PEF, **11** (3): 337–364, July, 2012. © Cambridge University Press 2012
doi:10.1017/S1474747211000564 First published online 16 February 2012

Redistribution, insurance and incentives to work in Latin-American pension programs

ALVARO FORTEZA and GUZMÁN OURENS
Departamento de Economía, Facultad de Ciencias Sociales, Universidad de la República, Uruguay
(*e-mail*: alvarof@decon.edu.uy, guzman@decon.edu.uy)

Abstract

We present a new database of social security indicators for 11 Latin-American countries designed to show how much they promise to pay in return to contributions. These are based on micro-simulations according to existing norms. We use response-surface analysis to characterize simulation results. Our results indicate that most programs are progressive. The length of service (LOS) has a strong impact on the expected returns to contributions. In several programs, the expected rates of return exhibit striking discontinuities in the LOS, mostly due to vesting period conditions. This implies these programs may be exacerbating income risk.

JEL CODES: H55, J14, J26

Keywords: Internal rate of return, replacement rate, redistribution, insurance, incentives to work.

1. Introduction

In this paper, we present a new database of social security indicators designed to assess pension schemes in terms of the payments they promise in return to contributions.[1] We use these data to assess several Latin-American pension programs in terms of their impact on income inequality, insurance and incentives to work. The indicators are based on micro-simulations of lifetime contributions and pension rights according to social security norms. Unless explicitly indicated, we consider pension norms as of 2007. We provide two synthetic indicators: the expected internal rate of

Anna Caristo, Cecilia Lara and Ana Inés Morató provided excellent research assistance. The World Bank financed this study, but we hold full responsibility for its contents. We want to thank Eduardo Morón, Alejandro Rodríguez, Rafael Rofman, Adolfo Sarmiento, José Varela and participants at seminars at Universidad Nacional de Córdoba, Argentina, Universidad de la República, Uruguay, the World Bank and Gothenburg University, Sweden, for useful comments on a previous version. A referee from this journal provided valuable comments on a previous version. We are also indebted to Diana Cárdenas, Loredana Helmsdorff and Ronaldo Gómez for calling our attention to details of the Colombian pension system, to Federico Escobar for clarifications about the Bolivian system and to Luis Eduardo Afonso for providing insights on the Brazilian system. We are especially grateful to David Robalino for his support throughout this project and for valuable comments on previous versions. The usual disclaimer applies.

[1] The complete database is available as an Excel file named 'Forteza_Ourens_Social_Security_Indicators_Version1.xls'.

return (IRR) and the replacement rate (RR) implicit in the simulated cash flows of contributions and benefits. The current version of the database covers the main pension programs in 11 Latin-American countries: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela.

Our set of countries includes a considerable variety of pension program designs. Some countries have traditional pay-as-you-go defined benefit (PAYG-DB) programs: Brazil, Ecuador[2], Paraguay and Venezuela. Other countries introduced individual accounts defined contribution (DC) programs and phased out the traditional PAYG-DB programs: Bolivia, Chile and Mexico. Colombia and Peru introduced savings accounts, but without phasing out the PAYG-DB programs: contributors can choose the program. The term 'parallel model' has been coined to refer to this design (Mesa Lago, 2006). Finally, a few countries introduced savings accounts and maintained the traditional PAYG-DB programs, like in the parallel model, but with the additional twist that each worker is covered by both schemes. This design was called the 'mixed model' and is represented in our study in Argentina[3] and Uruguay. We present a brief description of Latin-American pension programs in the appendix (Tables A1 and A2).

The design of a pension scheme has important implications in terms of income inequality, insurance and incentives to work. The effects are difficult to assess because the outcome depends on the interactions between several parameters of the scheme as well as on characteristics of the population and the economy. The IRR and the RR are two synthetic indicators useful in this assessment. The IRR measures the benefit that workers receive in return for their contributions, in terms of an implicit rate of return. The RR is the pension–wage ratio and provides a direct measure of the ability of the scheme to replace the wages that cease when a worker retires.

Our analysis focuses on the design of the schemes and hence on the promises they make rather than on actual performance. This acknowledgment/warning is important in a region where the gap between *de jure* and *de facto* policies is often wide. Most pension administrations cannot strictly abide by the law simply because they do not have the information needed to apply the rules. Also many workers who are legally covered by pension schemes are not covered in practice. Notwithstanding, the analysis of the design of the schemes and their adequacy to the local demographic and economic conditions is an important ingredient of a broader assessment of pension schemes in Latin America.

This paper and the accompanying database are part of a broader project to generate a new set of indicators of social security performance across the world, sponsored by the World Bank. Using IRRs and RRs to assess pension programs is of course not new (see, among many others, Duggan *et al.*, 1995; Beach and Davis, 1998; Leimer, 1999; Gustman and Steinmeier, 2001; Afonso and Fernandes, 2005), but to the best of our knowledge there is no similar database that provides estimations of these indicators for Latin-American pension programs on standardized and comparable

[2] In the 1990s, Ecuador passed a reform law that would introduce savings accounts, but the constitutionality of this law was contested and the savings accounts were not introduced.
[3] In 2008, the individual accounts pillar was phased out in Argentina. We nevertheless include this case as a mixed model because we are simulating the 2007 rules.

conditions. The most direct antecedents of this contribution are Robalino (2005), who follows a similar strategy to assess incentives, redistribution and sustainability of the pension schemes in the Middle East and North Africa, and Dorfman and Forteza (2010), who present a similar analysis for the Caribbean.

In the following section, we present the methodology. In Section 3, we present our results, focusing first on income redistribution and then on insurance and incentives to work. Section 4 presents conclusions.

2. Methodology

Social security programs involve pretty complex contracts between workers, employers and social security administrations. Workers and employers are supposed to contribute over several decades in exchange for pensions, some of which have to be paid until death, and often even beyond death (survivor benefits). Assessing the design of a program is not simple as the impact of each norm on the final result depends on other norms plus some demographic and socio-economic characteristics of the covered population. The IRRs and the RRs are two synthetic indicators that summarize the interactions between all these ingredients and provide the basis for meaningful comparisons across programs and time. While the analysis in this paper rests mostly on the IRRs and only subsidiary on the RRs, we comment on both here because both indicators were included in the database that accompanies this paper.

RRs denote 'the value of a pension as a proportion of a worker's wage during some base period, such as the last year or two before retirement or the entire lifetime average wage' (World Bank, 1994: p. xxiii). In order to make the results comparable across countries, we standardized this measure choosing the last year as the base period. In the denominator, we compute all labor income (net of contributions), and not only insured wages, because we want to measure the proportion of worker's labor income that is replaced with pensions. In a few cases, we will also refer to the RRs as they are defined in the legal norms. To avoid confusion, we will refer to the latter as the technical RRs. Unlike the RRs, the technical RRs are not directly comparable across countries and programs because of different definitions of the reference wage. Note that the RRs can be computed not only in DB programs that have a well-defined technical RR but also in DC and mixed social security programs, and the interpretation is the same: the percentage of the final wage that is replaced with the initial pension.

The literature has followed two different strategies to perform this type of analysis (Leimer, 1999). One is to use surveys and social security records to gather data on contributions paid and benefits received by workers. The other strategy is to simulate flows of labor income of hypothetical workers and compute the contributions and benefits according to existing norms. We follow the second approach, partly dictated by data availability and partly by our goals. We want to build a database of social security indicators that can be used to assess the design of the systems and that allow for cross-country comparisons. In developing countries, the gap between design and actual implementation is usually large, and hence contributions paid and benefits received may not accurately reflect the design of the programs. If our goals were instead to assess the performance of a program in a certain period or under specific circumstances that were observed in one or more countries, the first approach would probably be more appropriate. Regarding cross-country comparisons, it is usually difficult and risky to compare results provided in different studies because the assumptions are different. It is obviously easier to standardize conditions to facilitate comparisons using simulated working life histories than data from surveys and administrative records.

2.1. The simulations

Simulated workers are born in 2007. Unless explicitly indicated, we assume that they will be subject to the social security rules as of 2007.[4] The basic rules and parameters of each pension scheme were taken from Social Security Administration (2008) and complemented with local sources in most countries. The list of these sources is included in the references section. We present a brief description of the pension programs in the appendix.

In the parallel models (Colombia and Peru), we present simulations for both the PAYG-DB and the individual accounts DC programs. In the mixed models (Argentina and Uruguay), it is not possible to separate the DB and DC segments of the program so neatly, but some useful distinction can still be made. In the case of Argentina, workers can choose to contribute only to the PAYG or split contributions between both the PAYG and the individual accounts programs. So while some are covered exclusively by the PAYG program, no one is exclusively covered by individual accounts. We will refer to the former as PAYG and the latter as individual accounts, even though the latter is actually mixed. Something similar happens in Uruguay, but in this case only low-wage earners can make a choice: workers earning more than a certain threshold must participate in both DB and DC tiers. Hence, in this case, we will use the label 'individual accounts' to refer to simulations done for individuals who contribute to both tiers, either because they explicitly opted or because they had to participate in both. We will use the label 'PAYG' to refer to the set of rules that applies to individuals who did not opt to contribute to individual accounts. Readers should keep in mind, though, that some of them, those earning sufficiently high wages have to contribute also to the individual accounts tier even if they do not explicitly opt to do it.

We simulate the cash flows of contributions and pensions and compute the IRRs first in a 'base case scenario' and then in other scenarios designed to perform sensitivity analysis. We first describe the base case scenario in detail and then explain how and why the other scenarios differ from the base case.

