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Life expectancy at retirement and income levels in Chile

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We document that life expectancies at the age of retirement differ significantly by income levels and gender in Chile. Using a sample of over 500 thousand workers that retired under the annuity system, we find that, conditional on reaching retirement age, there is a three-year difference in life expectancy between the lower and higher income groups. Differences are similar for men and women. We also find that as income per capita in Chile expanded over the past three decades, poverty levels have decreased quite markedly among pensioners. The evidence on income distribution is less clear cut. While income inequality is lower for the new generations, it increases after retirement within each generation as the poor die younger than the rich workers. Gender differences are also noteworthy. First, income among women is less unequal than that of men at retirement age and afterwards. Second, income inequality among retired men progressively worsens over time, while among women it remains stagnant over time. Our results have important implications for welfare projections, the allocation of health subsidies among pensioners, and the structure and management of the reserves required to life-insurance companies.

KEYWORDS

life expectancy, retirement, pensioners, income, poverty, gender differences, Chile

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Esperanza de vida al momento de jubilar y niveles de ingresos en Chile

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Este estudio documenta que las expectativas de vida a la edad de jubilación difieren significativamente según los niveles de ingresos y género en Chile. Usando una muestra de más de 500 mil trabajadores que jubilaron bajo el sistema de rentas vitalicias, encontramos que, condicional a alcanzar la edad de jubilación, hay una diferencia de tres años en la esperanza de vida entre los grupos de ingresos más bajos y más altos. Las diferencias son similares para hombres y mujeres. También encontramos que a medida que el ingreso per cápita en Chile creció en las últimas tres décadas, los niveles de pobreza disminuyeron notablemente entre los jubilados. La evidencia sobre la distribución del ingreso es menos clara: si bien la desigualdad de ingresos es menor para las nuevas generaciones, esta aumenta en cada generación después de jubilar, a medida que los pobres mueren más jóvenes que los ricos. Las diferencias de género son notables. Primero, el ingreso entre las mujeres es menos desigual que el de los hombres al momento de jubilar. Segundo, la desigualdad de ingresos entre hombres jubilados empeora progresivamente con el tiempo, mientras que entre mujeres permanece estancada en el tiempo. Nuestros resultados tienen implicaciones importantes para las proyecciones de bienestar, la asignación de subsidios de salud entre los pensionistas y la estructura de reservas exigidas a las compañías de seguros de vida.

1 | INTRODUCTION

During the last four decades, Chile has become a regional pioneer in the design and implementation of reforms and modern social policies. At the core of such reforms is the social security system, particularly its contribution-defined, privately managed, individual accounts system. The pension system implemented in 1981 covers around 10.6 million workers and has around 1.3 million pensioners.

Chile's pension system has reached maturity and, as in most countries, faces the key challenge of dealing with increased longevity.[1] When the system started in the early 1980s, life expectancy in Chile at the time of retirement (60/65 for women and men, respectively) was 78 years for men and 81 years for women; by 2018 it has increased to 86 years for men and to 90 years for women. Higher longevity can be dealt with either higher contributions (currently 10% of wages with a ceiling of about UF 79 (roughly equivalent to US$3,200) or raising the retirement age.

Average longevity, nevertheless, may not be the only key challenge for the Chilean system: socioeconomic inequalities in mortality could potentially pose a serious impediment to enhance public health even in highly developed welfare states. Evidence for other OECD economies indicate that there are significant differences in mortality rates by income levels and other socioeconomic variables (see Isaacs and Choudhry, 2017 for the US and Mackenbach et al, 2003 for Western Europe). Evidence for Latin American countries is scant and does not discriminate by income level (see Temporelli and Viego, 2011). Such analysis has not been published for the Chilean case.

This paper documents that life expectancies at the age of retirement differ significantly by income levels and gender in Chile. Using a sample of over 500 thousand workers that retired under the annuity system, we find that, conditional on reaching retirement age, there is a three-year difference in life expectancy between the lower and higher income groups. Differences are similar for men and women. While we find that income inequality translates into mortality inequality, we also find that inequality at retirement age among annuitants is lower than that of pensioners under programmed withdrawals[2] or at the national level: we estimate Gini indices for monthly pensions for annuitants (0.374) and programmed withdrawals (0.409) which indicate much lower inequality than that of the household disposable income at the national level as estimated by the OECD (0.46)[3]. In fact, we find that as income per capita in Chile expanded over the past three decades, poverty levels have decreased quite markedly among the workers in our sample. Yet, the evidence on income distribution is less clear cut. We find that while income inequality is lower for the new generations, it increases after retirement within each generation as the poor die younger than the rich workers. Gender differences are also noteworthy. First, income among women is less unequal than that of men at retirement age and afterwards. Second, income inequality among retired men progressively worsens over time, while among women it remains stagnant over time. Our results have important implications for welfare projections, the allocation of health subsidies among pensioners, and the structure and management of the reserves required to life-insurance companies.

The paper is organized as follows. Following this introduction, Section II reviews the

[1] Other key issues we do not address in this paper are the decline in the rates of return of pension funds following the global decline in interest rates, the increasing number of independent workers, and the instability in contributions, especially among women.

[2] In the case of programmed withdrawals, it refers to first-month pensions.

[3] Income is defined as household disposable income in a particular year. It consists of earnings, self-employment and capital income and public cash transfers; income taxes and social security contributions paid by households are deducted. OECD (2020), Income inequality (indicator). doi: 10.1787/459aa7f1-en (Accessed on 14 June 2020).

received knowledge regarding the linkages –theoretical and empirical—between life expectancy and income levels. There is a rich literature for advanced economies but very little evidence on emerging countries and, unfortunately, none for the Chilean case. Section III presents the evidence for Chile. Section IV contains the empirical analysis of mortality rates, while Section V explores the distributional implications of the heterogeneity in mortality rates. Section VI concludes.

2 | THE RECEIVED KNOWLEDGE

There is an abundant literature on the links between income levels and life expectancy (see Elo, 2009). The consensus is, ceteris paribus, that higher income levels are associated with lower mortality rates and higher longevity. Much of the historical evidence was collected for "life expectancy at birth" and applied to the entire population. There is more debate on the evidence provided by some authors that income inequality is also linked to mortality rates, with those more affluent living significantly more than those in the first deciles of the income distribution (Wilkinson, 1990). Relative, not only absolute, income matters.

While valuable, this evidence provides limited information for life expectancy at the age of retirement which is the crucial issue for pensions, health and care for the elderly. More recent evidence indicates that in most OECD economies, remaining life expectancy at retirement age (a) is significantly lower for low-income individuals vis-à-vis high-income individuals, (b) it differs significantly by gender, with females having less inequality in longevity by income, (c) is becoming increasingly more unequal by income and educational levels.

