.50	0.04	0.90	0.50	0.90	0.50
Mean 2	1.33	0.03	0.84	0.44	0.84	0.44
Mean 3	1.16	0.02	0.79	0.37	0.79	0.39
Mean 4	0.99	0.01	0.73	0.31	0.73	0.33
Mean 5	0.81	-0.01	0.67	0.24	0.67	0.27
Mean 6	0.64	-0.02	0.61	0.18	0.61	0.21
Mean 7	0.47	-0.03	0.56	0.11	0.56	0.16
Mean 8	0.30	-0.04	0.50	0.05	0.50	0.10
Variance	0.10	0.01	0.10	0.10	0.10	0.10
Trunc. left	0	-99	0.5	0	0	0
Trunc. right	99	99	1	1	1	1

Source: Range of variation for Risk Aversion and Time preference parameters based Jimenez-Martin and Sanchez (2003). For the other parameters see main text.

To compute the ratio d for each θ_i we proceed as follows. First we use $C_b(a,m|M_d(.|\theta,\xi),E)$ with m=1,000 to compute the probabilities that at various ages a an

individual of the cohort would be in various states *e*. We define these probabilities by p(a,e) and compute them by simply counting the number of individuals in state e at age a and then dividing by *m*. Then, the probability that the data would have been generated by θ is given by the multinomial distribution:

$$P(Y \mid \boldsymbol{\theta}) = \prod_a \left(C_a \prod_e p(a,e)^{s(a,e)N_a} \right), \tag{4}$$

where N_a is the number of individuals of age *a* who were sampled from the population, s(a,e) the share of these individuals that is in state e (which come from the pseudo sample), and C_a the number of possible combinations of individuals across states. Because we are only interested in likelihood ratios, the sample size is normalized to 1 so that (4) becomes the Dirichlet distribution with parameters s(a,e).[5] The ratio d is then given by:

$$d = \frac{\prod_a \left(\prod_e p(a,e \mid \boldsymbol{\theta}')^{s(a,e)} \right)}{\prod_a \left(\prod_e p(a,e \mid \boldsymbol{\theta}_s)^{s(a,e)} \right)} \frac{f(\boldsymbol{\theta}_s \mid \boldsymbol{\theta}')}{f(\boldsymbol{\theta}' \mid \boldsymbol{\theta}_s)}, \tag{5}$$

where the normalizing constants for distributions are dropped from both the numerator and denominator. Then taking logs we then obtain:

$$\log(d) = \sum_a \sum_e s(a,e)\left(\log\left(p(a,e \mid \boldsymbol{\theta}')\right) - \log\left(p(a,e \mid \boldsymbol{\theta}_s)\right)\right) + \log\left(f(\boldsymbol{\theta}_s \mid \boldsymbol{\theta}')\right) - \log\left(f(\boldsymbol{\theta}' \mid \boldsymbol{\theta}_s)\right), \tag{6}$$

The only missing pieces to compute d are then probabilities of sampling the parameters given the means. Taking into account the left hand and right hand truncations and the variances of the normal distributions these probabilities are given by:

$$\log\left(f(\boldsymbol{\theta}' \mid \boldsymbol{\theta}_s)\right) = \sum_\theta \log \begin{cases} \left\{ \dfrac{N(\theta_i \mid \boldsymbol{\theta}_s, \Phi_s) - N(\theta_{\min} \mid \boldsymbol{\theta}_s, \Phi_s)}{N(\theta_{\max} \mid \boldsymbol{\theta}_s, \Phi_s) - N(\theta_{\min} \mid \boldsymbol{\theta}_s, \Phi_s)} \right\} & if \quad \theta_i < \theta_{s,i} \\[2em] \left\{ \dfrac{N(\theta_{\max} \mid \boldsymbol{\theta}_s, \Phi_s) - N(\theta_i \mid \boldsymbol{\theta}_s, \Phi_s)}{N(\theta_{\max} \mid \boldsymbol{\theta}_s, \Phi_s) - N(\theta_{\min} \mid \boldsymbol{\theta}_s, \Phi_s)} \right\} & if \quad \theta_i > \theta_{s,i} \end{cases}, \tag{7}$$

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[5] The Dirichlet distribution is a Bayesian prior of the parameters of the Multinomial distribution. It gives the likelihood of the probabilities p(a,e) given the shares of each cohort in each state.

where N is the cumulative normal distribution, i indexes the elements of θ and **Φ** is the variance covariance matrix of the prior distribution of the parameters that here is assumed to be a diagonal matrix (i.e., there are no prior correlations between the model parameters).

To assess the convergence of the various series we follow the method proposed in Gelman et al. (2000). The idea is to compare an over estimate and an under estimate of the posterior marginal variance of the parameters in θ and see whether they converge. The overestimate of the marginal variance is given by the weighted sum of the between sequences (B_i) and within sequences (W_i) variances for each parameter θ_i. We have:

$$\text{vâr}^+\left(\theta_i \mid Y\right) = \frac{n-1}{n} W_i + \frac{1}{n} B_i, \tag{8}$$

with

$$B_i = \frac{N}{Z-1} \sum_{z=1}^{Z} \left(\overline{\theta}_{i.z} - \overline{\theta}_{i..}\right)^2, \quad with \quad \overline{\theta}_{i.z} = \frac{1}{N} \sum_{n=1}^{N} \theta_{inz} \quad and \quad \overline{\theta}_{i..} = \frac{1}{Z} \sum_{z=1}^{Z} \theta_{i.z},$$

$$W_i = \frac{1}{Z} \sum_{z=}^{Z} \sigma_{iz}^2, \quad with \quad \sigma_{iz}^2 = \sum_{n=1}^{N} \left(\overline{\theta}_{inz} - \overline{\theta}_{i.z}\right)^2 \tag{9}$$

where Z is the number of independent sequences and N the number of samples in each sequence. Both, B_i and W_i overestimate the marginal posterior variance if the initial distribution is appropriately over dispersed, but the estimator is unbiased when n is large (n→∞).