In the base case scenario, workers enroll in the social security program at 30 and contribute without interruptions until they turn 65, when they retire and claim

[4] In Chile, Paraguay and Uruguay, we also simulate the reforms passed in 2007–2008. The main change in Uruguay was the loosening of the vesting period conditions. In the case of Chile, the assistance and minimum pension provisions were better integrated and expanded and the 20 years of contributions previously required to access the minimum pension guarantee was dropped. In Paraguay, individuals who fail to fulfill the 25 years of contribution required to access to a pension are now allowed to continue contributing, even if they are not working, to fulfill the condition.

pensions. Because of uncertain death, not all individuals complete this cycle, though. Following standard practice, we simulate the expected cash flows, computed as the flows of contributions and pensions conditional on being alive times the survival probabilities (Liebman, 2001; Brown *et al.* 2009; among others). We use the World Health Organization 2006 country- and sex-specific mortality tables (World Health Organization, 2008).[5]

Following Robichek (1975), we computed the expected IRRs (ρ) as the rates that cancel the expected discounted cash flows:

$$-\sum_{a=\mathbf{0}}^{a=r-\mathbf{1}} p(a)C(a)(1+\rho)^{-a}+\sum_{a=r}^{a=\max\text{age}} p(a)B(a,r)(1+\rho)^{-a}=0,$$

where $p(a)$ is the probability of worker's survival at age a, conditional on being alive at age 0; r is the age at retirement; $C(a)$ is the contribution to social security at age a; maxage is maximum potential age (survival probability is zero above this age); $B(a, r)$ is the amount of retirement benefits at age a conditional on retirement at age r.

The rate of return does not exist in scenarios in which individuals pay contributions but receive no benefits because they do not fulfill eligibility conditions. This is a drawback of this indicator, because it is not providing a measure of the return to social security contributions in these scenarios.

Age and labor earnings profiles are crucial for social security contributions and benefits. It is useful to distinguish the level and the shape of the age-earnings profiles. In the base case scenario, workers' lifetime average labor income is equal to their respective country's per capita GDP over their working life. This choice is meant to capture cases that are empirically relevant in each country.[6] As to the shape of the earnings profiles, we assumed that real wages grow at a constant rate across the life cycle. In the base case scenario, this rate is 2 ppa (percent per annum), equal to the assumed rate of growth of real GDP per capita.[7]

The flows over which we compute the IRRs include both the insured and the employers' contributions. Some might disagree with this choice, possibly arguing that only the insured contributions fall on workers' shoulders. Most economists would argue, however, that this distinction is not economically meaningful since both the insured and the employers' contributions are part of the payroll taxes. What could be more relevant is to split the impact of contributions between lower after-tax wages and higher labor costs. Payroll taxes would reduce after-tax wages one-to-one in the long run in a neoclassical small open economy model. In this environment,

[5] It is possible that these statistics underestimate the life expectancy of contributors to pension programs for two reasons. First, in Latin America the pool of contributors are relatively better off and are likely to have higher life expectancy than the excluded. Second, WHO mortality tables are cross sectional, i.e. they are not cohort specific. It is reasonable, however, to expect lower mortality rates for recent cohorts. Because of this, the IRRs that actual contributors of the cohort born in 2007 would get might be higher than reported in this study, at least in DB programs.

[6] Whitehouse (2007) and OECD (2009) use the average labor income of the population enrolled in Social Security rather than per capita GDP. We do not have this information for Latin American countries.

[7] This assumption ensures that in our simulations the aggregate labor income to GDP ratio remains constant, which is one of the stylized facts of long run growth as first described by Kaldor (see, for example, Acemoglu, 2009).

contributions represent a burden on workers' shoulders and should be fully included in the simulated cash flows. In practice, in a non-neoclassical world, the impact of payroll taxes on after-tax wages might be smaller than one-to-one even over relatively extended periods. If this is so, the burden of the system on workers would be smaller than assumed in our simulations. Nevertheless, computing the cash flows with total contributions would still be appropriate to assess the cost that the program imposes on the job position, which might be the most relevant approach in assessing incentive issues. In a non-neoclassical world, this assumption would be less appropriate for the assessment of the impact of pension programs on income inequality. Gruber (1999, p. 90) and Brown *et al.* (2009) make the same assumption. Hamermesh and Rees (1993, p. 212) review the empirical literature and conclude that employees bear most of the burden of payroll taxation, providing support to our assumption.

It should be noted that most pension programs have other sources of funds apart from contributions. Most governments partially finance these programs from general taxes. We made no attempt at computing the general taxes workers pay to indirectly finance pensions. The rates of return that workers receive from the pension programs are thus likely to be lower than what our simulations suggest. This is particularly true in the case of countries with mature pension programs, which usually have deficits that governments help to finance. If the payroll and general taxes were distributed similarly among workers, the results we got in terms of income redistribution would probably not differ qualitatively from what we would have gotten had we been able to compute all sources of pension funds. Under these conditions, the same workers who are net winners (losers) according to our analysis would continue being so in a more complete analysis that included these other sources of pension funds. In turn, the incentives to work should not hinge too much on general taxes that workers must pay independently of whether they participate in the social security system. Consider, for example, the case of Uruguay, where part of the value-added tax is earmarked to finance pensions. One could argue that the decision to participate in formal labor markets is relatively independent of the decision to pay the value-added tax. Things might be less clear in the case of the income tax, for the decision to evade social security contributions could somehow be linked to the decision to evade the income tax.

In the current version of our database, we have included results for three different types of units: single males, single females and two-person households. The structure of these households is highly stylized: it is composed of a man and a woman of the same age and with the same labor income. The analysis presented in this paper is based on the results obtained for these two-person households. In all cases, we have assumed that individuals do not generate survivor benefits or suffer disability, and so the only benefit they effectively receive is the old-age pension. These workers are nevertheless covered by disability and survivor insurance as well, and therefore contribute to the old-age, survivor and disability programs. They simply are not eligible for survivor and disability benefits because we assumed that they do not suffer disability and leave no survivors. Workers who do generate survivor benefits or receive a disability pension would receive higher IRRs than the set of workers simulated in the current version.

In the spirit of Whitehouse (2007) and OECD (2009), we standardized some conditions to make the results more comparable across countries and to focus mainly on design issues. We assumed that all pension funds and annuity providers receive the same 3.5 ppa real interest rate (net of fees and other costs) across countries and programs. While it is possible that different programs get different real interest rates, we prefer at this stage to explore differences between programs that do not hinge on the divergent abilities of the pension funds to yield different net returns. We used the same interest rate for discounting.

The insurable wage ceilings, the minimum and maximum pensions, minimum wages, insured wage thresholds and all other system parameters that are set in nominal terms grow at the same rate as the average wage and the nominal GDP per capita. In all the simulations and countries, these variables grow at 4.5 ppa. These assumptions ensure that these variables maintain a constant proportion over time, which looks like a sensible assumption in the long run.

The results are particularly sensitive to the assumptions made about the adjustment of pensions and, to a lesser extent, the 'valorization' of wages for pension computation. In most countries, we did not find formal indexation rules. Failing to adjust pensions to prices has been a common practice in the region. Nevertheless, we assumed that all programs index pensions to the consumer price index, unless explicitly indicated otherwise. Analogously, we adjusted wages used to compute pensions in DB programs ('valorization') according to inflation. Uruguay is an exception, since the constitution explicitly mandates indexation of pensions and valorization of wages to the average wage index. Hence, too, in the Argentinean PAYG pillar, wages are 'valorized' with the average wage index.

All the flows are before taxes, and so we computed gross IRRs. All the IRRs we present are real.

We performed sensitivity analysis in four dimensions, namely: (i) the average wage level, (ii) the rate of growth of wages, (iii) the length of service (LOS) and (iv) the age of retirement. We simulated 300 scenarios for each program, combining five average wage levels, three rates of growth of wages, five ages of enrollment to the programs and four retirement ages. The values were chosen to introduce enough statistical variation to determine whether the variables of interest significantly impact on the expected IRR. The details are as follows.

The average wage along the lifecycle of the simulated workers was set at five different levels, corresponding to one-quarter, one-half, one, two and four times the country's average GDP per capita over their working life. In a few cases, in which wages computed in this way would have been lower than the legal minimum wage, we imposed the legal minimum. Therefore, in countries with comparatively high minimum wages, the range of wages in the simulations is narrower than in other countries. In our simulations, like in the real world, minimum wages tend to compress the wage distribution.

We introduced variation in the slope of the age-earnings profiles setting the rate of growth of the real wage at 1, 2 and 3 ppa. Combining the five levels and three slopes, we simulated 15 different age-earnings profiles for each program.

The LOS is the number of years the individual is supposed to be effectively contributing. In our simulations, this is equal to the retirement minus the enrollment ages. Hence, while we do not explicitly simulate interruptions in the contribution spells, we do consider the main effect of these interruptions, namely the reduction of the periods of contribution. We considered five enrollment ages (25, 30, 35, 40 and 45) and four retirement ages (55, 60, 65 and 70), and so the LOS ranged between 10 and 45 years.

2.2. Response surfaces

Our simulations yield a wide range of IRRs, both across countries and scenarios, and hence the database has potentially interesting statistical variability. Having simulated thousands of scenarios, it is obviously impossible and not very enlightening to describe each and all of them in detail; hence, we will mostly appeal to regression analysis to characterize and summarize our simulation results. The regression model is a representation of the response of the outcome variable to the variation of the control variables across simulations. This representation is usually known as the response surface.

Besides being a parsimonious way of summarizing simulation results, response-surface analysis helps to dealing with what Hendry (1984) called the problem of specificity. Each simulation gives information about the performance of the program with one set of parameter values. A finite number of simulations extend this information, but only to a finite set of parameter values. Results are often presented in several tables. With no further analysis, users of this information often have to interpolate from the results in the tables, something that may be difficult and even misleading. Response-surface analysis is a systematic way of extending the simulation results to a continuous range of parameter values. It is particularly useful in the case of complex systems like pension programs, where exogenous variables often interact (the impact of one variable on the outcome depends on the value of other variables) and so simple interpolation may not be warranted. Also response surfaces in pension programs often exhibit discontinuities – the outcome variable exhibits a discrete jump when the exogenous variable varies by a very small amount – something that may be relevant for the assessment of the programs and difficult to identify without this type of analysis. An example of this is the discrete and often large change in the IRR we observe when an individual adds one period of service that is just enough to fulfill a vesting period condition and he/she has already fulfilled other eligibility conditions (like minimum retirement age).