In what follows, we review the literature to collect the received knowledge and identify the main stylized facts that can illuminate our analysis of the Chilean case.

2.1 | Income and life expectancy at birth

A large body of research has documented significant associations between income and mortality, with the strength of the association varying by age and how income and wealth are measured (e.g., Elo and Preston 1996). While the relationship between income levels and life expectancy may be well established –namely, higher income levels lead to lower mortality rates— the transmission mechanisms remain nevertheless poorly understood. Higher income has been associated with greater longevity, and differences in life expectancy across income groups have been reported to increase over time. However, the association between life expectancy and income varied substantially across areas; differences in longevity across income groups decreased in some areas and increased in others. The differences in life expectancy correlate with health behavior and local area characteristics.

Deaton and Paxson (1999) document that people in the US whose family income was less than $5,000 in 1980 could expect to live about 25 percent fewer years than people whose family income was greater than $50,000. Using individual data and a panel of aggregate birth cohorts observed from 1975 to 1995, they find that individual income reduces the risk of death, and does so even when controlling for education. Only some of the effects of income, however, can plausibly be attributed to the reduction in earnings of those about to die. The panel of cohorts also shows a strongly protective effect of income; while the long-run effects of higher income is to lower mortality rates, cyclical increases in income may raise mortality.

Chetty et al. (2016) use a sample of over 1.4 billion person-year observations for individuals aged 40 to 76 years collected in the US between 2001 and 2014. The analysis yielded

four results. First, higher income was associated with greater longevity throughout the income distribution. The gap in life expectancy between the richest 1% and poorest 1% of individuals was 14.6 years for men and 10.1 years for women. Second, inequality in life expectancy increased between 2001 and 2014. Life expectancy increased by 2.34 years for men and 2.91 years for women in the top 5% of the income distribution, but by only 0.32 years for men and 0.04 years for women in the bottom 5%. Third, life expectancy for low-income individuals varied substantially across local areas. In the bottom income quartile, life expectancy differed by approximately 4.5 years between areas with the highest and lowest longevity. Changes in life expectancy between 2001 and 2014 ranged from gains of more than 4 years to losses of more than 2 years across areas. Fourth, geographic differences in life expectancy for individuals in the lowest income quartile were significantly correlated with health behaviors such as smoking, but were not significantly correlated with access to medical care, physical environmental factors, income inequality, or labor market conditions. Life expectancy for low-income individuals was positively correlated with the local area fraction of immigrants, fraction of college graduates, and government expenditures.

NASEM (2015) found that for men born in 1930, individuals in the highest income quintile (top 20%) could expect to live 5.1 years longer at age 50 than men in the lowest income quintile. This gap has increased significantly over time. Among men born in 1960 and at age 50, those in the top income quintile could expect to live 12.7 years longer than men in the bottom income quintile. Isaacs and Choudury (2017) found similar patterns for women: the life expectancy gap between the bottom and top income quintiles of women at age 65 expanded from 3.9 years for the 1930 birth cohort to 13.6 years for the 1960 birth cohort.

2.2 | Income distribution and life expectancy at birth

Wilkinson (1990) is among the first to systematically analyze the striking tendency for life expectancy to be highest in those developed countries where income is distributed more equally, rather than in those which are the richest. Tests using British data found that changes in mortality were significantly, positively and independently related to changes in the proportion unemployed and the proportion of low relative earnings in each occupation. Wilkinson (1992) extends the analysis to investigate the relation between average income and life expectancy for 23 countries in the OECD. These data seem to confirm that there is, at best, only a weak relation between gross national product per head and life expectancy in developed countries but suggest the existence of a strong cross-sectional relation between life expectancy and income distribution.

What causal mechanisms underlie these status-related associations is not well established. Moreover, despite the large literature in support of the importance of relative versus absolute income for health, there are others who cast doubt on its relevance (see Cutler et al. 2008). Thus, the lively debate concerning the association between relative versus absolute social status and health outcomes is likely to continue. Furthermore, cross-country evidence, while insightful, cannot represent the time-series evolution of a particular country.

One possible explanation is based on occupations during working life. Studies have shown an inverse association between mortality and civil service rank in Britain and other countries; the higher the rank the lower is mortality, especially in the case of cardiovascular disease mortality (Marmot et al. 1997). These findings suggest that it is relative, not absolute, social status that matters for health. Higher status leads to a lower level of stress, more perceived control over one's life, and less status anxiety. This argument is similar to those made regarding the role of income and financial resources that emphasize the relative rather than absolute deprivation perspective with respect to income effects on health outcomes.

Katikireddi et al. (2017) analyzed adults of working age (20–59 years) using linked census and death records in Britain. Main occupation was coded into more than 60 groups in the 2001 census, with mortality follow-up until Dec 31, 2011. They calculate age-standardized all-cause mortality rates (per 100,000 person-years), stratified by sex, and find that mortality rates by occupation differed by more than three times between the lowest and highest observed rates in both men and women. Among men, health professionals had the lowest mortality, with low rates also shown in managers and teachers. The highest mortality rates were in elementary construction and housekeeping and factory workers. Among women, teachers and business professionals had low mortality, and factory workers and garment trade workers had high rates. Mortality rates have generally fallen but have stagnated or even increased among women in some occupations, such as cleaners.

In a similar study for the US economy, Johnson et al. (1999) compare mortality differences for specific and general categories of occupations using a national cohort of approximately 380,000 persons aged 25-64 from the U.S. National Longitudinal Mortality Study. They find that higher risk is observed in moving across the occupational spectrum from the technical, highly skilled occupations to less skilled and generally more labor-intensive occupations. Mortality differences obtained for specific occupations are almost completely accounted for by adjustments for income and education. Important differences are shown to exist for selected specific occupations beyond those accounted for by social status, income, and education. High-risk specific occupations include taxi drivers, cooks, longshoremen, and transportation operatives. Low-risk specific occupations include lawyers, natural scientists, teachers, farmers, and a variety of engineers.

2.3 | Gender gap and life expectancy at birth

Regarding the gender longevity gap, Fedotenkov and Derkachev (2017) find that in most countries, women live longer than men but such differences in longevity are country-specific and change over time. Furthermore, they show that a lower gender longevity gap is associated with a higher real GDP per capita, a higher level of urbanization, lower income inequality, lower per capita alcohol consumption and a better ecological environment.

2.4 | Health and life expectancy at birth

Lutz and Kebede (2018) assert that progress in human health and life expectancy is closely associated with socioeconomic development. Better nutrition and greater affordability of health care associated with higher income have been widely considered as primary determinants of historical and contemporary mortality declines. In many of the studies of this issue that followed Preston's lead, the assumption that income is the most important driver of mortality decline has been an unquestioned starting point. Seaman et al. (2019) take the extreme perspective that life expectancy inequalities are an established indicator of health inequalities.