For a finite n, however, the within variance (W_i) should be an underestimate because the individual sequences have not had yet time to range over all the targeted distribution and therefore have less variability. Then an indicator of the potential gains of continuing with the iterations is:

$$\sqrt{\hat{R}_i} = \sqrt{\frac{\text{vâr}^+\left(\theta_i \mid Y\right)}{W_i}}, \tag{10}$$

If R_i is equal or close to one the series have converged. For applications like ours where we are less interested in the precision of the posterior joint distribution but care more about taking into account sufficient heterogeneity in behaviors, we consider values up to 1.2 (see Table 1).

Table 2: Convergence Statistics for Various Parameters

	B_i	W_i	$Var(\theta_i|Y)$	R_i
Risk Aversion	1.1178	2.7617	2.6589	0.9628
Time Preference	0.0029	0.0018	0.0018	1.0383
Alfa1	0.0298	0.0748	0.0720	0.9624
Alfa2	0.1980	0.0911	0.0978	1.0734
Prob. Keep Formal Job	0.0475	0.3281	0.3106	0.9465
Prob. Work if Retired	0.1099	0.1095	0.1095	1.0002

Source: Authors' calculations.

The joint distributions of model parameters are presented in Figure 5. In general, these distributions are in line with our priors and for the risk aversion and time preferences, in line with other results in the literature. For our purposes, the main goal is to capture enough variation in individual preferences to then analyze the impact of the various programs and the introduction of possible reforms. This is the objective of the next section.

Figure 5: Joint Distribution of Model Parameters[6]
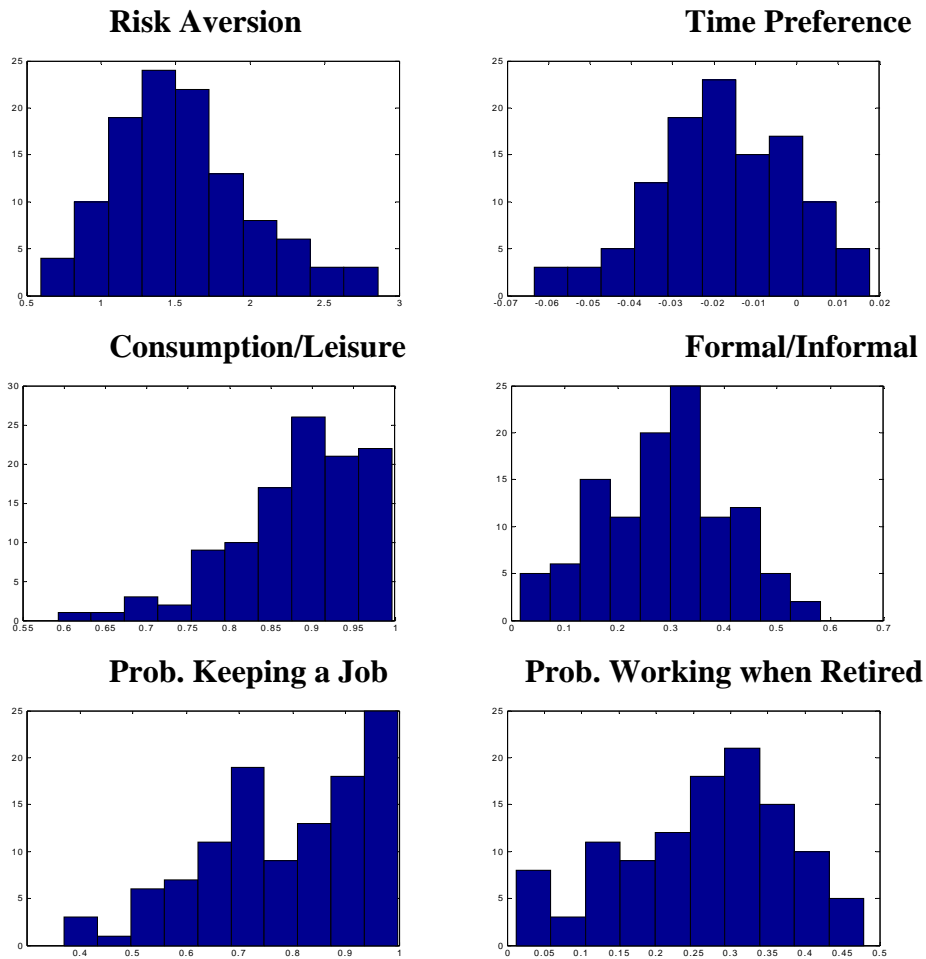
Source: Results of MH sampler.

5. POLICY ANALYSIS

We start by looking at the marginal impact of each of the programs "across" the joint distribution of parameters. We basically ask the question what would be the impact on the output variables of interest of removing, one at the time, the pension system, the unemployment insurance system, and the unemployment FGTS savings accounts. We do this only for individuals with average earnings. We then look at the joint effect of a policy package that separates the insurance and redistributive functions in the pensions

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[6] These distributions are preliminary and should not be quoted.

and unemployment insurance systems. This is done by having one single formula for pensions and UI benefits that is "incentives neutral" and then using explicit subsidies to finance transfers to individuals with no or limited savings capacity. This second part of the analysis is done for individuals earning 100% and 50% of the economy wide average wage.