Response-surface analysis has been used in several fields. In econometrics, for example, response surfaces have been extensively used to summarize and assess the outcomes of Monte Carlo simulations (Hendry, 1984, provides a survey). In these applications, the usual goal of the analysis is to characterize the distribution of statistics when purely analytical characterization is not feasible. Response-surface methodology is also extensively used in engineering to optimize processes (Myers *et al*., 2009). The outcome is usually an indicator of the efficiency of an industrial process and the control variables are conditions of the process that can be modified at will to get the most efficient result. The analysis involves characterizing the response surface and then using it to find the point at which the process is optimized.

Our response-surface analysis is close to the typical econometric use of the methodology and departs from engineering applications in that we do not pursue the optimization of a process but the characterization of the impact on the response variable of changes in control variables. But we depart from typical econometric applications and come closer to some engineering applications of the methodology in that our simulations are deterministic.[8]

We run the following regression:

$$\begin{aligned}\text{IRR} = {} & \beta_0 + \beta_w w + \beta_{w2} w^2 + \beta_{\hat{w}} \hat{w} + \beta_{\text{los}} \text{los} + \beta_{\text{los2}} \text{los}^2 + \beta_{\text{los\_Dves1}} \text{los} \times \text{Dves1} \\ & + \beta_{\text{los2\_Dves1}} \text{los}^2 \times \text{Dves1} + \beta_{\text{los\_Dves2}} \text{los} \times \text{Dves2} + \beta_{\text{Dves1}} \text{Dves1} \\ & + \beta_{\text{Dves2}} \text{Dves2} + \beta_{\text{ra}} \text{ra} + \beta_{\text{ra2}} \text{ra}^2\end{aligned}, \quad (1)$$

There are five sets of regressors in this equation: the wage level (in natural logs, w), the rate of growth of wages ($\hat{w}$), the length of service (los), dummies for vesting periods (Dves1, Dves2) and the retirement age (ra).

The wage level is meant to capture the redistributive nature of the program. The pension schemes are supposed to be progressive in the sense that workers with low average income should receive higher returns than the well off, and so $\beta_w + 2\beta_{w2} w$ is expected to be negative in the relevant range values.

The rate of growth of real wages along the life cycle is meant to capture the impact of the shape of the age-earnings profile on redistribution. Higher rates of growth of wages imply steeper-earnings profiles. In DB programs, the benefit formula is often based on the average of contribution wages in the last few years of contribution, which tends to be higher the steeper the earnings profiles. Hence, we expect $\beta_{\hat{w}}$ to be positive in these programs.

The LOS equals the years of effective contribution in our simulations. In most programs, pensions are supposed to be increasing functions of the periods of contribution, but other provisions like minimum and maximum pensions often interfere. Also, even when pensions increase with the number of periods of contribution, it is not *a priori* obvious whether the compensation is actuarially fair.

Most programs have vesting-period conditions. They most often apply not only for ordinary pension eligibility but also for minimum pension guarantees, special 'advanced-age' benefits and reimbursement of contributions. We included in the regressions dummies that indicate whether vesting-period conditions are being fulfilled, i.e., variables that are equal to 1 when the LOS is equal to or larger than the minimum number of periods required to access a benefit and 0 otherwise. In a few cases, we had to include in the regression two dummies for vesting-period conditions (Dves1 and Dves2). More formally, these dummies are defined as follows: $\text{DvesI} = 1$ if $\text{los} \geqslant \text{vesI}$ and 0 otherwise, where vesI *i*s the vesting-period condition, i.e., the minimum number of periods of contribution required to access benefit $I \in \{1,2\}$. We ordered benefits in such a way that $\text{ves1} < \text{ves2}$.

In most cases, the impact of the LOS on the IRRs depends crucially on whether the vesting-period conditions are being fulfilled. Interaction of the LOS with dummies

[8] Our simulation model is stochastic regarding death, but our statistics of interest, the expected internal rate of return, is not so. Hence, we only generate one replication for each 'experiment'.

that capture this status is the key to an appropriate characterization of the response surface in those cases. We also allow for different intercepts conditional on whether the vesting-period conditions are fulfilled.

Response surfaces often show discontinuities in the LOS when the contributor switches the vesting status, i.e., when by adding one more period of contributions the contributor becomes eligible for a benefit. The impact of such changes on the IRRs can be computed with the help of the regression model. Let ves1 be the minimum LOS or number of periods of contribution required to access benefit number 1. We are interested in computing: $E[\text{IRR}|\text{los}=\text{ves1}]-E[\text{IRR}|\text{los}=(\text{ves1}-1)]$, i.e., the difference in the expected value of the IRR when the LOS is exactly equal to the vesting-period condition and when it is one period less than that. Using that $\text{Dves1}=1$ if $\text{los}\geqslant\text{ves1}$ and 0 otherwise, we have that

$$E[\text{IRR}|\text{los}=\text{ves1}]-E[\text{IRR}\mid\text{los}=(\text{ves1}-1)]$$
$$=E[\text{IRR}\mid\text{los}=\text{ves1}\&\text{Dves1}=1]-E[\text{IRR}\mid\text{los}=(\text{ves1}-1)\&\text{Dves1}=0]$$

Applying this expression to regression model (1), the expected impact on the IRR of adding one more year of contributions when the additional year changes the vesting status is

$$E[\text{IRR}\mid\text{los}=\text{ves1}]-\text{E}[\text{IRR}\mid\text{los}=(\text{ves1}-1)]$$
$$=\beta_{\text{los}}+\beta_{\text{los2}}(2\text{ves1}-1)+\beta_{\text{los\_Dves1}}\text{ves1}+\beta_{\text{los2\_Dves1}}\text{ves1}^2+\beta_{\text{Dves1}}$$

$$E[\text{IRR}\mid\text{los}=\text{ves2}]-\text{E}[\text{IRR}\mid\text{los}=(\text{ves2}-1)]$$
$$=\beta_{\text{los}}+\beta_{\text{los2}}(2\text{ves2}-1)+\beta_{\text{los\_Dves1}}+\beta_{\text{los2\_Dves1}}(2\text{ves2}-1)+\beta_{\text{los\_Dves2}}\text{ves2}+\beta_{\text{Dves2}}$$

Finally, the retirement age has, in principle, ambiguous effects on the rates of return. Most programs reward late retirement with higher pensions, but it is not *a priori* obvious whether these rewards compensate workers for more periods contributing and fewer periods collecting pensions. A quadratic expression in the age of retirement provided the best fit in several cases.

3. Results

We organize our results in terms of the two main dimensions of Latin-American pension programs we are assessing in this study, namely (i) income redistribution and (ii) insurance and incentives to work. The first two regressors are meant to capture redistribution and the last three to capture insurance and incentives to work. Table 1 summarizes the regression results.

3.1 Redistribution

Results in Table 1 indicate that Latin-American pension programs are mostly progressive: they are designed to provide higher IRRs to low- than to high-income workers. In no program did we find a positive slope of the response surface in wages and in most programs we did find negative slopes.

A quadratic function in (log) wages fitted the data significantly better than the (log) linear function in the Latin-American pooled regression. The coefficient multiplying wages is negative and the coefficient multiplying the squared wage level is positive, both are highly significant, implying a convex function. The slope is negative within the whole simulated wage range in most cases. Our point estimate of the semi-elasticity of the IRRs to the average wage level is −0.98 when the wage level equals per capita GDP.[9] Therefore, individuals earning, for example, 1.1 times per capita GDP are expected to get IRRs at 0.098 percentage points lower on average than individuals earning per capita GDP. These figures provide an idea of how redistributive Latin-American programs are on average, but there is much diversity across programs in the region. We turn now to the analysis of individual pension programs.

In most programs, the coefficients that multiply the natural log of wages turned out to be negative and highly statistically significant. In no program did we find a positive coefficient and in only three programs we could not reject the hypothesis that this coefficient is zero. These three programs are the Ecuadorian and Paraguayan PAYG-DB and the Peruvian individual accounts programs. It should be mentioned that in the cases of Ecuador and Paraguay, the range of wages in our simulations turned out to be narrower than initially planned, because of the minimum wage. In the case of Paraguay, we could not simulate workers earning per capita GDP or less since the minimum wage is larger than per capita GDP. Hence, rather than simulating wages ranging from one-fourth to four times per capita GDP, we simulated Paraguayan wages ranging from about 1.5 to 4 times per capita GDP.[10] In Ecuador, the minimum wage is higher than one-half per capita GDP so that the first two scenarios (a quarter and a half of per capita GDP) are actually the same. The simulated wages in Ecuador thus ranged from 0.6 to 4 times per capita GDP. In these wage ranges, contributions and pensions scale up proportionally in Paraguay and almost proportionally in Ecuador as wages increase. Hence, the IRRs are the same or almost the same in these scenarios. This is a result of the wage compression caused by minimum wages that are high relative to the country per capita GDP. We cannot rule out the possibility that these two programs look more redistributive at higher-income levels, but our simulations do show that they are not redistributive among workers earning less than four times per capita GDP.

Like in the Latin-American pooled database, a quadratic function in (log) wages fitted the data significantly better than the (log) linear function in several programs. In all but two cases, the coefficient multiplying the squared wage level turned out to be positive, implying a convex function. A typical example is presented in Figure 1 for the Chilean program after the 2008 reform, but a similar pattern emerges for Argentina, Brazil, Chile, Mexico, Uruguay and Venezuela. In all these cases, the increase in the IRR that is associated with a decrease in wages is larger, the lower the wages, reinforcing the redistributive nature of the programs. The Peruvian and the Colombian PAYG-DB are the only programs that yielded a significantly negative coefficient multiplying the squared wage level.

[9] With model (1), the semi-elasticity of the IRRs to wages ($s = \exp(w)$) is $s\ \partial IRR/\partial s = \partial IRR/\partial w = \beta_w + 2\beta_{w2} w$. Therefore, evaluated at the per capita GDP wage level, i.e. at $s = 1$ and $w = 0$, the semi-elasticity is β_w.

[10] We could have simulated richer workers to get the same wage spread in Paraguay as in other countries, but we preferred to build the base case scenario in all countries with workers earning per capita GDP (or the closest possible to that amount when minimum wages were above per capita GDP).