The association between income and adult health outcomes has received greater attention in the United States than in Europe, although European studies have similarly documented significant associations between income and adult health and mortality (e.g., Banks et al. 2006, Elo et al. 2006, Van Doorslaer et al. 1997). Relatively few studies, however, have compared the income-health gradient among developed countries. Two studies that did make such comparisons found the income-health gradient to be steeper in the United States than in several European countries. Van Doorslaer et al. (1997), for example, documented that among noninstitutionalized adults, income-related inequality in self-rated health was greater in the United States than in Europe. Banks et al. (2006) also reported significant

associations between income and chronic diseases among middle-aged adults in England and the United States, with the income-health gradient being generally somewhat more significant and steeper in the United States.

Rehnberg (2019b) questions the frequently used "age-as-leveler" hypothesis[4] to explain decreasing inequality and a weakened relationship between socioeconomic position and health in old age. His study examined whether health status can explain the age pattern in the association between income and mortality as predicted by the age-as-leveler hypothesis in Sweden using longitudinal data for the period 1991–2002. He finds that the association between income and mortality weakens in those aged 84 and older. However, health status explained a large part of the effect that age had on the association between income and mortality. Analyses done after stratifying the sample by health status showed that the association between income and mortality was strong in people who reported good health and weak or nonexistent in those who reported poor health.

Stevens et al. (2015) note that mortality rates are pro-cyclical. In explaining this fact, they find little evidence that cyclical changes in individuals' own employment-related behavior drives the relationship. Noting (a) that most additional deaths that occur when the economy is strong are among the elderly –particularly elderly women and those residing in nursing homes— and (b) that staffing in nursing homes moves countercyclically, they conclude that cyclical fluctuations in the quality of health care may be a critical contributor to cyclical movements in mortality.

2.5 | Education and life expectancy at birth

In her authoritative survey, Elo (2009) concludes that educational attainment is the single socioeconomic status indicator that most consistently exhibits a significant association with various measures of all-cause and cause-specific mortality. Preston and Elo (1995) study educational differentials in U.S. mortality among both men and women in the early 1980s. They found that differentials are larger for men than for women, and for those at working age (25-64 year of age) vis-à-vis those age 65 and above. These differentials persist but are reduced in magnitude when controls for income, marital status and current place of residence are introduced.

The income-health gradient discussed above may also depend on the level of education, at least in the United States, such that fewer income-related health disparities are evident at higher than at lower levels of schooling (Schnittker 2004). In addition to protecting individuals from chronic financial stress and facilitating access to health generating resources (such as superior housing in safe neighborhoods and leisure activities), financial resources may be particularly important when coping with ill health (Smith 2007). Meara et al. (2008) estimate that life expectancy at age 25 in 2000 in the United States was 7 years higher for individuals who had attended at least some college (56.6 years) than for those with a high school education or less (49.6 years). Large differences in life expectancies by educational attainment have similarly been documented in several European countries (e.g., Deboosere et al. 2009). In addition, numerous studies have found education to be a significant predictor of health and mortality in developed countries (e.g., Elo and Preston, 1996; Smith, 2007) and in less developed countries of Asia and Latin America (Smith and Goldman, 2007; Kaneda and Zimmer, 2007). Whether this country-specific variation is due to a different meaning of education or an interaction with country context is, nevertheless, not well established.

Zimmer and House (2003), however, found that income, but not education, predicted functional decline at older ages, and Herd et al. (2007) documented that income was a more

[4]The "aging-as-leveler" hypothesis posits inequalities in health decrease across the lifespan due to reductions in resource inequality that occur with increasing age (Brown et al. 2012).

significant predictor of the progression of functional limitations and chronic conditions than of their onset.

2.6 | Life expectancy at retirement age and individual income

The issue of life expectancy at retirement age has become an area of active research in developed economies in the last decade. In particular, because of the implications for social security systems and pensions. Houben (2018) notes that due to the increase in life expectancy, the focus of discussions on a suitable pensionable age have been limited to an age-discussion: as longevity is setting in, everyone is expected to retire at a later moment during his/her lifespan. However, in the entire discussion, issues around the expected years after retirement have not been tackled: a well-known issue for pension funds that don't ensure a homogeneous set of policyholders is that the lower educated members with a lower expected life expectancy may subsidize their higher educated fellow policyholders. Thus, two main questions arise (a) is the increase in life expectancy a trend which is applicable throughout the entire population or are there specific groups which mainly profit from this trend?, and (b) How can pension funds and regulators take into account these differences between participants without harming the principles of risk-sharing, and collectivity, and without discriminating against certain sub-groups?

OECD (2011) estimates that life expectancy at pensionable age in developed economies is forecast to increase by about 3 years for men and 2.5 years for women between 2010 and 2050. Kalwij et al. (2011) quantify the association between individual income and remaining life expectancy at the statutory retirement age in the Netherlands in the period 1996–2007. They find that, conditional on marital status, individual income is about equally strong and negatively associated with mortality risk for men and women and that spouse's income is only weakly associated with mortality risk for women. For both men and women, the remaining life expectancy at age 65 for low-income individuals is estimated to be about two-and-a-half years less than that for high-income individuals.

Wenau et al. (2019) examine mortality trends across socioeconomic groups since the late 1990s among retired German men aged 65 and above. Large administrative data sets were used to estimate mortality, grouped according to their working-life biographies. Individual pension entitlements served as a measure of lifetime income. Changes in total life expectancy at age 65 over time were decomposed into effects of group-specific mortality improvements and effects of compositional change. Their results indicate that male mortality declined in all income groups but as mortality improved more rapidly among higher status groups, the social gradient in mortality widened. Since 1997, the distribution of pension entitlements of retired East German men has shifted substantially downwards. As a result, the impact of the most disadvantaged group on total mortality has increased and has partly attenuated the overall improvement.

Hoffman et al. (2019) study the correlations between socio economic indicators and mortality by gender and age groups in Finland. They find that the total effects of education are substantially mediated by occupation and income, and the effects of occupation is also mediated by income. Income is more important for men and occupational class more important among elderly women. Mortality inequalities are generally smaller in older ages, but the relative importance of income increases. Rehnberg (2019a) studies the association between income and mortality across ages in Sweden and find that the income-mortality association was curvilinear with diminishing returns of income in both mid-life and late-life. He finds that mortality inequalities in income decrease with age and absolute mortality inequalities in income increase with age up to age 85-90, after which the mortality inequalities decrease. Health decline only partly explain the weakened income-mortality

association among the oldest old.