Under the status-quo the simulations predict that over time, around 30-35 percent of the cohort would be outside of the formal sector. This is consistent with the current distribution of age cohorts as discussed in Section 4. But, clearly, there is a large variation. Some individuals spend most of the time contributing to the social security, while others spend most of the time outside. This can be seen in the left panel of Figure 6 that presents the probability of been contributing for different "types of individuals."

In terms of retirement, around half of the cohort would retire between ages 55 and 60. This is also consistent with the analysis of cohorts presented in Section 4 and the micro-data analyzed in World Bank (2008). But again, the variation in retirement patterns can be considerable. Some individuals can retire as early as 53, others can delay retirement until 70 (see right panel of Figure 6). As indicated above, these differences in behaviors reflect different preferences. In general, risk taking behavior, preferences for future over present consumption, and preferences for consumption over leisure, provide incentives for delaying retirement. Clearly, here we are assuming that pensions do not carry uncertainty. In the simulations they are automatically indexed by inflation. In practice, indexation can be discretionary and these would make pensions less attractive for risk adverse individuals.

Figure 6: Probabilities of Contributing to INSS and Retiring
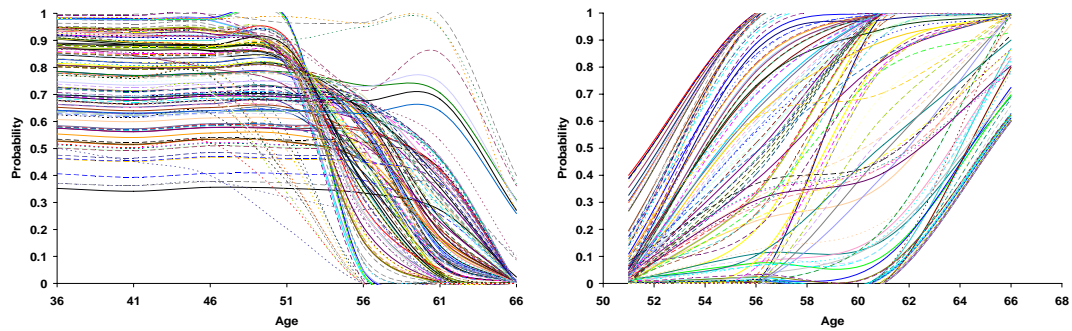
Source. Simulation model.

The simulations also predict average asset accumulations by age 55 of around 3.5 times yearly average earnings in present value.[7]   These predictions have not been compared with real data but the order of magnitude is not disparate.[8] This level of assets would correspond to individuals who save around 10 percent of their earnings per year.[9] But savings also vary considerably depending on preferences (see Figure 7).   The individual who saves the least would have assets worth in present value less than one year of average earnings. The individual who saves the most could have assets worth 7 times yearly average earnings in present value.

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[7] These assets exclude the pension wealth from the mandatory system but include accumulations in the FGTS program.

[8] For a review of the literature of pensions on individual savings see Takayama (1990).

[9] This assumes that the real interest on savings is 1 percentage points above the growth rate of wages.

Figure 7: Individual Preferences and Assets Accumulations
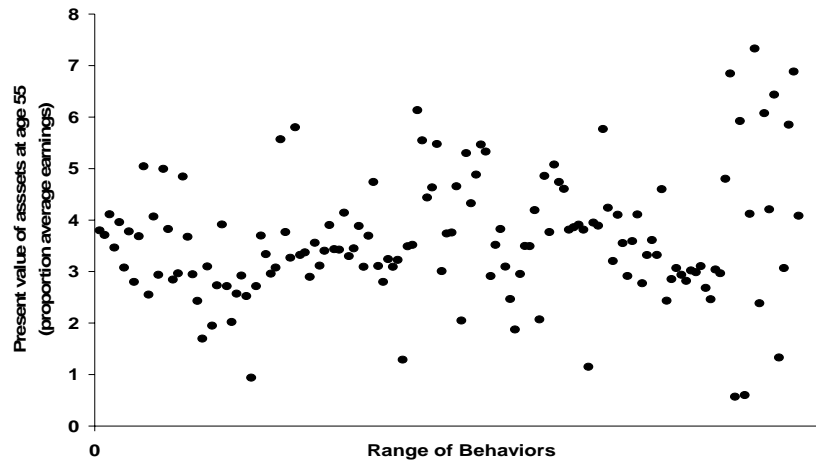
Source. Simulation model.

In terms of the impact of current programs, the results suggest that the pension system reduces individual savings, increases contribution densities, increases (mildly) UI expenditures, and contains FGTS payments. Indeed, when the pension system is removed, average assets holdings at age 55 increase, participation in the formal sector decreases, unemployment benefits fall (slightly), and FGTS payments go up (see Figure 8). These are the impacts that could be observed for most individuals but not always. There are cases where the opposite effects are observed, showing the complexity of evaluating public policy. Impacts are very much dependent on individual preferences; two different individuals can react in two very different ways.

That savings go up is to be expected as individuals would have incentives to compensate for the loss of pension wealth. The reduction in the contribution density, on the other hand, has to be interpreted with caution. It does not mean necessarily that the pension system provides good incentives to contribute *at the margin*. In fact, Section 2 showed that incentives for the median worker are very week. But this simulation does not provide information on the incentives to contribute at the margin. The results only say that the current pension system is a "good deal" and that workers are better off by contributing at least up to a minimum to receive benefits. This is consistent with the high IRRs presented in Section 2. The question of whether incentives to contribute at the margin can be improved will be addressed when looking at policy reforms. What the

results do suggest, for now, is that in the absence of the pension system individuals would value less formal jobs and there could be more demand for UI benefits and FGTS payments. FGTS payments do increase considerably in the simulations but UI expenditures fall (mildly). The reason for the latter is that with sparser contribution densities UI benefits are also lower and fewer individuals qualify.