Table 1. *The IRRs regressions*

	Latin America (2007 norms) [1]	Argentina individual accounts	Argentina PAYG	Bolivia	Brazil	Chile (2007 norms)	Chile (2008 norms)	Colombia individual accounts	Colombia PAYG	Ecuador
Wage (Ln)	−0.926***	−1.017***	−1.991***	−1.383***	−0.976***	−0.882***	−1.348***	−0.548***	−0.803***	−0.011
	(0.032)	(0.015)	(0.055)	(0.087)	(0.027)	(0.047)	(0.052)	(0.043)	(0.037)	(0.038)
Wage (Ln) squared	0.185***	0.250***	0.579***		0.422***	0.475***	0.546***		−0.112**	
	(0.039)	(0.018)	(0.067)		(0.033)	(0.057)	(0.064)		(0.045)	
Wage growth	0.099***	0.001	0.156**	0.018	0.089***	0.019	−0.078	0.009	0.144***	0.309***
	(0.039)	(0.018)	(0.066)	(0.105)	(0.032)	(0.056)	(0.063)	(0.052)	(0.044)	(0.046)
Length of service (los)	−0.544***	−0.061***	−0.220***	−0.735***	−0.199***		−0.178***	0.117***		0.231***
	(0.140)	(0.007)	(0.028)	(0.070)	(0.006)		(0.031)	(0.013)		(0.042)
Squared length of service (los^2)	0.049***			0.010***			0.002***			
	(0.006)			(0.001)			(0.001)			
los × Dves1 [2]	0.758***	0.050***	0.064*		0.113***	−0.316***		−0.211***	−0.149***	−0.416***
	(0.096)	(0.009)	(0.036)		(0.014)	(0.057)		(0.017)	(0.008)	(0.050)
los^2 × Dves1	−0.053***					0.004***				
	(0.006)					(0.001)				
los × Dves2	−0.013**	0.013***	0.058***							0.008
	(0.005)	(0.002)	(0.008)							(0.028)
Dves1		−0.735***	0.122	7.607***	−4.280***	6.736***		7.783***	12.429***	6.527***
		(0.193)	(0.727)	(0.563)	(0.520)	(0.869)		(0.502)	(0.243)	(0.833)
Dves2										0.746
										(0.701)
Retirement age	1.113***	−0.037***	1.085***	2.095***	2.258***	0.759***	0.030***	0.092	0.804***	3.840***
	(0.164)	(0.003)	(0.281)	(0.447)	(0.136)	(0.236)	(0.012)	(0.217)	(0.181)	(0.197)
Squared retirement age	−0.009***		−0.009***	−0.017***	−0.018***	−0.006***		−0.001	−0.007***	−0.030***
	(0.001)		(0.002)	(0.004)	(0.001)	(0.002)		(0.002)	(0.001)	(0.002)
Constant	−33.198***	4.872***	−27.504***	−53.565***	−62.590***	−20.415***	5.941***	−1.549	−25.090***	−118.929***
	(5.168)	(0.214)	(8.612)	(13.740)	(4.249)	(7.318)	(0.741)	(6.711)	(5.623)	(6.025)
Observations	4,341	300	300	300	285	300	300	300	300	300
Adjusted R^2	0.515	0.944	0.838	0.691	0.951	0.681	0.754	0.740	0.970	0.780

	Mexico	Paraguay (2007 norms)	Paraguay (2008 norms)	Peru (Individual accounts)	Peru (PAYG)	Uruguay (2007 norms) Individual accounts	Uruguay (2007 norms) PAYG	Uruguay (2008 norms) Individual accounts	Uruguay (2008 norms) PAYG	Venezuela
Wage (Ln)	−0.985***	−0.000	0.009	−0.000	−2.332***	−0.767***	−0.706***	−0.909***	−0.918***	−1.428***
	(0.045)	(0.027)	(0.037)	(0.000)	(0.047)	(0.025)	(0.027)	(0.026)	(0.029)	(0.098)
Wage (Ln) squared	0.588***				−0.388***	0.223***	0.480***	0.297***	0.573***	0.225*
	(0.055)				(0.057)	(0.030)	(0.033)	(0.032)	(0.035)	(0.119)
Wage growth	0.057	0.244***	0.205***	−0.000	0.153***	0.039	0.050	0.047	0.059*	0.252**
	(0.054)	(0.033)	(0.044)	(0.000)	(0.056)	(0.030)	(0.033)	(0.032)	(0.034)	(0.117)
Length of service (los)		−0.363***	0.287***	0.000	−0.483***					−0.826***
		(0.049)	(0.041)	(0.000)	(0.053)					(0.078)
Squared length of service (los^2)		0.003***	0.004***		0.005***					0.009***
		(0.001)	(0.001)		(0.001)					(0.001)
los × Dves1 [2]	−0.079***		−0.712***			−0.060***	−0.077***	−0.016	−0.020*	
	(0.009)		(0.046)			(0.006)	(0.007)	(0.010)	(0.011)	
los^2 × Dves1										
los × Dves2						0.010	0.012	−0.034***	−0.043***	
						(0.014)	(0.015)	(0.012)	(0.013)	
Dves1	3.203***		15.935***			5.136***	4.635***	4.424***	3.531***	29.803***
	(0.297)		(1.063)			(0.182)	(0.245)	(0.245)	(0.301)	(0.631)
Dves2						0.244	0.358	0.943***	1.204***	
						(0.495)	(0.533)	(0.336)	(0.355)	
Retirement age	0.464**	1.916***	2.938***	−0.000	2.056***	0.281**	0.338**	0.602***	0.729***	2.048***
	(0.221)	(0.143)	(0.192)	(0.000)	(0.236)	(0.130)	(0.140)	(0.135)	(0.143)	(0.501)
Squared retirement age	−0.004**	−0.016***	−0.024***		−0.017***	−0.002**	−0.003**	−0.005***	−0.006***	−0.016***
	(0.002)	(0.001)	(0.002)		(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)
Constant	−11.662*	−45.615***	−93.562***	3.500***	−46.379***	−10.140**	−11.583***	−19.983***	−23.364***	−71.439***
	(6.871)	(4.402)	(5.836)	(0.000)	(7.350)	(4.008)	(4.320)	(4.169)	(4.408)	(15.397)
Observations	300	210	300	300	255	300	291	300	291	300
Adjusted R^2	0.713	0.914	0.848	−0.009	0.937	0.884	0.828	0.895	0.865	0.921

***$P<0.01$, **$P<0.05$, *$P<0.1$.

[1] Country dummies are not reported.

[2] DvesI = 1 if los ⩾ vesI and 0 otherwise, where vesI as indicated in Table 2 with $I \in \{1,2\}$.

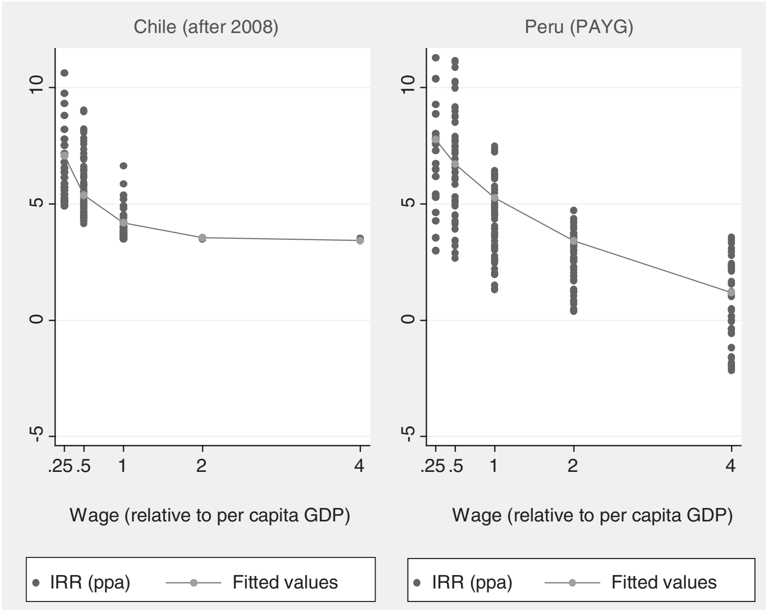
Source: Authors' computations.

Table 2. *Impact on the IRRs of fulfilling the vesting period conditions*

	First vesting-period condition			Second vesting-period condition		
Program	Ves1 (years)	E[ΔIRR][1] (ppa)	P-value	Ves2 (years)	E[ΔIRR] (ppa)	P-value
Argentina, individual accounts	25	0.5	0.000	30	0.4	0.000
Argentina, PAYG	25	1.5	0.000	30	1.6	0.000
Bolivia	15	7.2	0.000			
Brazil	35	−0.5	0.000			
Chile (2007 norms)	20	1.9	0.000			
Chile (2008 norms)						
Colombia, individual accounts	30	1.6	0.000			
Colombia, PAYG	25	8.7	0.000			
Ecuador	20	−1.6	0.000	30	0.1	0.933
Mexico	25	1.2	0.000			
Paraguay (2007 norms)						
Paraguay (2008 norms)	25	−1.6	0.000			
Peru, individual accounts						
Peru, PAYG						
Uruguay, individual accounts (2007 norms)	15	4.2	0.000	35	0.5	0.000
Uruguay, PAYG (2007 norms)	15	3.5	0.000	35	0.7	0.000
Uruguay, individual accounts (2008 norms)	15	4.2	0.000	30	−0.1	0.360
Uruguay, PAYG (2008 norms)	15	3.2	0.000	30	−0.1	0.373
Venezuela	15	29.2	0.000			

[1] $E[\Delta IRR] = E[IRR \mid los = ves] - E[IRR \mid los = (ves - 1)]$.
Source: Authors' computations.

Minimum and maximum pensions are two of the provisions that directly impact on redistributions. All the programs analyzed in this study have minimum pensions, but not all of them have maximum pensions. In some cases, there is a ceiling on insured wages, so that above this ceiling contributions are voluntary. In the case of DB designs, the ceiling on contributions indirectly generates a ceiling on benefits, but unlike maximum pensions, ceilings are not redistributive. The clearest example of the use of minimum and maximum pensions to redistribute is the Peruvian PAYG program, where the maximum is only about twice the minimum. The Argentinean program also performs redistributions through the basic pension, which does not depend on contributed amounts and therefore is flat across income levels. The Mexican government pays a flat contribution for every working person (*cuota social*). This flat contribution implies a greater subsidy, as a proportion of insured contributions, for people with lower earnings, and this makes the IRRs decrease with income. In the case of Colombia, workers earning four minimum wages or more have to pay an extra contribution.