Ayuso et al. (2016) show that the link between heterogeneity in longevity and lifetime income across countries is mostly high and often increasing. In pension systems, this translates into an implicit tax/subsidy for pensioners with different life expectancy, with rates reaching 20 percent and higher in some countries. Such rates risk perverting redistributive objectives of pension schemes and distorting individual life-cycle labor supply and savings decisions. This calls for mechanisms that neutralize or at least significantly reduce the effects of heterogeneity in longevity through changes in pension design. The paper explores a number of interventions in the accumulation, benefit determination, and disbursement stages.

Waldron (2007) analyzes trends in mortality differentials and life expectancy by average relative earnings for male Social Security–covered workers aged 60 or older in the US. In general, for birth cohorts spanning the years 1912– 1941 (or deaths spanning the years 1972–2001 at ages 60–89), the top half of the average relative earnings distribution has experienced faster mortality improvement than has the bottom half. The sample is expected to be selectively healthier than the general population because of a requirement that men included in the sample have some positive earnings from ages 45 through 55.

Beltrán-Sánchez and Subramanian (2019) investigate changes in survival at older ages in high-income countries and show that although survival chances have improved, these improvements are concentrated at the top of the survival distribution where there is a small share of the population. Using data from 37 countries from Europe, the Americas, Asia, and Oceania they find, for example, that among females who survive to age 85 in their most recent birth cohort (1925) about half dies within 8 years while those in the top 25% of the survival distribution live at least 50% longer (12 years or more). Importantly, estimates of lifespan inequality at older ages suggest that years of life lost have increased in recent times and among recently born cohorts leading to increased uncertainty in the age of death at older ages.

2.7 | Longevity studies for Latin American economies

There is virtually no solid research on this issue for Latin American economies. Two papers are noteworthy. Temporelli and Viego (2011) study the incidence of general living conditions on average longevity for Latin America and Caribbean countries during the period 1970-2005, using panel data. Their results suggest a positive but decreasing effect of income on life expectancy and a positive impact of workers' education on the population's average longevity. Damianovic (2015) uses a sample of 22 counties in Chile and finds a high correlation between life expectancy and average income at the county level, particularly among those counties where income distribution is relatively more homogeneous.

2.8 | Reverse causality? Mortality and retirement age

Most of the literature focuses on statutory retirement ages or, at best, treat early retirement as an independent decision. This, nevertheless, has been challenged in a few papers. Kalemli-Ozcan and Weil (1990) examine the role of declining mortality in explaining the rise of retirement age over the course of the 20th century. They build a model in which individuals make labor/leisure choices over their lifetimes subject to uncertainty about their dates of death. In an environment with high mortality, an individual who saves for retirement faces a high risk of dying before he can enjoy his planned leisure. In this case, the optimal plan is for people to work until they die. As mortality falls, however, it becomes optimal to plan and save for retirement. They show that this "uncertainty effect" of declining mortality

would have more than outweighed the "horizon effect" by which rising life expectancy would have led to later retirement.

Bloemen et al. (2013) investigate the reverse causality and estimate the impact of early retirement on the probability to die within five years, using administrative micro panel data covering the entire population of the Netherlands. Among the older workers they focus on a group of civil servants who became eligible for retirement earlier than expected during a short time window. This exogenous policy change is used to instrument the retirement choice in a model that explains the probability to die within five years. They find, for men that early retirement, induced by the temporary decrease in the age of eligibility for retirement benefits, decreased the probability to die within five years by 2.5 percentage points. This is a strong effect.

3 | EVIDENCE FOR CHILE

The data used in our analysis is based on the universe of annuities issued for pensioners since the inception of the new social security system in the period 1983-2018. The Chilean pension system operates, since 2008, using a three-pillar structure with the following characteristics: all dependent workers[5] must save 10% of their monthly wages in their preferred pension fund subject to a monthly limit of 10% of UF 79.3.[6] This limit has been variable over the years.

At retirement, workers must decide the destiny of their accumulated funds: (a) they can buy an annuity from life insurance companies; (b) they can follow a programmed withdrawal scheme from pension funds (or a combination of these two). Pensioners are allowed to spend some of the funds at will, provided the remaining funds are at least sufficient to pay an annuity equivalent to the minimum pension (*excedente de libre disposición*[7]). There is also a solidarity pillar in the pension system whereby the government provides minimum pensions and complementary pensions for those that have insufficient funds in their personal accounts. The third pillar comprises the funds that workers voluntarily save on top of mandatory savings in pension funds. These latter funds have a tax-deduction benefit.

Accumulated funds are transferred to insurance companies at the time of retirement using a centralized auctioning system that ensures a competitive basis for purchasing annuities with annuity rates depending on market conditions. In addition to retirement annuities and programmed withdrawals, the system comprises survival and disability insurance components.

The statutory retirement age is 65 years old for men and 60 years old for women. Under certain conditions, early retirement is allowed. Many workers retire, nevertheless, after the statutory retirement age. Also, receiving a pension from the system does not preclude the worker from continuing work.

[5] Until 2019, independent workers would contribute on a voluntary basis.

[6] UF, or *Unidad de Fomento*, is a Chilean currency unit indexed to inflation, with the value of the UF adjusted daily. 1 UF is worth approximately USD 40.

[7] Any affiliate that has at least 10 years of affiliation in any pension system, may withdraw part of the balance of their individual capitalization account as a Free Disposal Surplus (*Excedente de Libre Disposición*) if their pension funds allow them to obtain a pension at least equal to 70% of the average of their taxable income in the last ten years, and declared income and one hundred percent of the maximum pension with solidarity contribution.

3.1 | The available data

As mentioned, our analysis is based on the universe of annuities issued for pensioners since the inception of the new social security system in the period 1983-2018. Table 1 shows that there are around 730 thousand records in the RIS database, corresponding to the total number of annuities issued since 1983. Of these, roughly 150 thousand correspond to disability pensions, and other pensions primarily inherited from the previous pension system. We drop these observations and focus on those annuities purchased by non-disabled pensioners. As can be seen, 80% of pensioners are still alive as of December 2018 while the rest died, but the records are kept in the database. Around 70% of pensioners are males and 30% are females.

The information regarding the characteristics of pensioners in the database is rather limited but still enlightening. It basically comprises the amount of funds available for purchasing annuities, the annuity rate offered and accepted, the monthly pension benefit, the dates of birth, retirement and death of the pensioners, and their gender. Table 2 provides the salient characteristics of the pensions in our database. The data is recorded in UFs, an inflation-adjusted accounting unit, that expresses all values in real terms and allows for intertemporal comparability. It can be seen that there is a wide disparity in accumulated pension funds and that the distribution is highly skewed, with mean around US$ 80 thousand, median of less than US$ 60 thousand and a maximum that exceeds US$ 3 million. The latter is the result of voluntary saving on top of the mandatory contribution of 10% of the wage. This voluntary saving had been largely driven by the high return rates offered by pension fund administrators during the period of sustained, high growth of the Chilean economy and also because of attractive tax benefits. While on average for the period 1981-2017 the annual real return of pension funds has been 8.1%, in the 1980s the returns were in excess of 12% and in the 1990s it was 10% per year. The quality of the information for the period 1983-1994 is deemed weak by experts so for econometric and statistical analysis we only use the data for the period 1995-2018 but keep in the database the entire universe of pensioners.