Figure 8: Effects of Removing the Pension System
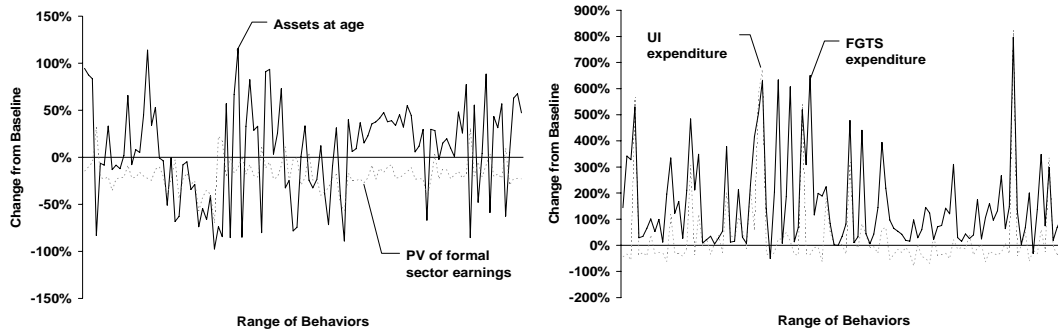
Source. Simulation model.

The unemployment insurance system, on the other hand, seems to increase FGTS expenditures, pension expenditures, and individual assets; it is also like to generate a mild negative impact on contribution densities. Like in the case of pensions, removing the unemployment insurance system would induce different behavioral responses. In the large majority of cases, however, incentives to keep jobs covered by the social security would increase and this would reduce outflows and FGTS expenditures (see Figure 9). There would also be a positive, but very mild, effect on contribution densities. At the same time, eliminating UI would provide incentives for early retirement, given that the benefit of waiting to retire (which includes having access to unemployment insurance) would be reduced. In the current system, this reduces the value of contributory pensions but increases the value of the minimum pension top-up. Finally, eliminating UI would reduce individual assets at age 55. The main explanation is that part of life-time savings would have to be used during periods of unemployment.

Figure 9: Effects of Removing the Unemployment Insurance System
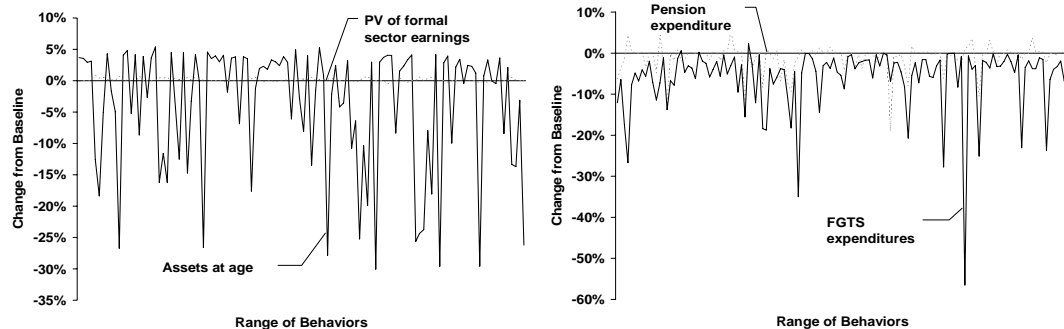
Source. Simulation model.

The effects of FGTS are similar to those of the UI system. In general, sparser contribution densities, and higher unemployment benefits, pension expenditures and individuals assets. Thus, the simulations show that eliminating FGTS would first have a large negative impact on the present value of assets at 55 – this simply because of the elimination of forced savings to the individual unemployment savings accounts which are financed by employers (

Figure **10**).[10] As expected, eliminating FGTS would also provide incentives to keep and find formal sector jobs. This would increase contribution densities (thus earnings from the formal sector) and reduce expenditures on unemployment benefits. Finally, eliminating FGTS would reduce the benefits of delaying retirement. Other things being equal, individuals would advance retirement and, as discussed before, this would reduce contributory pensions and increase the cost of the top-up for the minimum pension.

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[10] If savings were financed by individuals themselves, then substitution effects could take place. Eliminating FGTS in that case might not reduce assets. Except, if optimal savings rates were below the FGTS contribution rate, given that in this model individuals cannot dissave.

Figure 10: Effects of Removing FGTS
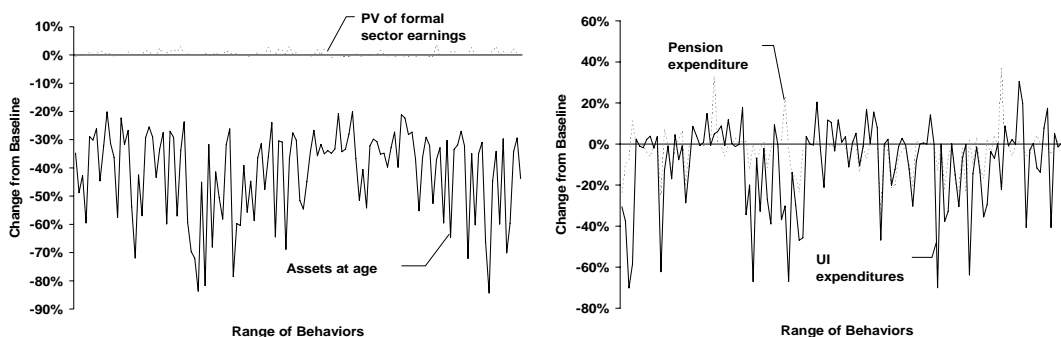
Source. Simulation model.
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Next we look at the effects of possible reforms that introduce "incentive neutral" benefit formulas and make redistribution explicit and focused on individuals with limited savings capacity. The proposed policy changes are summarized in Table 3, some of the details are as follows:

In the case of pensions, the new proposed benefit formula is:

$$p_R = \frac{\beta_w + \beta_e + \beta_g}{G_R(irr)} \left(\sum_{i=a}^{R} w_a.(1 + irr)^{R-a} \right), \qquad (11)$$

where p_R is the pension paid by the system at retirement age R; β_w, β_e, and β_g are the contribution rates paid to the system respectively by the employee, the employer and the government (when there are explicit subsidies); a is the age when the individual joins the system, *irr* is the rate of return that the system pays on contributions; and $G_R(irr)$ is an annuity factor that also depends on *irr*. In our application, *irr* is assumed to be equal to the growth rate of the average wage, which as shown in Robalino and Bodor (2008) is a good proxy to the sustainable internal rate of return of a pay-as-you-go system (although in most cases this proxy would be below the sustainable rate).

In terms of contribution rates, we assume that employees pay 7.65% (equal to the minimum contribution rate today) and that out of the 20 percentage points paid by the employer, 7.65 percentage points are allocated to finance old-age pensions.

Also, current eligibility conditions are changed. The new proposed rule is that before age 65 individuals can retire at any age as long as they are able to finance an

annuity equal to the minimum pension guarantee. After age 65 individuals can retire regardless of the level of the annuity and then become eligible for subsidies.

Table 3: Summary of Policy Interventions

RGPS	UI	FGTS
The current three benefit formulas are replaced by a formula that pays the same IRR on contributions to all members irrespective of the retirement age. The contribution rate to finance old-age pensions is set to 7.65% for both employees and employers. The minimum vesting periods and retirement ages are eliminated. The only condition for retirement is to be able to finance a pension above the minimum, except after age 65 when individuals can retire regardless of the balance in their accounts and receive subsidies. **Subsidy option 1:** A pension top-up to secure a minimum pension (assumed to be 42% of average earnings) that can be used after age 65. **Subsidy option 2:** A matching contribution of 6 percentage points for individuals with incomes below a threshold (assumed to be 50% of average earnings). Plus, a small means-tested flat pension (assumed to be 20% of average earnings).	The system is integrated with the FGTS. In essence, the contribution goes to FGTS to subsidize the accounts of individuals with limited savings capacity. The matching simulated here is 20%.	The reformed system focuses on consumption smoothing and thus moves from lump sum to monthly payments. The only constraints for withdrawal is that balances in the individual accounts (after taking into account subsidies) need to be positive. It is assumed that FGTS pays market rates of return on balances in individual accounts.

Source. Authors.

Finally, two types of subsidies are considered: (i) a top-up after age 65 that brings the pension to a minimum (here set at 42% of average earnings); or (ii) matching contributions for workers with earnings below a threshold (here set at 50% of average

earnings), combined with a small consumption tested pension (here set at 20% of average earnings) that is offered after age 65.

For the income protection system the proposal analyzed here is to merge UI and FGTS. In essence, the revenues currently collected for the UI system would be transferred to the FGTS to subsidize the accounts of individuals with limited savings capacity (in the application here, however, it is assumed that the subsidies are allocated across the board). So the effective contribution rate to the FGTS goes up by 2 percentage points.[11] The other important change is that the FGTS would focus on consumption smoothing and therefore would move from lump sum payments to monthly payments. Individuals can withdraw benefits as long as there is a positive balance in their accounts (after taking into account subsidies). The amount of the transfer here is equal to one month of salary per month, but in practice individuals could be free to set lower amounts.

The results of the policy simulations show that the proposed reforms, with or without matching contributions, can both improve incentives and reduce the cost of the programs. In the case of the top-up, contribution densities increase by 5% to 20% for most "types" and more in the case of the individual's earnings 50% of the average wage (see Figure 11). As a result, expenditures in old-age subsidies are reduced, particularly in the case of high income workers. Lower subsidies and a more sustainable rate of return on contributions also contribute to higher savings and therefore a higher level of assets at age 55. Finally, FGTS payments increase, mainly as a result of the matching contributions coming from the UI system.

The policies to allocate subsidies in the pension system are compared in Figure 12. We see that contribution densities increase more under the top-up than the matching contributions (see top-left panel). This does not necessarily imply that incentives are better under a top-up than under matching contributions. It really depends on how the two are implemented. In our example, contribution densities under matching are shorter mainly because individuals have fewer incentives to delay retirement until age 65, when

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[11] In the simulations the dismissal fine paid by the employer is preserved but this is an issue that would also need to receive attention in practice.

only a small flat means tested pension is offered.[12]   But, while active, matching contributions do provide incentives to contribute to the system, and this is reflected in a reduction in FGTS transfers relative to the top-up (see bottom-right panel of see Figure 12).   So, even without a restriction on the retirement age, matching contributions can contribute to increase contribution densities and savings (for the latter, we find similar effects that in the case of the top-up).   Finally, given a less generous minimum pension, expenditures on old-age subsidies are considerably lower under the proposed matching contribution, almost half.