Source: Authors' computations

Figure 1. Simulated and fitted IRRs in selected programs. The impact of the wage level.
Source: Authors' computations.

It is interesting to note that all the DC individual accounts programs, save the already mentioned Peruvian one, are progressive. Provisions like minimum pensions, government matching contributions and basic universal pensions complement these otherwise actuarially fair programs rendering them redistributive. The Bolivian and Chilean individual account schemes, for example, yield the same IRRs for a wide range of sufficiently high-income levels, but low-income workers get higher returns, thanks to minimum pensions and government subsidies.

In the case of Chile, a reform passed in 2008 strengthened the redistributive ingredients in the benefit formula. Before the reform, Chilean workers who had contributed at least 20 years but whose accumulated funds did not self-finance a pension above the 'minimum pension guarantee' were tapped to this minimum. The reform will gradually substitute the 'solidarity contribution' (*Aporte Previsional Solidario*) for the 'minimum pension guarantee' (*Pensión Mínima Garantizada*). The solidarity contribution is designed in such a way that pensions are always increasing functions of individual cumulative contributions (unlike the minimum pension guarantee that provides the same pension to all beneficiaries). Unlike the minimum pension, the solidarity contribution requires no minimum number of contribution periods to access the benefit. This is a key innovation, for many workers with small accumulations in their accounts were not eligible for the minimum pension guarantee because they had not contributed 20 or more years (Berstein *et al.*, 2006). The reform will be fully effective in about 15 years. According to our estimations, the reform increased the degree of redistribution in the Chilean system as measured by the semi-elasticity of the IRRs to the wage levels. For a worker earning a wage equal to per capita GDP, the semi-elasticity changed from -0.882 to -1.348.

Low-income workers tend to have flatter age-earnings profiles than high-income workers and this might impact on pensions (Bosworth *et al.*, 1999). Many schemes provide pensions that depend on the average insured wages during the last few years of the working careers. These pension formulas benefit workers whose earnings profiles are steeper along the lifecycle, as their contributions are based on wages that are on average low relative to the wages used to compute their pension. Because of this effect, the programs might be less redistributive than what the previous analysis suggests.

Estimating age-earnings profiles for different income levels in the 11 countries covered in this study is well beyond the scope of this paper. We rather assessed the sensitivity of the IRRs to different profiles to see whether this effect is likely to be relevant in the region. To this end, we considered three age-earnings profiles, associated with wage growth equal to 1, 2 and 3 ppa.

Considering the region as a whole, we do not find a large impact of the age-earnings profiles on the returns to social security contributions (Table 1). The coefficient that multiplies the wage growth regressor is positive and significant at 1% level, but the amount of the effect is rather small: the IRR increases 0.1 ppa for each point of increase in the rate of growth of wages. The coefficient is positive and significantly different from zero in all PAYG-DB programs, with the exception of Uruguay (2007 norms). The programs in which this effect tends to be larger use relatively short spells of contribution to compute pensions: Ecuador, Peru and Venezuela base pensions on five and Paraguay on 3 years of contribution. The rate of growth of wages does not show a significant impact on the IRR in individual accounts programs.

These results suggest that the fact that poor workers have comparatively flat age-earnings profiles is not likely to have a major impact on the returns they get from social security in most Latin-American pension programs. However, this issue deserves more attention in some cases. Ecuador and Paraguay, for example, combine a comparatively high positive impact of the rate of growth of wages and a low impact of average wages on the IRR, and therefore pension programs do not seem to contribute to reduce income inequality in these two countries.

3.2 Insurance and incentives to work

Pension schemes are bound to distort *incentives*. Contribution rates are taxes that reduce the incentives to work, at least in the formal sector; and pensions reduce the incentives to save. The less than actuarially fair reduction in benefits that is usually associated with shorter working careers constitutes a hedge against negative shocks in the labor market; it also generates incentives to choose shorter careers. Singularly, it protects senior workers who lose their jobs, but it also opens a window to opportunistic behavior. Hence, too, some design characteristics constitute an invitation to gamble, like the benefit formulas based on last salaries. In many developing countries, these elements are compounded by weak enforcement that facilitates late enrolment and gambling. In this section, we use the IRRs to analyze both the incentives pension programs provide to work and the insurance they offer against shocks that negatively impact on the length of working careers.

There is a widespread concern in Latin America for the impact that low densities of contribution have on pension rights. Several studies have warned that large segments of the Latin-American population contribute only for short periods and may not be eligible for pensions, because they do not fulfill vesting-period conditions, or if they do, they may receive small pensions, because entitlements tend to be linked to contributions (Berstein *et al.*, 2006; Forteza *et al.*, 2009; Bucheli *et al.*, 2010; among others). Some pension schemes provide insurance against this risk with benefit formulas that are relatively inelastic to the contribution history. However, this insurance is usually incomplete, probably because of moral hazard and adverse selection problems. We analyze the impact of the LOS on the expected IRRs to assess the degree of insurance pension programs provide against the risk of short working careers. A pension scheme that does not provide any insurance at all against this risk will effect an actuarially fair reduction in benefits when the LOS decreases. The expected IRR of this scheme will be inelastic to the LOS. The scheme provides insurance if the IRRs decrease as the LOS increases and exacerbates risk in the opposite case.

The age of retirement is another factor that may impact on the length of the contribution period, but it has a distinct component: early retirement provides protection against the risk of losing jobs at ages at which it is difficult to find a new job. Naturally, this insurance also provides incentives to retire early. The behavior of retirement and the incentives in social security to retire have been a major motive for concern in developed countries in recent years (Gruber and Wise, 1999, 2004, 2007). In this section, we analyze the impact of retirement ages on the IRRs response surfaces.

3.2.1 The LOS

The results of the regressions summarized in Table 1 show that the IRR response surfaces tend to be complex functions of the LOS. This variable enters the equations in level, squared and interacted with up to two vesting-period conditions. The response surfaces often exhibit large statistically significant discontinuities in the LOS (Figure 2).

Vesting-period conditions have a striking impact on the IRRs in most programs. Individuals who fall short of fulfilling those conditions tend to get much smaller IRRs. Table 2 presents the expected impact on the IRR of contributing one additional year when vesting-period conditions are binding, i.e., when the additional year switches the status from not fulfilling to exactly fulfilling vesting-period conditions. The table indicates the condition, the expected change in the IRR and the *P*-value. In most cases, failing to fulfill the condition implies a significant drop in the expected IRR.

In PAYG-DB programs, individuals failing to comply with the eligibility conditions often experience large losses. One of the most dramatic examples occurs in Venezuela where the average IRR of individuals contributing less than 15 years is −13 ppa. Something similar, albeit less extreme, happens in the Colombian PAYG pillar, where individuals contributing less than 25 years get an average expected IRR

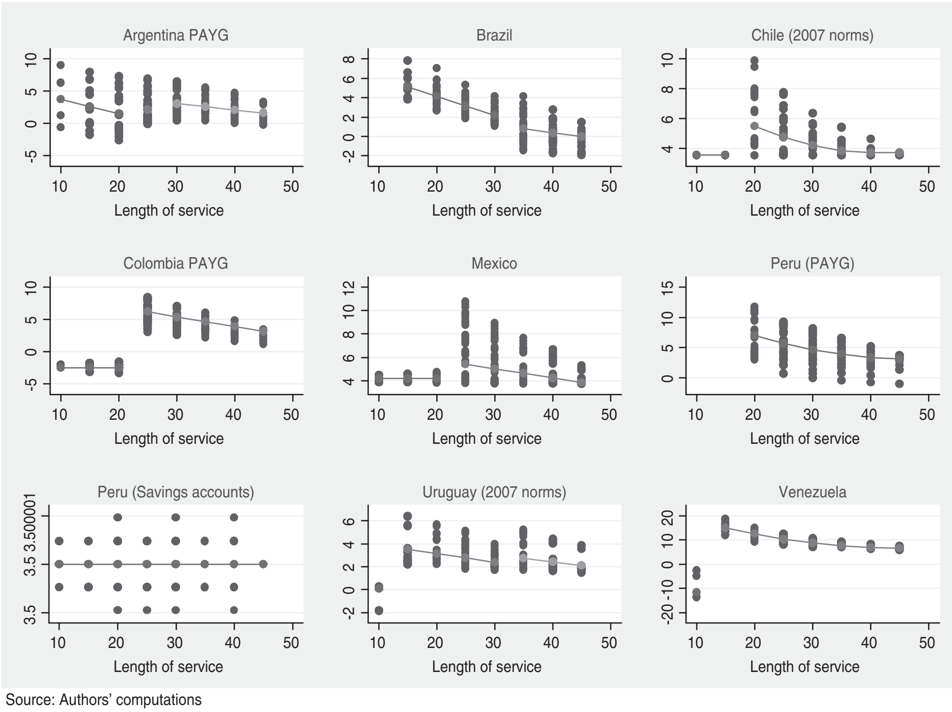


Figure 2. Simulated and fitted IRRs in selected programs. The impact of the LOS. *Source:* Authors' computations.

of −2.2 ppa. The expected impact on the IRR of falling short of the vesting conditions by exactly one year is almost nine percentage points in the Colombian PAYG program and 29 percentage points in the Venezuelan program (Table 2). These individuals are not eligible for pensions and only receive a small lump sum compensation for their contributions. Things are even worse in many DB programs that do not compensate individuals failing to comply with the eligibility conditions. When this happens, the IRRs are not defined, because the cash flows only have negative numbers, and individuals are therefore not represented in the response surface models in Tables 1 and 2.[11] Nevertheless, individuals contributing less than the vesting periods lose all their contributions in these programs.[12]

Some programs require a minimum LOS to access to minimum pensions. Individuals who do not fulfill these conditions tend to get much smaller returns. The Bolivian, Chilean (before 2008) and Colombian individual account programs, for example, require 15, 20 and 25.5 years of contribution to access the minimum-pension guarantee, respectively.[13] Workers contributing fewer periods would get the rate of

[11] The number of observations in regressions in Table 2 is less than 300 in programs in which this happens.
[12] The fact that the IRR does not exist in those cases is an obvious drawback of the indicator. The expected net present value of the cash flows is an alternative indicator that does not suffer from this drawback.
[13] The Colombian individual accounts program pays a minimum pension to individuals who have contributed at least 1,325 weeks (approximately 25.5 years). This threshold is currently lower, but it is gradually being increased to reach 1,325 weeks in 2015 (law 797/2003, article 65). Since we are simulating individuals who are born in 2007, we adopted this threshold for our simulations.

return of pension funds net of fees. In turn, thanks to minimum pensions, Bolivian, Chilean and Colombian workers contributing exactly 15, 20 and 25.5 years to these programs would receive 7.2, 1.9 and 1.6 percentage points more each year, respectively. In Chile, the 2008 reform eliminated this gap by removing the vesting-period condition.

