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Pension Income Indexation: A Mean-Variance Approach

ABSTRACT This paper proposes a theoretical framework to study pension income indexation from the retirees' point of view. The theoretical model is then used to calculate the optimal indexation measure for different cohorts of retirees using historical data from Uruguay. The results suggest that for most of the cohorts, but particularly for those retiring in the 1970s and 1990s, the optimal strategy would be to choose the consumer price index (CPI) as the pension income indexation measure. Even for cohorts retiring after the 1989 Constitutional reform that established the average nominal earnings index (ANEI) as the indexation measure, the CPI is still the preferred indexation measure. To show the robustness of the results, two alternative criteria are used to assess the two indexation measures, with similar results.

JEL Codes: G11, D12, D60

Keywords: Cost of living, pension income, indexation, mean-variance portfolio choice

The choice of the best indexation measure to adjust pension income is critical in periods of high inflation. Several countries have adopted automatic indexation using either the consumer price index (CPI) or an index linked to nominal earnings, or even a combination of both.[1] From a policy perspective, understanding what income path best matches consumption needs during retirement years is a highly important question because of the increasing number of retirees. Recent reforms in pension systems that replaced defined benefit with defined contribution schemes imply the transfer of risk from employers to employees. In this new setting, annuities need to be linked to indexes that represent the changes in the cost of living of retirees.

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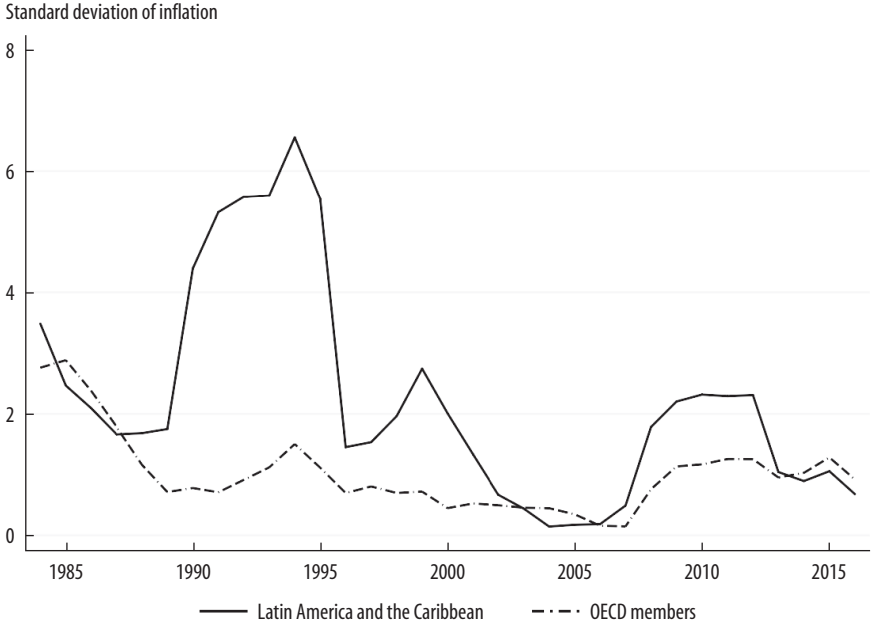
1. See Piggott and Sane (2009) for a detailed discussion of the different indexation mechanisms adopted in several countries.

FIGURE 1. Volatility of Inflation: Latin America versus OECD



Source: World Bank, World Development Indicators.

In the United Kingdom, a country with relatively stable inflation, the discussion has been on whether to use the retail price index (RPI) or the CPI to adjust social security benefits and state pensions. The idea is that differences in the consumption basket of retirees versus the general population result in heterogeneity in inflation rates, so the indexation rule needs to capture changes in retirees' cost of living.

Studying optimal indexation rules becomes even more relevant in contexts of high volatility of inflation, such as in developing countries. Figure 1 shows the five-year moving standard deviation of the inflation rate in Latin America and the Caribbean vis-à-vis the member countries of the Organization for Economic Cooperation and Development (OECD) from the mid-1980s until 2016. In general, developing countries suffer not only from higher inflation rates but also from more volatility in inflation. Thus, in the context of developing countries, the choice of the indexation mechanism is key for retirees to be able to maintain their level of consumption during retirement.