Figure 11: Impacts of Proposed Policy Interventions (top-up)
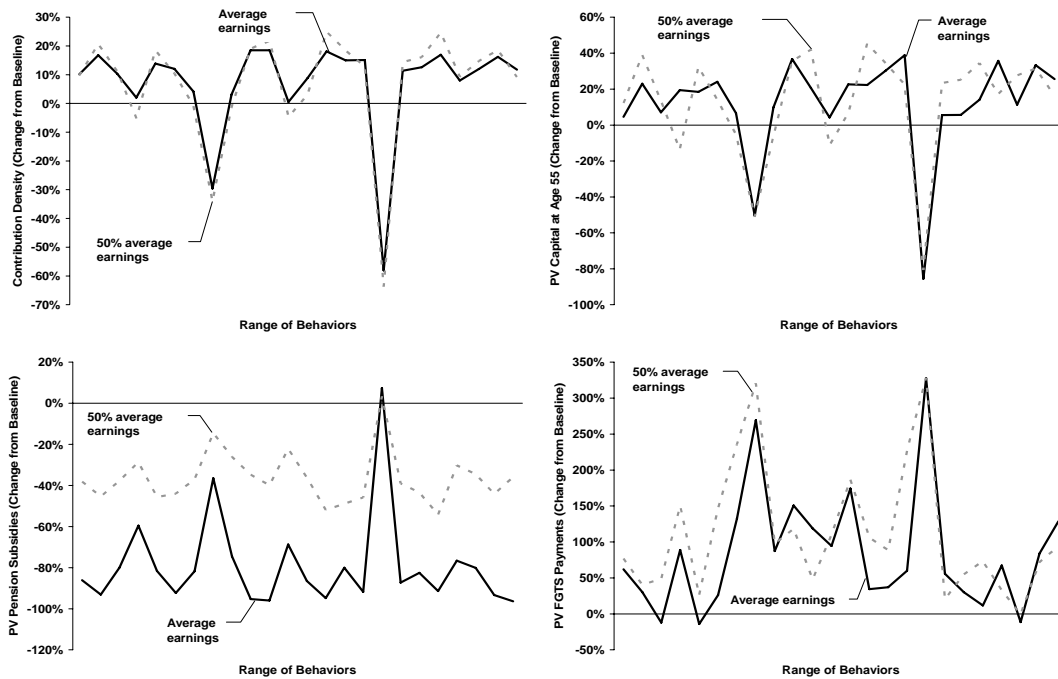
Source. Simulation model.

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[12] Larger contribution densities could be obtained, for instance, if the matching contributions could only be cashed after a given age.

Figure 12: Relative Impacts of the Top-Up and Matching Contributions
(Individuals Earning 50% of the Average Wage)
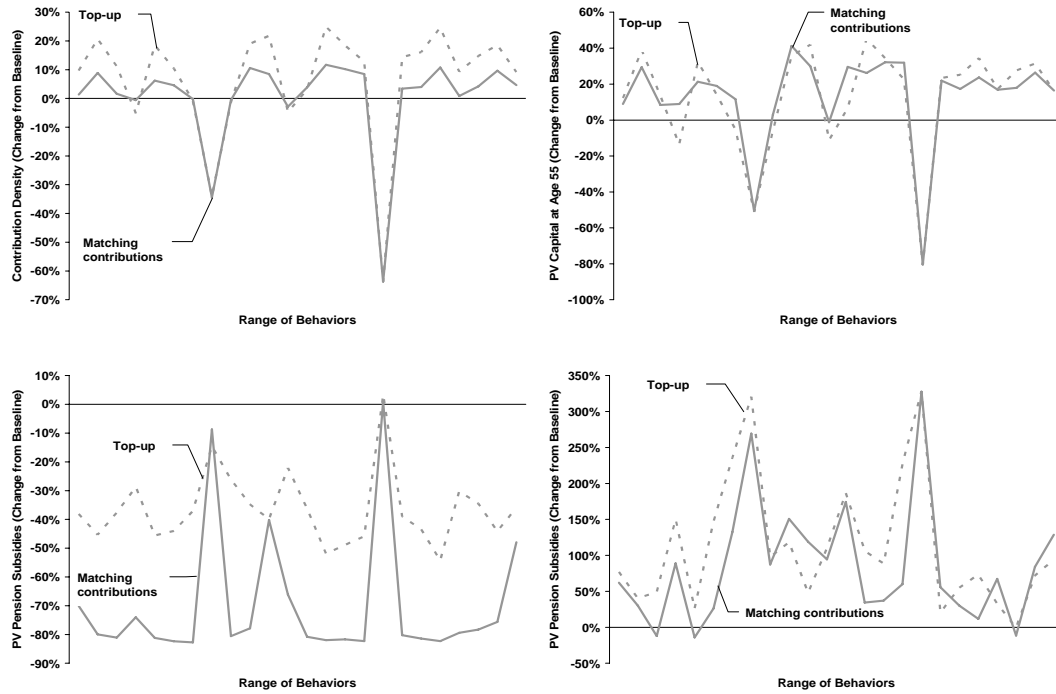
Source. Simulation model.

Clearly, the gains discussed above have to come at a cost (i.e., lower utility) for certain individuals. These costs are not evaluated here, but our conjecture is that inter-temporal social welfare would increase. First, because the financial sustainability of the system would improve and this would reduce potentially regressive intergenerational transfers; new generations would be better off. Second, because the reforms generate more formal sector work and higher savings. Finally, subsidies would be better targeted and thus benefit those individuals who need them the most.

6. CONCLUSIONS

In this paper we make contributions to the literature both in terms of analytical methods and policy analysis. On methods, we solved and estimated a stochastic model of optimal inter-temporal behavior where representative agents make decisions about how

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much to save, when to retire, and the level of effort they invest in keeping or finding formal sector jobs, *given* the rules of a real-live income protection and pension systems. The dynamics of the model depend on five key parameters: preferences regarding consumption and leisure, preferences regarding formal Vs. informal work, attitudes towards risks, the rate of time preference, and the distributions of two exogenous shocks that affect movements in and out of the social security system.