It should be noted that the discrete jumps in the IRRs mentioned above are only 'average' impacts, smoothed out by the parsimonious regression representations of the response surface. We have observed many other sizeable discrete jumps in the IRRs of simulated individuals stemming from small variations in the LOS.

In most programs, the IRRs tend to be decreasing in the LOS, if the vesting period thresholds are not crossed. Indeed, adding years of contributions tends to reduce the IRRs, unless it implies a change in the vesting status (Figure 2). When this happens the IRRs increase, often dramatically, as already shown. But once the vesting period conditions have been fulfilled, the programs tend to pay less than actuarially fair compensations for extending the LOS. Hence, the response surfaces tend to have maximums in the LOS at vesting periods.

Departing from all other programs analyzed in this study, the Peruvian individual accounts program shows no significant effect of the LOS on the IRRs (Table 1 and Figure 2). This program is thus the only one that looks actuarially neutral in this respect.

There is an incentive rationale for the low IRRs we observe associated with short services in many programs, but this design implies that these programs exacerbate income risk, if short LOS is not entirely due to individual choices. In turn, the negative response of the IRRs to the extension of the LOS observed at longer lengths of service provides a hedge against the risk of interruptions. Therefore, these pension programs tend to provide incentives to contribute and to exacerbate risk when contribution histories are relatively short, and to provide insurance against the risk of interruptions when contribution histories are sufficiently long.

One of the goals of the recent wave of reforms in Latin-American pension programs has been to improve social protection. In previous years, some analysts had been warning about the risk that many low-income individuals could fail to fulfill eligibility conditions to get minimum pensions or even ordinary pensions (Berstein *et al.*, 2006; Bucheli *et al.*, 2010). In line with these concerns, some reforms loosened eligibility conditions. Among them, the Chilean 2008 reform is probably the most comprehensive attempt at improving social protection while keeping sustainability. A subsidy that supplements low self-financed pensions substituted the minimum pension and the former independent-assistance program. The subsidy decreases with the amount of the self-financed pension. It is a means tested benefit, but has no vesting-period condition. As it is shown in Figure 3, the reform smoothed out the IRR response surface, eliminating the discontinuity that existed with previous norms at 20 years of contribution.

3.2.2. Retirement age

Pension programs impact on workers' decision to stop working. There is a large literature that analyzes the relationship between social security provisions and

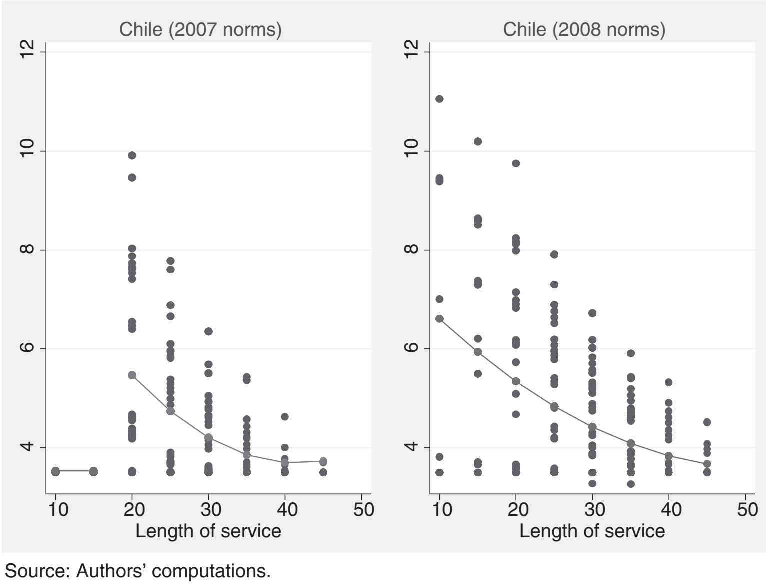


Figure 3. Chile, the IRRs and the LOS before and after the 2008 reform.
Source: Authors' computations.

labor-force participation, mostly in developed countries. The main motivation for these studies is the steady decline in labor-force participation of senior workers observed in recent decades in most developed countries precisely when life expectancies have risen dramatically. Gruber and Wise have documented these trends and systematically explored the relationship between retirement ages and incentives inherent in social security programs in 11 developed countries (Gruber and Wise, 1999, 2004, 2007). They provide evidence that social security systems have contributed to reduce retirement ages in those countries. To the best of our knowledge, there is no comparable systematic effort to analyze the impact of social security programs on retirement in developing countries. While replicating Gruber and Wise's analysis for the Latin-American region is well beyond the scope of the present document, we do provide some systematic comparable analysis of incentives to retire inherent in pension programs in the region using our estimations of IRRs.

As we have already mentioned, we are interested not only in the analysis of the incentives to retire but also in the social protection that pension programs provide against the risk of short working careers. Programs that provide strong incentives to postpone retirement punish workers who retire early. From an insurance perspective, however, it seems desirable to protect workers who retire at relatively young ages due to adverse circumstances that are beyond choice. Hence, we will use our estimations of the IRRs to discuss the insurance that pension programs provide against this risk.

A quadratic function in retirement age provides the best fit for the Latin-American pooled database (Table 1). The coefficients multiplying retirement age and its squared

Table 3. *Impact on the IRRs of retiring a year later*

	Age			
Program	55	60	65	70
Argentina, individual accounts	−0.04	−0.04	−0.04	−0.04
Argentina, PAYG	0.10	0.01	−0.08	−0.17
Bolivia	0.21	0.04	−0.13	−0.30
Brazil	0.27	0.09	−0.09	−0.27
Chile (2007 norms)	0.09	0.03	−0.03	−0.09
Chile (2008 norms)	0.03	0.03	0.03	0.03
Colombia, individual accounts	−0.03	−0.04	−0.05	−0.06
Colombia, PAYG	0.03	−0.04	−0.12	−0.19
Ecuador	0.57	0.27	−0.03	−0.33
Mexico	0.08	0.04	0.01	−0.03
Paraguay (2007 norms)	0.17	0.02	−0.14	−0.30
Paraguay (2008 norms)	0.34	0.10	−0.13	−0.37
Peru, individual accounts	0.00	0.00	0.00	0.00
Peru, PAYG	0.17	0.00	−0.17	−0.34
Uruguay, individual accounts (2007 norms)	0.05	0.03	0.01	−0.01
Uruguay, PAYG (2007 norms)	0.06	0.03	0.01	−0.02
Uruguay, individual accounts (2008 norms)	0.08	0.03	−0.01	−0.06
Uruguay, PAYG (2008 norms)	0.10	0.04	−0.02	−0.08
Venezuela	0.32	0.17	0.01	−0.15

Source: Authors' computations.

value are significantly different from zero at the usual significance levels, the former positive and the latter negative. The IRRs response surface is thus concave in retirement ages and exhibits a maximum at about 63 years. According to these results, Latin-American pension programs seem to be designed to disincentive retirement at early ages. The counterpart is that workers who lose jobs and cannot continue contributing at these ages tend to be punished with lower IRRs on their contributions to social security. At these retirement ages, pension programs are exacerbating risk. Notwithstanding, the response surface is pretty flat in a considerably wide vicinity of the maximum, so for these retirement ages Latin-American programs are on average close to actuarially neutral to changes in retirement ages (Table 3).

A similar pattern emerges in most pension programs in the region: like in the pooled database, individual programs exhibit concave, but pretty flat, response surfaces. The retirement ages that maximize the IRRs range from 43 in the Colombian individual accounts program to 66 in the Uruguayan (2007 norms) one. This wide range of IRR-maximizing retirement ages is partly due to the flat response surfaces: small variation in the parameters may significantly shift these points. The incentives to retire at some specific ages are not sharp (see Table 3).

The sensitivity of the IRRs to the retirement age is also small in the few programs in which the response surface is not concave in the retirement age. The Argentinean and Colombian individual account programs are the only ones for which we find monotonically decreasing IRRs in the retirement age, but the amount of the decrease is very small: 0.04 percentage points per year in Argentina and between 0.03 and 0.06 percentage points per year in Colombia. The IRRs show no sensitivity to the retirement age in the Peruvian individual accounts program.

According to these results, the IRRs are basically inelastic to the retirement age in Latin-American pension programs. In interpreting these results, it is important to keep in mind that we are controlling for the LOS. Therefore, we are not changing the LOS in parallel with the retirement age as it is normally done in studies of retirement. We do so to disentangle the effects on the IRRs of the LOS and the retirement age that are otherwise mixed.[14] The low elasticity of the IRRs to the retirement age, we find in this study, means that retirement ages do not have large direct impacts on the IRRs. This does not, of course, mean that a worker cannot materially modify the expected IRRs by changing the age of retirement if the worker also changes the LOS. It rather means that the impact of retirement ages largely depends on the induced change in the LOS.

4. Concluding remarks

We present in this paper estimations of the expected IRR that formal workers in 11 Latin-American countries receive from social security. We use this indicator to study how the programs treat both individuals of different standings and individuals of similar standings in different circumstances. Analyzing the return of the former, we assess whether social security programs in Latin America reduce income inequality. Analyzing the return of the latter, we assess insurance and incentives to work.