TABLE 1 Structure of the RIS Database

Observations	Women	Men	Total
Total RIS Database	194,360	536,419	730,779
Disabilities and other pensions	28,131	123,532	151,663
Usable database	166,229	412,887	579,116
Alive with annuity	116,729	134,398	251,127
Alive with early retirement	34,007	174,843	208,850
Dead with annuity	10,329	31,858	42,187
Dead with early retirement	5,164	71,788	76,952

Source: Own elaboration based on data from Superintendencia de Valores y Seguros (2019).

It can be seen that there are two available sources of information vis-à-vis income that can be used for the analysis. On one hand, monthly pensions indicate the amount of resources available for the pensioners during the period of retirement. On the other hand, the amount of saving in pension funds is an indication of the stock of wealth the pensioner amassed during his/her working life. To the extent that mortality depends inversely on income, these two variables provide different but complementary information: in relative terms fewer low-income workers ought to reach retirement age and fewer poor ought to survive if

TABLE 2 Pension Fund Characteristics

	Savings in Pension Funds (UF)	Monthly Pension (UF)	Annuity Return (%)
Mean	2,091	10.9	3.9
Median	1,508	7.8	3.6
Maximum	86,771	382.7	9.6

Notes: UF, or Unidad de Fomento, is a Chilean currency unit indexed to inflation, with the value of the UF adjusted daily. 1 UF is worth, approximately, USD 40. *Source:* Own elaboration based on data from Superintendencia de Valores y Seguros (2019).

they reach retirement.

It is important to note that by its nature the data on annuities are biased towards the middle class and the most affluent in the country. The reason is that workers who do not have sufficient funds to purchase an annuity equal to or greater than the Basic Solidarity Pension (around 160 dollars per month) cannot opt for an annuity. They have to retire under the Programmed Withdrawal System.[8]

On the basis of this information we have chosen three income and wealth brackets for our analysis, as shown in Table 3. In terms of monthly pensions, the low-income group of less than USD 200 per month would locate pensioners slightly above the minimum pension. The medium-income-bracket threshold corresponds to twice the minimum pension and all pensions above that level are classified as high. Wealth brackets were chosen in a consistent manner: we computed the minimum accumulated wealth that, given the observed sales rate of December 2019, would produce a monthly pension equivalent to UF 5 for the low wealth group and doubled that figure for the medium wealth group.

TABLE 3 Definition of Income and Wealth Brackets

	Low	Medium	High
Accumulated Wealth	Less than UF 1,200	UF 1,200 to UF 2,400	More than UF 2,400
Total pensioners	214,977	206,689	157,359
Monthly pensions	Less than UF 5	UF 5 to UF 10	More than UF 10
Total pensioners	124,124	242,948	212,044

Source: Own elaboration based on data from Superintendencia de Valores y Seguros (2019).

3.2 | Data limitations

As discussed, the data in our database focus mostly on the characteristics of the annuity and the market conditions at the time of purchase. Based on the literature review, one can identify several missing characteristics that would be useful when understanding the linkages between income distribution and mortality rates.

Our two indicators of income and wealth are measured with potentially significant error. Pensions, on one hand, are not the only source of income for pensioners; other forms of income arise from being partially employed after retirement, the return on investments and

[8]This requirement takes the present form in 2008, meaning that some annuities are for less than this amount.

savings, government and private transfers, etc. On the other hand, pension funds are not the only form of wealth for pensioners, with housing and other investments as obvious alternative forms of wealth.

As discussed in the literature review, survival rates tend to depend on education levels because the occupational history of more educated workers is tilted towards less dangerous and/or less stressful positions as well as because more educated workers are able to save financial resources that help them cope better with the hardships of ageing. Our database is unfortunately mute on occupational or educational levels.

The third important limitation of the database is that it refers only to individual pensions and wealth whilst in a number of occasions the key income measures are those of the household.

3.3 | Data cleaning

The database contains some observations with zero-valued monthly pensions and/or premia, which we deem as mis-recorded and therefore have been dropped. These observations are less than 0.01% of the data. Also, experts consider the accuracy of income measurements prior to 1995 to be of low quality, so this period is not used for the estimation of adjustment factors. Non-disabled and annuity purchasing pensioners exposed since 1995 constitute 87% of the database.

4 | EMPIRICAL ANALYSIS OF MORTALITY RATES

The first part of our analysis consists in recalibrating the official mortality tables used by insurance companies to calculate reserves in the Chilean Annuity System as required by the pension system authorities. The reason has to do with the fact that mortality tables include all risks (annuities, programmed withdrawals, and other pensions) whilst we concentrate only on those that purchase annuities after retirement.

Mortality tables are estimated for a certain base year and later adjusted on a yearly basis to reflect improvement factors (e.g., improved health systems leading to higher survival rates). In Chile, current mortality tables are dynamic, and the base-year is 2014. Consequently, mortality rates —identified as $Q_{x,t}$— are updated as follows:

$$Q_{x,t} = Q_{x,2014}\,(1 - AA_x)^{t-2014}, \tag{1}$$

where $Q_{x,t}$ is the probability that a person of age x at time t dies within a year. AA_x is the improvement factor for a person of age x.

For the re-calibration of mortality tables, we assume that present official improvement factors are valid for the full period from 1995 to 2017. We estimated a general adjustment factor using maximum likelihood methods and separating by gender. Factor f, which is applied to the mortality table, so that $Q_{x,t} = f Q_{x,2014}\,(1 - AA_x)^{t-2014}$, is estimated using data only for those workers that were exposed after 1995, since data prior to 1995 is weak. The estimation includes every annuity pensioner who was exposed in the period 1995-2017. Only ages above the normal retirement age (60 for women and 65 for men) were considered in the estimation.

The interpretation of the adjustment factor is as follows. If $f = 1$, official mortality tables match the observed mortality during the period. If $f < 1$, official mortality tables assign too low a probability of survival vis-à-vis the observed mortality, i.e., those that retired after 1995 are living longer than what official mortality tables estimate.

The results of recalibrating mortality rates are presented in Table 4. Our results indicate that both retired males and females that purchased annuities live on average slightly longer than the general population as would be expected using the official mortality tables. The numbers are quite close to 1, indicating that the official tables are not far off. In fact, these small differences in survival rates would imply that life expectancy would increase around 3 months for men (at age 65) and 4 months for women (at age 60).