The model was applied to Brazil to explore how changes in the pensions and income protection systems could affect contribution densities, retirement patterns, savings, and programs costs. We estimated the joint distribution of model parameters using a generalized version of the Gibbs sampler -- the so called Metropolis-Hastings (MH) algorithm. To this end, based on the Brazilian annual household survey, we first created a pseudo panel of the distribution of age-cohorts across states (contributing to the social security, out of the social security, unemployed, or retired) controlling for income and region. The MH algorithm was then used to sample parameters from the joint distribution to maximize the likelihood of the data for the 1990 cohort of 25 years old males. The results showed that the model does a good job in replicating the distribution of the members of the cohort across states. Moreover, because the parameters are related to individual preferences or exogenous shocks, the joint distribution is unlikely to change when the social insurance system changes. Thus, the model can be used to analyze policy interventions over a large range of possible behavioral responses.

In terms of policy analysis, we used the model first to analyze the potential effects that the current income protection and pensions systems are having on contribution densities, saving decisions, retirement ages, and programs cost. We showed that in most regions of the joint distribution, the programs are reducing savings rates and making contribution densities sparser. We also showed that there are important interactions between programs. For instance, the UI system might be providing incentives to delay retirement. The pension system, on the other hand, might provide incentives to enroll in the social security and also contain UI expenditures. This result emphasizes the need to take an integrated approach to the analysis of eventual reforms.

We then looked at the impact of a reform strategy that would simplify and integrate benefit formulas and eligibility conditions, while separating the insurance and

redistributive functions of the system. In the case of pensions this involves introducing a single benefit formula that pays a constant rate of return on contributions, independently of the retirement age, and then using explicit subsidies to top-up pensions after a certain age and/or match the contributions of individuals with limited savings capacity. For the income protection system the proposed reform consists in integrating *Seguro Desemprego* and FGTS. In essence, the revenues currently collected for the UI system would be transferred to the FGTS to subsidize the accounts of individuals with limited savings capacity. Moreover, unemployment benefits would be paid on a monthly basis not as a lump-sum. We showed that these reforms can improve incentives and have significant positive effects on contribution densities, savings, and the probability of delaying retirement, while reducing expenditures in old-age subsidies. We also showed that matching contributions can have significant effects in extending contribution densities.

There are, of course, limitations to the analysis. First, the model remains a simplified representation of reality. While it can reproduce the distribution of a given cohort across states, there is no guarantee that it is a fair representation of how individuals react to *change* (even if their preferences remain the same). For instance, as Prospect Theory tells us, individuals might react differently to gains than to losses. We have addressed this by looking at a broad range of possible behavioral responses, but still the results should be interpreted with caution. Different specifications for the utility function would need to be considered in the future.

The second limitation is that we work in a partial-equilibrium framework. Several of the reforms discussed here are likely to affect the demand for labor and equilibrium wages and this would influence the steady-state impact of the proposed reforms.

Third, given the considerable demands on computing time, we have not been able to look at the pensions and unemployment insurance systems in their totality, and have focused instead on a single age-gender cohort and two income levels. The impacts of the proposed reforms could be different if the analysis is done for a larger set of individuals and controlling for other characteristics such as education. We also think that our

estimates of the posterior joint distribution of model parameters could be improved if working with individual records instead of a pseudo panel. We expect that this will be possible in a forthcoming version of the paper.

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Pensions

The proportional Length of Contribution Pension is Given by:

$$p_R = \frac{0.31*v}{G(R)}\left(1+\frac{0.31*v+R}{100}\right)*LifeTimeWage*0.7*\min(\frac{1}{0.70},(1+0.05*(R-54)))$$

where R is the retirement age, v the vesting period, G(R) life expectancy at age R, and *LifeTimeWage* is the average of all salaries indexed by inflation.

The full Length of Contribution Pension is given by:

$$p_R = \frac{0.31*v}{G(R)}\left(1+\frac{0.31*v+R}{100}\right)*LifeTimeWage$$

The aging pension is:

$$p_R = (0.7+0.01*v)*LifeTimeWage$$

Unemployment Insurance

The value of monthly UI benefits varies from R$380 (the Brazilian Minimum Wage) to R$710.97, depending on the average wage computed in the last three-month period of work. Values are depicted in the table below.

Monthly wage range	UI benefit
Up to R$627.29	0.8 * average monthly wage Minimum value = 1 Minimum Wage (R$380.00)
R$627.30 to R$1,045.58	R$501,83 + 0.5 * value exceeding R$627.29 Maximum value = R$710.97
More than R$1,045.58	R$710.97

ANNEX 2: MOVING FROM CROSS-SECTIONAL TO LONGITUDINAL COHORTS

The main source of information used in this paper is the microdata from the Pesquisa Nacional por Amostra de Domicílios (PNAD) –National Household Sample Survey. This survey is goes to the field each year (except the years of the Census) and is managed by the Instituto Brasileiro de Geografia e Estatística (IBGE) - Brazilian Institute of Geography and Statistics. It is a comprehensive research on socio-economic characteristics of the population and households in Brazil. The issues include topics such as income, occupations, social security, education, fertility, etc. Each year are interviewed around 0.25% of the Brazilian population, which corresponds to just over 420,000 records. For this exercise we used the PNADs for years 1990, 1996, 2001, and 2006. In addition, we relied on aggregate data from the Statistical Yearbook of Social Security, published yearly by the Ministry of Social Security.