Our analysis of inequality is based on simulations run for hypothetical workers who differ in terms of wage level, and age-earnings profiles. Most programs analyzed in this study are progressive in the sense that they provide higher returns to low- than to high-income workers. This result holds both for DB and DC programs.

Some words of caution are in order here. As we mentioned above, we are simulating highly stylized families, composed of couples, in which both members work the same period of time and get equal wages when they do. Moreover, we are not considering survivor and disability benefits. Things might be different for more realistic families and the whole old-age, survivors and disability insurance (OASDI) benefit package. Gustman and Steinmeier (2001) show that, when analyzed at the individual level, the U.S. social security looks very redistributive, favoring low-income workers, but it looks much less so at the family level.

Limited social security coverage is a second motive to be cautious. Our assessment of the progressiveness of the social security systems is based on the comparison of the IRRs received by covered workers with different average incomes. In Latin America,

[14] Studies of the incentives to retire implicit in pension programs usually analyze the impact of changing retirement ages and simultaneously changing the number of periods of contribution (Gruber and Wise, 1999, 2004, 2007). Postponing retirement thus implies three main effects: (i) contributing one more period, (ii) receiving pensions one less period if the individual is already entitled to a pension and (iii) receiving a different, probably higher, pension. In controlling for the LOS when we analyze changes in retirement ages, we are focusing on the last two effects. The first one is captured in our analysis of the LOS.

governments often contribute to the financing of social security with general taxes and significant sections of the population are outside the system (i.e., not covered). The net effect, the government transfers benefit a populace generally comprised the better-off (i.e., the covered worker). This caveat should be kept in mind when comparing the progressiveness of different programs in the region. Countries with very low coverage and significant government transfers to social security might end up undoing the redistribution that pension programs were supposed to achieve by design.

Also, pension programs might be less redistributive than what our analysis suggests if poor workers had systematically lower life expectancies. Garrett (1995) compares the net U.S. social security returns of households with different average income taking into account varying mortality rates. He simulates U.S. workers of the 1925 birth cohort and finds that differences in mortality rates may eliminate the progressive spread in returns across income levels. Duggan *et al.*, (1995) analyze the impact of differential mortality rates on the progressivity of the U.S. social security using actual work-history records. They find that income-adjusted mortality rates affect the distribution of benefits across income levels, though not enough to undo the basic progressivity of the program. Beach and Davis (1998) report substantial reductions in the rates of return from the U.S. social security for low-income workers when differential mortality rates are taken into account. We do not have income-adjusted mortality tables for the population covered by the pension programs analyzed in this study. Hence, we could not take these effects into consideration.

We do not find sizeable impacts of the age-earnings profiles on the returns to social security contributions in most programs. The coefficients multiplying the regressor that captures earnings profiles – the rate of growth of wages – turned significantly different from zero in most DB programs, but the size of these coefficients only in a few programs looks large enough to materially impact on the programs' progressivity. This does not mean that the age-earnings profile is not relevant in other programs, though. We considered in this study only a limited set of profiles and we cannot extrapolate our findings to other profiles. We did not simulate, for example, working careers in which earnings fall in the last few years.

In most programs, retirement ages do not seem to have a sizeable direct impact on the IRRs. Indeed, after controlling for the LOS, the effect of changing the retirement age was second order in most cases. Hence, it is mostly through changes in the LOS that retirement ages impact on the IRRs.

The LOS has significant and often dramatic effects on the returns to social security contributions in Latin America. The stylized response surfaces we used to summarize our simulation results tend to smooth out discontinuities and yet we did find some remarkable changes in the IRRs stemming from relatively minor changes in the LOS. In many cases, we found changes in the lifetime expected IRRs of more than 5 percentage points caused by a one-year change in the LOS. These sizeable changes are invariably associated to vesting-period conditions.

In a world of uncertainty in which workers may not be able to fulfill vesting-period conditions because of bad shocks, the sharp changes in the IRRs that are associated with small changes in the LOS exacerbate risk. In the absence of moral hazard (e.g., if short contribution histories were just the result of bad luck) the optimal insurance would be to provide full protection against the risk of short working careers. Full insurance in this case means that pensions should be independent of the number of periods of contribution. But as individuals can materially modify the probability of getting a job in the formal sector making choices unobserved by the social security administrations, a full insurance program would severely distort incentives. Individuals would in this case avoid contributions. The standard solution to moral hazard in the insurance industry is to provide partial insurance. In pension programs, this means that pensions cannot be held constant irrespective of contributions. The optimal degree of risk the individual should be facing depends on parameters that are not directly observable, and so we cannot easily determine such a rule. An actuarially fair reduction of the pension in response to shorter contribution histories – i.e., a flat IRR response surface in the LOS – would already be harsh (no insurance against the risk of short contribution careers), but the observed designs that at some point reduce pensions by more than that look unnecessarily harsh. Rather than providing insurance, these programs create risk.

Our results regarding the return workers with short contribution careers receive from social security also have a bearing on the income inequality issue. Low-wage workers have more frequent and durable interruptions in their contribution histories than high-wage workers (Forteza *et al.*, 2009; Bucheli *et al.*, 2010). The very low IRRs that several pension programs yield to workers with short contribution histories impact thus primarily on low-income workers.

The IRR is a useful synthetic indicator, but it has an important drawback in our context: it is not defined when workers receive no benefits, and there are several scenarios in our simulations in which workers do not fulfill vesting conditions and receive no benefits. In these cases, alternative indicators, like the net present value of the cash flows or the ratio of discounted benefits over discounted contributions, could be more useful.

References

Acemoglu, D. (2009) *Introduction to Modern Economic Growth*. Boston: MIT.

Afonso, L. E. and R. Fernandes (2005) Uma estimativa dos aspectos distributivos da previdencia social no Brasil. *Revista Brasileira de Economia*, **59**(3): 295–334.

Beach, W. and G. Davis (1998) Social security's rate of return. CDA 98-01. *Heritage Foundation*, **21**: 12.

Berstein, S., G. Larraín, and F. Pino (2006) Chilean pension reform: coverage facts and policy alternatives. *Economía*, **6**(2): 227–279.

Bosworth, B., G. Burtless, M. Favreault, J. O'Hare, C. Ratcliffe, K. Smith, E. Toder, and C. Uccello (1999) *Modeling Income in the near Term – Projections of Retirement Income through 2020 for the 1931–1960 Birth Cohorts*. Washington, DC: The Brookings Institution.

Brown, J. R., J. L. Coronado and D. Fullerton (2009) Is Social Security Part of the Social Safety Net? NBER WP 15070.

Bucheli, M., A. Forteza and I. Rossi (2010) Work histories and the access to contributory pensions: the case of Uruguay. *Journal of Pension Economics and Finance*, **9**(3): 369–391.

Dorfman, M. and A. Forteza (2010) Strengthening Caribbean Pensions. Improving Equity and Sustainability. Washington, DC: World Bank. Report No. 47673-LAC.

Duggan, J., R. Gillingham and J. Greenlees (1995) *Progressive Returns to Social Security? An Answer from Social Security Records*. Washington, DC: Office of Economic Policy, U.S. Department of the Treasury. Office of Prices and Living Conditions. U.S. Bureau of Labor Statistics, Research Paper 9501.

Forteza, A., I. Apella, E. Fajnzylber, C. Grushka, I. Rossi and G. Sanroman (2009) Work Histories and Pension Entitlements in Argentina, Chile and Uruguay. Washington, DC, World Bank Discussion Paper No. 0927.

Garrett, D. (1995) The effects of differential mortality rates on the progressivity of social security. *Economic Inquiry*, **33**: 457–75.

Government of Argentina (1993–2007) Laws 24.241, 26.222. Decree 1.306/00.

Government of Brazil (1991–1999) Law 8.213. Decree 3.265.

Government of Chile (2008) Law 20.255. Diario Oficial/Normas Generales/Año 2008/DO 17/03/2008 LEY 20.255.

Government of Colombia (1993) Law 100. Diario oficial año CXXIX. N. 41148. 23, Diciembre.

Government of Colombia (2003) Law 797. Diario oficial año CXXXVIII. N. 45079. 29, Enero.

Government of Colombia (2007) Law 1122. Diario oficial año CXLII. N. 46506.9, Enero.

Government of Uruguay (1995) Law 16.713. Published D.O. 11 Sep/995 – No. 24372.

Government of Uruguay (2002) Law 17.445. Published D.O. 9 Jan/002 – No. 25926.

Government of Uruguay (2008) Law 18.395. Published D.O. 6 Nov/008 – No. 27606.

Government of Venezuela (2008) Decree 6266. http://www.ivss.gov.ve/pdf/leydelsegurosocial.pdf.

Gruber, J. (1999) Social security and retirement in Canada. In Gruber, J. and D. A. Wise (eds), *Social Security and Retirement Around the World*. Chicago, IL: University of Chicago Press, 77–99.

Gruber, J. and D. A. Wise (eds) (1999) *Social Security and Retirement Around the World*. Chicago, IL: University of Chicago Press.

Gruber, J. and D. A. Wise (eds) (2004) *Social Security Programs and Retirement Around the World: Micro Estimation*. Chicago, IL: University of Chicago Press.

Gruber, J. and D. A. Wise (eds) (2007) *Social Security Programs and Retirement around the World: Fiscal Implications of Reform*. Chicago, IL: University of Chicago Press.

Gustman, A. and T. Steinmeier (2001) How Effective Is Redistribution under the Social Security Benefit Formula? *Journal of Public Economics*, **82**: 1–28.

Hamermesh, Daniel S. and Albert Rees (1993) *The Economics of Work and Pay*. New York: Harper Collins College Publishers.

Hendry, D. (1984) Monte Carlo simulation in econometrics. In Griliches Z. and M. Intriligator (eds), *Handbook of Econometrics*. Amsterdam: North Holland, 937–76.

Liebman, J. B. (2001) Redistribution in the current U.S. Social Security System. NBER WP 8625.

Leimer, D. R. (1999) Lifetime redistribution under the social security program: a literature synopsis. *Social Security Bulletin*, **62**(2): 43–51.

Mesa Lago, C. (2006) Private and public pension systems compared: an evaluation of the Latin American experience. *Review of Political Economy*, **8**(3): 317–34.