TABLE 4 Recalibrating Mortality Tables

	Observations (year-person)	f-factor
Males	1,908,407	0.951
Females	998,898	0.977

Source: Own elaboration based on data from Superintendencia de Valores y Seguros (2019).

We replicate this exercise using data by gender and income/wealth brackets and report the results in Table 5. It can be seen that adjustment factors do differ significantly by income/wealth levels: mortality rates decrease as "income" increases, whether income is measured as pension income or wealth at retirement. This is consistent with the international literature discussed above. The differences between rich and poor workers are quite significant: independently of the measure of income used, life expectancy for the affluent is around three years higher than the low-income group in our sample. The gap is about the same for men and women. In our view this is a lower bound for such gap since our sample is, as mentioned, biased towards those pensioners that are allowed to purchase an annuity, i.e., the richer ones.

TABLE 5 Official Mortality Table Adjustment Factor, f, and Life Expectancy for Different Pension Levels and Accumulated Funds

	Official	Adjusted	Wealth at Retirement			Monthly Pension		
	Table	Official Table	High	Medium	Low	High	Medium	Low
Correction Factor Men	1	0.951	0.745	0.969	1.098	0.798	1.021	1.155
Correction Factor Women	1	0.977	0.722	0.926	1.082	0.817	0.986	1.165
Life Expectancy Men (after 65) (years)	20.7	20.9	23.1	20.9	19.9	22.5	20.5	19.5
Life Expectancy Women (after 60) (years)	30.8	31.2	32.9	31.4	30.1	32.4	30.9	29.5

Notes: The adjustment factor, f, was calculated using the exposed and deceased populations above the "normal retirement age" (60 for women and and 65 for men). The estimation of the adjustment factor is based on every annuity pensioner who was exposed in the period 1995-2017.
Source: Own elaboration based on data from Superintendencia de Valores y Seguros (2019).

4.1 | Implications on the Necessary Capital per Unit of Pension and the Annuity-Equivalent Sales Rate

Table 6 shows the implications of the above adjustments to the mortality tables on the Necessary Capital per Unit of Pension (NCUP) at the normal retirement age, using a 2.70%

annual discount rate.[9]

The Necessary Capital per Unit of Pension (NCUP) is the necessary capital to finance an annuity which will pay $1 starting at a specific date, and for the rest of the pensioner's life (and of his/her beneficiaries). It is the expected "present value" of future payments of one unit of pension. The larger the NCUP, the lower the pension will be. The NCUP depends on two variables: i) probability of being alive (the pensioner and his/her beneficiaries) in every year in the future, and ii) interest rates. In particular, the lower (the higher) the probability of being alive in the future, the higher (the lower) the pension. Moreover, the higher the interest rate, the lower the NCUP (less funds will be needed today to produce a unit of pension in future periods), and so the larger the pension; the lower the interest rate, the higher the NCUP (more funds will be needed today to produce a unit of pension in future periods), and so the lower the pension.

Column 2 in Table 6 shows the NCUP for men and women, both married and single. Values are higher for married individuals because they need to finance pensions for the surviving spouse. Values are also higher for women than men because women can retire five years earlier and live longer (five years on average). Column 3 of Table 6 show that adjusting the official tables using the *average* life expectancy induces only small changes in computed NCUP. However, when computing NCUP according to levels of wealth or monthly pensions, the differences can be substantial. For example, in the case of unmarried men, the NCUP computed using the Official Table underestimates the value computed using the wealth-adjusted table by around 9% when wealth is high, but it over-estimates it by around 3% in the case of the low-wealth bracket.

TABLE 6 Necessary Capital per Unit of Pension, Wealth at Retirement and Monthly Pension

	Official	Adjusted	Wealth at Retirement			Monthly Pension		
	Table	Official Table	High	Medium	Low	High	Medium	Low
NCUP (man, single)	183.38	184.65	199.31	185.09	178.26	195.62	182.24	175.48
NCUP (man, married)	228.03	229.65	241.22	230.4	223.82	238.25	227.21	220.9
NCUP (woman, single)	245.17	247.33	256.09	248.47	241.73	253.75	245.77	238.47
NCUP (woman, married)	252.75	254.73	263.93	255.75	249.21	261.5	253.12	246.1

Notes: The NCUP was calculated using official tables CB-H-2014 and RV-M-2014, updated to 2019, for men and women respectively. Couples at the time of pension are assumed to be 65 (husband) and 60 (wife), with no other beneficiaries. The surviving spouse receives 60% of the pension obtained by the pensioner. *Source:* Own elaboration based on data from Superintendencia de Valores y Seguros (2019).

Differences in life expectancy may also be analyzed using the "equivalent sales rate" offered to the pensioners. The sales rate, which is published for each pensioner, is the rate which equals the present value of expected pension flows to the premium paid at $t = 0$, using the official mortality tables. In turn, the premium paid at $t = 0$ is equal to the accumulated funds transferred to the life insurance company from the Pension Fund Administrator (AFP).

The equivalent sales rate is the rate which equals the present value of expected pension flows to the premium paid at $t = 0$, using the group's mortality table. This means, for example, that a 2.70% "official" sales rate, has a higher/lower equivalent sales rate if the group has a higher/lower longevity.

[9]This is the average market sales rate for annuities during the 9-month period ending in June 2019. Source: *Comisión para el Mercado Financiero*. Extracted on June 12, 2020 from http://www.svs.cl/institucional/estadisticas/svtas_tas_int_med_rvp.php

Table 7 shows the impact of adjustments to the mortality tables on annuity-equivalent sales rates. The base annual rate used was, as before, 2.7%. The initial adjustment in the mortality tables for annuitants implies an increase in the equivalent sales rate of approximately six basis points (bps). The overall annuitant population has a lower mortality than implied by the official mortality tables (adjustment factor f is less than unity). This would mean that when the sales rate is published as 2.7%, it is really 2.76%. Since the different groups have different mortality rates, the equivalent sales rate ranges between 2.26% and 3.47%, depending on income, gender and marital status as shown in Table 7.

TABLE 7 Base Annuity Sales Rate and Annuity Equivalent Sales Rate (%)

Unit	Base Annuity	Annuity	Wealth at Retirement			Monthly Pension		
Capital	Sales Rate	Population	High	Medium	Low	High	Medium	Low
Man, single	2.70	2.77	3.47	2.79	2.42	3.30	2.64	2.26
Man, married	2.70	2.76	3.12	2.78	2.55	3.03	2.69	2.44
Woman, single	2.70	2.76	3.01	2.80	2.60	2.95	2.72	2.49
Woman, married	2.70	2.76	3.00	2.78	2.60	2.94	2.71	2.50

Notes: Equivalent sales rate: rate obtained using the group's mortality table, which gives the same pension as the one obtained using the official table, at 2.70%. *Source:* Own elaboration based on data from Superintendencia de Valores y Seguros (2019).