For the analysis the population was divided in the following groups:

a) *Workers "with carteira."* This group includes all individuals that work in the formal private sector. Or, for the purposes of this paper, which contribute to the social security system. Thus, civil servants and military are excluded from our analysis

b) *Workers "without carteira."* This group includes all workers who are in the informal sector. Or, for the purposes of this paper, which do not contribute to the basic social security system.

c) *Unemployed.* This group included all unemployed individuals. It means they are not working they are looking for a job.

d) *Retired workers.* This group includes all who receive old-age benefits and are not in the labor market. This caveat is important, because in Brazil a worker can retire, receive their benefit and continue working, without any changes, either in his situation in the labor market, either in his situation as beneficiary.

People were then divided by cohorts of 5 years, according to the following division: 16-20 years; 21-25 years; 66-70; and 71+. All persons under the age of 16 years were excluded from the dataset because that is the legal age of initiation of work and contribution to social security.

The main complication at this stage was with the retirees. The PNAD does not provide information on whether the person receives his retirement from the Regime Geral de Previdência Social (RGPS) - General Social Security System or the National Social Security Institute (i.e., if the person is a retiree from the private or public sector). To this end, the data from the survey was matched to the data from the Anuário Estatístico de Previdência Social (AEPS) - Statistical Yearbook of Social Security, which contains retirees by sector and age groups. Given that the age groups are not the same some additional adjustments were necessary. As the age-cohorts made by AEPS start from an age x and our cohorts from an age x + 1, the two information have only 4 years in common (80% of data). Thus, we built a new cohort x', composed of 0.8 * (similar cohort of AEPS) + 0.2 * (previous cohort of AEPS).

Moving from cross-sectional to longitudinal cohorts

With the pseudo-panel formed by the PNADs it is possible to describe the behavior along the life cycle of a *few* cohorts. For example, the cohort aged x in 2006 was x-5 years old in 2001, x-10 years old in 1996 and so on. But the question we want to answer is: what will happen with that cohort in 5 years from now? And in n years from now? This means trying to predict the percentage of individuals of that cohort that will be in each of the four groups that defined above in the next n years. We considered two methods.

Method 1. The assumption here is that the behavior of a given cohort will be similar to what happened with individuals of other cohorts, (that can be observed in other PNADs), when they were the same age. For example, in 2006 a given percentage of individuals aged x were in the formal sector. In 2011, this cohort will be 5 years older. We postulate that the percentage of individuals from the cohort who would be in the informal sector is a weighted average of percentages found for the cohort aged x +n in the previous PNADs. The weighting gives greater importance to more recent years. For each cohort and for each group, the procedure is repeated. So we have:

$$PCT_{x,i,j} = \frac{a * PCT_{x,i,j-5} + b * PCT_{x,i,j-10} + c * PCT_{x,i,j-15} + d * PCT_{x,i,j-21}}{a + b + c + d}$$

where PCT_{xij} is the percentage of people who was in the group i, aged x, in the year j. The terms a, b, c and d represent the weights of each year in the equation.

Method 2. In this case, for each cohort, we estimate the relationship between the percentages of individuals in each group found in each pair of consecutive PNADs. For instance, in the first PNAD there is a given percentage for people aged x that is in category y. In the following PNAD, we take into account the age group x +n (i.e., the same cohort) and look at the percentage still in category y. We compute the growth rate RG:

$$RG = 1 - \frac{PCT_{x,i,j}}{PCT_{x-5,i,j-5}}$$

After this, we calculated the mean rates for going from age x to age x+5 for every category. We used these means to input values for the distribution of the cohorts in the years when we do not observe them. The results for each group are normalized in such a way that the sum of the four groups is always 100.

Methods 1 and 2 give similar results for workers with *carteira* (see Table). For workers without *carteira* the second method seems to overestimate this group, especially for older workers. For the unemployed and the retired the same thing occurs, the difference is more important for the latter. In the analysis we therefore opted for the first method.

Age (2006)	Method 1	Method 2	Longitudinal data
31-35	52,56	52,56	52,56
36-40	52,54	49,53	51,49
41-45	51,64	45,28	51,66
46-50	48,90	39,04	49,44
51-55	41,86	30,47	43,10
56-60	30,46	21,19	30,93
61-65	17,09	12,35	16,33
66-70	4,80	4,29	4,35
71+	0,93	0,95	0,87

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This paper solves and estimates a stochastic model of optimal inter-temporal behavior to assess how changes in the design of the income protection and pension systems in Brazil could affect savings rates, the share of time that individuals spend outside of the formal sector, and retirement decisions. Dynamics depend on five main parameters: preferences regarding consumption and leisure, preferences regarding formal Vs. informal work, attitudes towards risks, the rate of time preference, and the distributions of two exogenous shocks that affect movements in and out of the social security system (independently of individual decisions). The yearly household survey is used to create a pseudo panel by age-cohorts and estimate the joint distribution of model parameters based on a generalized version of the Gibbs sampler. The model does a good job in replicating the distribution of the members of the cohort across states (in or out of the social security / active or retired). Because the parameters are related to individual preferences or exogenous shocks, the joint distribution is unlikely to change when the social insurance system changes. Thus, the model is used to explore how alternative policy interventions could affect behaviors and through this channel benefit levels and fiscal costs. The results from various simulations provide three main insights: (i) the Brazilian SI system today might generate unnecessary distortions (lower savings rates, less formal employment, and more early retirement) that increase the costs of the system and might generate regressive redistribution; (ii) there are important interactions between the income protection and pension systems, which calls for joint policy analysis when considering reforms; and (iii) current distortions could be reduced by creating an actuarial link between contributions and benefits and then giving matching contributions or matching capital to individuals with limited savings capacity, which requires having individual savings accounts that can be funded or notional.

HUMAN DEVELOPMENT NETWORK