Myers, R. H., D. C. Montgomery and C. M. Anderson-Cook (2009) Response Surface Methodology. Process and Product Optimization Using Designed Experiments. Wiley Series in Probability and Statistics, 2nd edition. USA: John Wiley and Sons Inc.

OECD (2009) *Pensions at a Glance 2009. Retirement-Income Systems in OECD Countries*. Paris: OECD.

Robalino, D. (2005) *Pensions in the Middle East and North Africa. Time for Change*. Washington, DC: World Bank.

Robichek, A. A. (1975) Interpreting the Results of Risk Analysis. *Journal of Finance*, **30**(5): 1384–86.

SAFP (2010) El Nuevo sistema de pensiones. Chile. Series de Documentos, Superintendencia de Pensiones http://www.safp.cl/573/propertyvalue-2474.html.

Social Security Administration (2008) *Social Security Programs Throughout the World: The Americas, 2007*. Washington, USA: Social Security Administration, ISSA.

Whitehouse, E. (2007) *Pensions Panorama*. Washington, DC: The International Bank for Reconstruction and Development/The World Bank.

World Bank (1994) *Averting the Old Age Crisis. Policies to Protect the Old and Promote Growth*. Washington, DC: World Bank.

World Health Organization (2008) http://www.who.int/whosis/database/life_tables/life_tables.cfm.

Appendix: Description of Latin American pension programs

Table A1. *Typology of Latin American pension programs*

Program	Type of program	Observations
Argentina, individual accounts	Mixed	Mixed two-tier program. First tier: PAYG-DB (PBU, basic universal pension). Second tier: workers choose between individual accounts and PAYG-DB.
Argentina, PAYG-DB	Mixed	
Bolivia	Individual accounts	IA plus minimum pensions.
Brazil	PAYG	
Chile (2007 norms)	Individual accounts	IA plus subsidies to supplement low pensions.
Chile (2008 norms)	Individual accounts	IA plus subsidies to supplement low pensions.
Colombia, individual accounts	Parallel	Individuals opt between PAYG-DB and individual accounts.
Colombia, PAYG-DB	Parallel	
Ecuador	PAYG	
Mexico	Individual accounts	Individual accounts plus matching contributions ('cuota social') and minimum pensions.
Paraguay	PAYG	
Peru, individual accounts	Parallel	Individuals opt between PAYG-DB and individual accounts.
Peru, PAYG-DB	Parallel	
Uruguay (2007 norms), individual accounts	Mixed	Mixed two-tier program. First tier: PAYG-DB. Second tier: individual accounts. Low-income workers may opt to redirect half of their contributions to individual accounts.
Uruguay (2007 norms), PAYG-DB	Mixed	
Uruguay (2008 norms), individual accounts	Mixed	
Uruguay (2008 norms), PAYG-DB	Mixed	
Venezuela	PAYG	

Table A2. *Main parameters in Latin American contributory old-age pension programs* (*as of 2007, unless indicated otherwise*)

Program	Contributions [1]	Qualifying conditions	Benefit [2]
Argentina, individual accounts	Employee: 11.00%; Employer: 11.44%	Men: age $\geq$ 65 and los $\geq$ 30; women: age $\geq$ 60 and los $\geq$ 30 or age $\geq$ 70 and los $\geq$ 10 or annuity $\geq 0.5\bar{w}$	PBU + annuity, where: PBU = 2.5 × MOPRE × 12 (1 + 0.01 max (0, min (15, los − 30))) and MOPRE = US$26
Argentina, PAYG-DB		Men: age $\geq$ 65 and los $\geq$ 30; women: age $\geq$ 60 and los $\geq$ 30	PBU + ‘Additional’, where: ‘Additional’ = 0.015 × min (35, los) × $\bar{w}$
		Age $\geq$ 70 and 30 > los $\geq$ 10 (with at least 5 years of contributions during the 8 years previous to retire)	0.7 × PBU + ‘Additional’
Bolivia	Employee: 12.21%; Employer: none	Age $\geq$ 65 or annuity $\geq 0.7\bar{w}$	Annuity + minimum pension
Brazil	Employee: 8–11%; Employer: 20%.	(a) ‘Length of service’: Men: los $\geq$ 35; women: los $\geq$ 30	$= \bar{w} \times$ ‘fator previdenciário’[3].
		(b) ‘Advanced age’: Men: age $\geq$ 65 and los $\geq$ 15; women: age $\geq$ 60 and los $\geq$ 15	$= 0.7(1 + 0.01\ \text{los})\bar{w} \leq \bar{w}$
Chile (2007 norms)	Employee: 13.04% (10% individual account + 1.49% disability and insurance premium + 1.55% average administrative fee, as of April 2011) (employers with more than 100 workers pay the 1.49% D&I premium)	Men: age $\geq$ 65; women: age $\geq$ 60 or annuity $\geq 0.7\bar{w}$ and annuity $\geq$ 1.5 minpen	Annuity $\geq$ minpen
Chile (2008 norms)		Men: age $\geq$ 65; women: age $\geq$ 60 or annuity $\geq 0.7\bar{w}$ and annuity $\geq$ 1.5 minpen	Annuity + ‘solidarity complement’[4].
Colombia, individual accounts	Employee: 4–8%; Employer: 12%	Annuity $\geq$ 1.1 minwage	Annuity
Colombia. PAYG-DB.		Men: age $\geq$ 60 and los $\geq$ 25; women: age $\geq$ 57 and los $\geq$ 25	$(r + 0.015(\text{los} - 25))\ \bar{w}$, where: $r = 0.655 – 0.05(w/\text{minwage})$
Ecuador	Employee: 6.64%; Employer: 3.10%	Age $\geq$ 60 and los $\geq$ 30 or age $\geq$ 65 and los $\geq$ 15 or age $\geq$ 70 and los $\geq$ 10 or los $\geq$ 40	$(0.5 + (\text{los} - 10)/60)\ \bar{w}$ $(1 + (\text{los} - 40)0.0125)\ \bar{w}$
Mexico	Employee: 1.125%; Employer: 5.15%; government: 0.225% + flat contribution for each day of contribution (decreasing in the wage rate)	Age $\geq$ 65 and los $\geq$ 25 or annuity $\geq$ 1.3 minpen	Annuity $\geq$ minpen

Table A2. (*cont.*)

Program	Contributions [1]	Qualifying conditions	Benefit [2]
Paraguay (2007 norms)	Employee: 9%; employer: 14%	Age $\geqslant$ 60 and los $\geqslant$ 25 or 60 > age $\geqslant$ 55 and los $\geqslant$ 30	$\bar{w}$ $(0.8+0.04\min(4, \text{age}-55))\,\bar{w}$
Paraguay (2008 norms)	Employee: 9%; employer: 14% + contributions while not working ('*Continuidad en el beneficio*'): employee: 12.5%	Age $\geqslant$ 60 and los $\geqslant$ 25 or 60 > age $\geqslant$ 55 and los $\geqslant$ 30	$\bar{w}$ $(0.8+0.04\min(4, \text{age}-55))\,\bar{w}$
Peru, individual accounts	Employee: 12.72%	Age $\geqslant$ 65 or annuity $\geqslant 0.5\bar{w}$	Annuity
Peru, PAYG-DB	Employee: 13%	Age $\geqslant$ 60 and los $\geqslant$ 20 Men: 60 > age $\geqslant$ 55 and los $\geqslant$ 30; women: 60 > age $\geqslant$ 50 and los $\geqslant$ 25	$(0.3+0.02\min(35, (\text{los}-20)))\,\bar{w}$ $(0.3+0.02\min(35, (\text{los}-20)-0.04(60-\text{age})))\,\bar{w}$
Uruguay, individual accounts (2007 norms)	Employee: 15%; employer: 7.5%	Age $\geqslant$ 65 or age $\geqslant$ 60 and los $\geqslant$ 35	Annuity
Uruguay, PAYG-DB (2007 norms)		Age $\geqslant$ 60 and los $\geqslant$ 35 Age $\geqslant$ 70 and los $\geqslant$ 15	$rr\times\bar{w}$, with: $0.50\leqslant rr\leqslant 0.825$ $rr\times\bar{w}$, with: $0.50\leqslant rr\leqslant 0.7$
Uruguay, individual accounts (2008 norms)	Employee: 15%; employer: 7.5%	Age $\geqslant$ 65 or age $\geqslant$ 60 and los $\geqslant$ 30	Annuity
Uruguay, PAYG-DB (2008 norms)		Age $\geqslant$ 60 and los $\geqslant$ 30 Age $\geqslant$ 70 and los $\geqslant$ 15	$rr\times\bar{w}$, with: $0.45\leqslant rr\leqslant 0.825$ $rr\times\bar{w}$, with: $0.50\leqslant rr\leqslant 0.65$
Venezuela	Employee: 1.93%; employer: 4.82%	Men: age $\geqslant$ 60 and los $\geqslant$ 15; women: age $\geqslant$ 55 and los $\geqslant$ 15	US\$ 138 + $(0.3+0.01(\text{los}-15)+0.05(\text{age}-60))\,\bar{w}$

Notes: age, age when pension is claimed, in years; los, length of service when pension is claimed, in years; $\bar{w}$, average wage (wages included in this average vary considerably between programs); minpen, minimum pension; PBU, pensión básica universal (basic universal pension); MOPRE, módulo previsional (pension unit).

[1] In most programs, contributions to old-age, survivor and disability insurance (OASDI) cannot be separated into three distinct components. We report OASDI contributions in all cases.

[2] In all individual accounts programs, annuities are computed using gender-specific mortality tables. Bolivia is in the process of switching to unisex tables, according to the reform law passed on December 10, 2010.

[3] 'Fator previdenciário' is a decreasing function of life expectancy at retirement.

[4] 'Solidarity complement' is reduced with the level of the annuity and becomes zero if annuity $\geqslant$ PMAS, where PMAS is the Maximum Pension with Solidarity Complement.

Source: Authors' based on Social Security Administration (2008) and legal norms listed in references.

https://doi.org/10.1017/S1474747211000564 Published online by Cambridge University Press