Results could suggest that there is a cross subsidy from lower to higher income groups since they die earlier on average. However, two comments are in order: a) Companies may use their own mortality tables for pricing purposes. Insurance companies could, in principle, use different sales rates for the different income groups. b) The existence of fixed costs when issuing and administering a policy may justify a lower-than-average sales rate for the lower-income groups. Determining whether, historically, lower-income groups have obtained a higher or lower sales rate than higher-income groups is beyond the scope of this paper.

5 | INCOME DISTRIBUTION AND POVERTY AMONG PENSIONERS

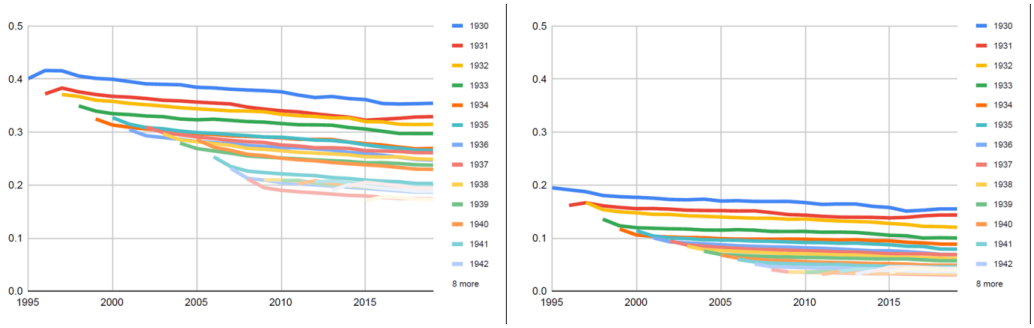
In this section we use our long-term dataset to study income distribution and poverty levels among pensioners. We first focus on poverty levels by age-cohort and by gender. We define the poverty threshold to be equivalent to UF 5 per month, while extreme poverty threshold corresponds to USD 160 per month. The results are presented in Figure 1.

Three elements are worth noting in Figure 1. First, within each age-cohort poverty and extreme poverty levels among pensioners decline in time, both for men and women. This is the result of the above-mentioned differences in life expectancy between income groups: because in each cohort the poor die earlier than the rich, poverty rates at the age-cohort level decline over time.

Second, in the case of men younger cohorts tend to have a significantly lower poverty rate. Consider poverty among male pensioners: those that retired in 1995 exhibit an average poverty rate that is around twice as high as the poverty rate of those that retired in 2010. Because pensions in Chile are the result of mandatory saving over the work life-cycle, the lower poverty rates of newer generations of pensioners reflect both, the sustained growth in wages and incomes of Chilean workers, and the improvement in education and other characteristics by each successive generation.[10]

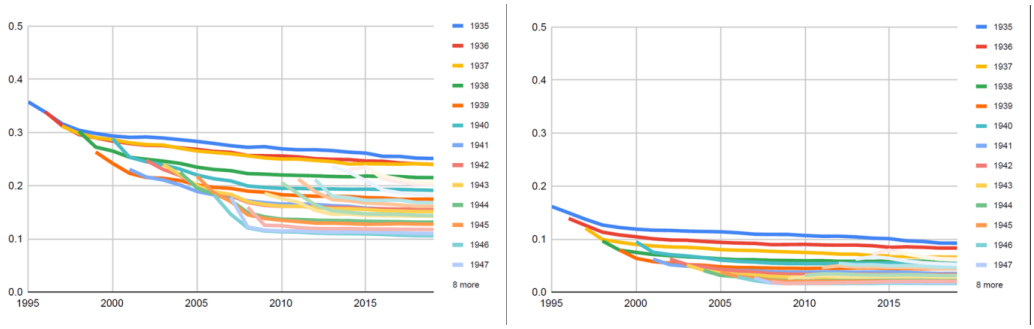
[10]See Alves et al. (2013) for a methodology to decompose the contribution of worker characteristics and returns

Third, in the case of women, however, there is a significant reversion in poverty decline. While the generations born in 1935 till 1948 each exhibit a smaller rate of poverty and extreme poverty than the previous generation, the younger generations since 1949 saw the opposite trend. The poverty rate dropped to around 10% for women born in 1946-1947, and bounded back to around 20% for the 1955 cohort. Extreme poverty levels and trajectory exhibit similar trends. The causes of this phenomenon are yet to be studied.



(a) Poverty by age cohort, men

(b) Extreme Poverty by age cohort, men



(c) Poverty by age cohort, women

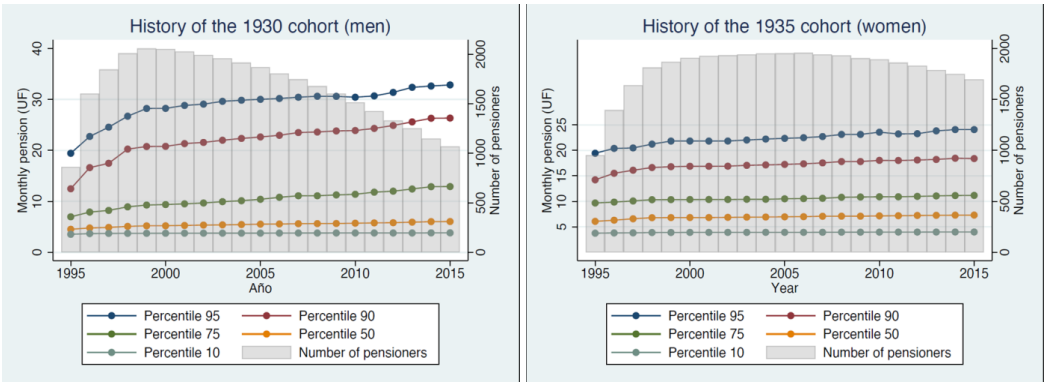
(d) Extreme poverty by age cohort, women

FIGURE 1 Poverty Rates Among Pensioners by Age-Cohort

One important caveat is that our definition of poverty and extreme poverty is based only on individual monthly pensions, thus excluding additional sources of income and wealth in property and other types of assets, which would likely reduce poverty rates. Our measure of poverty also ignores household structures (members of the family, ages, etc.), which may also impact on actual poverty levels.

While the evidence on poverty is straightforward, that of inequality is more cumbersome. In order to have a long-term perspective that would allow us to observe almost complete stories of pensioners after retirement, we focus on the generation born in 1930. Women of such generation started to retire in 1990, while men started to retire in 1995. In figure 2 we characterize this generation in terms of retirement age and income. Grey bars indicate the stock of pensioners in each year, where it can be seen that men tended to postpone retirement for a couple of years but women retired mostly at retirement age. Grey bars also reflect the higher longevity of women: note that 20 years after retirement, 50% of men pensioners have passed away. Note also that women pensions are, on average, significantly lower than those of men.

to human capital over wage inequality, and evidence of the importance of the former.



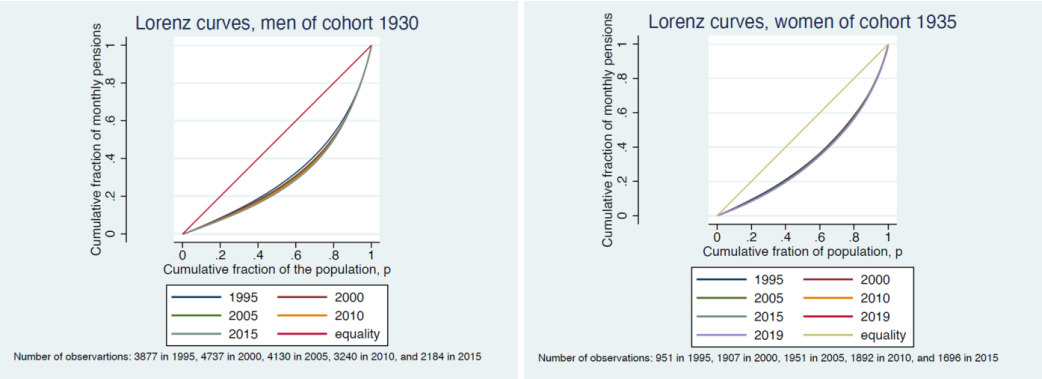
(a) (b)

FIGURE 2 Income and Inequality for the Cohorts at Retirement-Age in 1995

Dotted, colored lines in Figure 2 represent different deciles in the distribution of monthly pensions for male pensioners of the 1930 generation and female pensioners of the 1935 generation—both of which reached retirement age in 1995. In the case of men, it can be seen in Panel A that monthly pensions remain flat for the 10th percentile over the entire post-retirement period, while that of higher deciles tend to increase systematically. There are two forces at work. Initially, higher income workers have an incentive to postpone retirement and accumulate more funds for retirement. The incentive for low income workers exists but it may be negligible. Later, as the number of new pensioners dwindles, average income for pensioners in the 90th percentile continues to grow because low income pensioners die earlier. As a consequence, inequality within the 1930s generation worsens. The 90/10 percentile ratio for men is around 6 after twenty years of retirement.

While in principle the same forces are at work for women of the 1935 generation, evidence indicates that their relative strength differs notoriously. In Panel B of Figure 2, it can be seen that while monthly pensions remain flat for the 10th percentile over the entire post-retirement period, the increase in monthly pensions for those in the 90th percentile is much more modest than that of men. The income distribution among women do not change over time after retirement as much as that of men.

A complementary way to portray changes in income distribution among pensioners is presented in Figure 3 where we show computed Lorenz curves for the generations that reached retirement age in 1995, and for every 5 years afterwards. In synch with the above evidence, two elements show up immediately. First, income inequality among retired men progressively worsens over time as evidenced in a declining Lorenz curve, while among women it remains stagnant overtime. Second, income among women is less unequal than that of men at retirement age and afterwards.



(a) (b)

FIGURE 3 Income Distribution of the Cohorts at Retirement-Age in 1995

It may be unconventional to compare Lorenz curves within a single, shrinking population; still, this tool is useful in appreciating the implicit differences between the subpopulations of survivors and non-survivors. When poorer persons have lower survival rates, the income distribution of the surviving individuals increases over time in the stochastic-dominance sense —i.e., it improves— but, at the same time, the Lorenz curve of that cohort deteriorates. In the case of women though, this effect is almost imperceptible.

6 | CONCLUSIONS

The Chilean pension system allows workers to retire under two alternative mechanisms: programmed withdrawals from their individual premia or purchasing an annuity. We study mortality rates among 580,000 workers that chose to retire using the annuity system. Our results indicate that both retired males and females live on average slightly longer than the general population, as would be expected using the official mortality tables. Our estimates indicate that such gap would be around 3 months for men (when retiring at age 65) and 4 months for women (when retiring at age 60). However, we also found that mortality rates differ significantly by income/wealth levels, independently of whether income is measured as pension received or accumulated funds at retirement. This is consistent with the international literature discussed. The differences between rich and poor workers are in fact quite significant: life expectancy for the high pension/wealth pensioners is around three years higher than high pension/wealth pensioner in our sample. The gap is about the same for men and women.

In our view this is a lower bound for such gap since our evidence is based on annuities and, in the Chilean Pension System, annuities are available only for middle-to-higher earnings workers. By excluding low-income individuals—those with access to the Solidarity Pillar—it is very likely that the 3-year difference may underestimate the real difference between the lowest and highest income groups in Chile.

The paper also unveils interesting evidence on the evolution of income and income distribution. Three elements are worth noting regarding income levels and, thereby, poverty. First, within each age-cohort poverty and extreme poverty levels among pensioners decline in time, both for men and women. This is the direct result of the above mentioned differences in life expectancy between income groups. Second, while there are some reversions, in general younger cohorts tend to have significantly lower poverty rates. The effect is more significant among women. Third, extreme poverty levels and trajectory are very similar

between men and women.

While the evidence on poverty is straightforward, that of inequality is less clear-cut. Focusing on the generation born in 1930—as a representative of the full life-cycle of Chilean workers—we found that in the case of men, monthly pensions remain flat for the 10th percentile of pensioners over the entire post-retirement period, while those of higher deciles tend to increase systematically as a result of their higher longevity. As a consequence, inequality within the pensioners of the 1930 generation worsens over time. There are two forces at work. Initially, higher income workers have an incentive to postpone retirement and accumulate more funds for retirement. Such incentive for low income workers is most likely negligible. Later, as the number of new pensioners dwindles, average income for pensioners in the 90th percentile continues to grow because low income pensioners die earlier. The 90/10 percentile ratio for men is around 4 at retirement and climbs up to 6 after twenty years of retirement.

While in principle the same forces are at work for women of the 1935 generation, evidence indicates that their relative strength differs notoriously. On one hand, income among women is less unequal than that of men at retirement age and afterwards. On the other hand, we found a much softer postponement effect –perhaps because average pensions are much lower—and we also found that monthly pensions remain flat over the entire post-retirement period for the 10th percentile, and with small differences for every other decile of the pension distribution. Consequently, income inequality among retired women of a given cohort tends to remain stagnant overtime.

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