The contributions of this paper are twofold. First, I propose a theoretical framework to study pension income indexation from the point of view of retirees, where retirees' indexation choice is modeled using a mean-variance optimal portfolio framework. Much as with the standard mean-variance portfolio choice problem, the optimal choice of indexation measure depends not only on the return but also on the associated consumption risk. I consider two alternative risky assets, the CPI and the average nominal earnings index (ANEI), and a risk-free asset given by the retiree's cost-of-living index. I then derive the analytical expression for the optimal portfolio share in the CPI as a function of asset excess returns, the variance and covariance, and the retiree's risk aversion. The results provide an indication of which indexation measure best suits consumption needs during retirement. Moreover, the closed-form solution of the model allows it to be used as a tool to analyze different policies when thinking about pension income indexation in any country.

The paper's second contribution is empirical, as the model is applied to historical data for Uruguay. According to Article 67 of the constitution and Law No. 17,687, pension income in Uruguay is adjusted by the previous year's increase in the official ANEI.[2] I first approximate changes in retirees' cost of living by computing household-specific inflation rates. I then compute the optimal portfolio in terms of the ANEI and CPI for different generations of pensioners using historical data. In the long run, wages are expected to grow faster than prices. However, because a person lives, on average, for twenty years after retirement, the timing of retirement is key for assessing the advantageousness, from the retiree's point of view, of using the ANEI or CPI to adjust pension income. In the particular case of Uruguay, analyzing whether the ANEI or the CPI is a better measure of retirees' cost of living is critical for designing a well-functioning annuities market.

The focus of this paper is to study the best indexation mechanism from the retiree's perspective, but the indexation mechanism is also essential for the sustainability of the pension system. In the very long run, real wages should grow in line with productivity, so a system in which pensions are indexed to wages should put more pressure on pension finances in the long run. However, given the cyclical economic crises that developed and especially developing countries have to face, there might be periods of low or null wage growth accompanied by high inflation. In that case, an inflation-linked pension system would have more pressure on its finances in periods of low economic

2. *Índice Medio de Salarios Nominales,* published by the National Statistics Institute of Uruguay.

growth. The design of a pension system and, in particular, the choice of the indexation mechanism should consider not only what is best for the retirees but also how the different indexation measures affect the sustainability of the system in the short and long run.

The rest of the paper is organized as follows. The literature is summarized in the next section. Subsequent sections present the mean-variance portfolio choice model and apply the model to the Uruguayan data. I also discuss the implications of the different indexation mechanisms for the financial sustainability of the pension system. The final section concludes.

Literature Review

A strand of literature in the United Kingdom focuses on the inflation experience of different household types. Crawford estimates Tornqvist-type price indexes for seventy-four commodities to study changes in the cost of living of different types of households from 1978 to 1992.[3] He finds small differences in the inflation rate experienced by the different types of households. In particular, richer households experienced higher inflation than poorer ones in this period owing to the fall in relative prices of necessities and the corresponding price increase of luxuries. Crawford and Smith study the inflation experience of different types of households from 1976 to 2000.[4] Using data from the UK Family Expenditure Survey (FES) and computing household-specific inflation rates, they find that the distribution of inflation varies substantially over time. They do not find a particular pattern in the dispersion of inflation across households over time but suggest that household inflation is more dispersed in periods of high inflation. They report that between 1976 and 2000, only 35 percent of the households experienced inflation within one percentage point of the average inflation rate. They also studied the inflation experienced by different types of households, indicating that, on average, inflation is higher for high-income households, nonpensioners, mortgagers, the employed, single adults, and younger households. Finally, they show the importance of considering the different inflation rates across households in studying inequality over time.

3. Crawford (1994).
4. Crawford and Smith (2002).

More recently, Leicester, O'Dea, and Oldfield studied the inflation experience of older households and Levell and Oldfield studied the inflation experience of low-income households in the United Kingdom.[5] In particular, Leicester, O'Dea, and Oldfield used data from the UK FES to compute household-specific inflation rates between 1977 and 2008 and found that there was no difference in the average inflation rate of pensioners (5.8 percent) and nonpensioners (5.9 percent) during the period, although there were substantial differences in given years. They also studied how inflation varied among pensioners and found that those aged seventy-five or older suffered more than younger pensioners from the rapid increase in fuel and food prices.

From a theoretical perspective, Lluberas studied the welfare consequences of cost-of-living adjustments for a consumer who buys an annuity to finance his or her consumption during retirement.[6] The main conclusion of the model is that if the consumer has access to an individual-specific inflation-linked annuity, the Arrow-Debreu result could be replicated. In particular, annuities act as an Arrow security with the different states of nature given by different inflation rates, and thus the consumer can insure not only against survival risk but also against inflation risk.

Model: Mean-Variance Portfolio Choice

Assume a worker retires at time $t = 0$ and starts receiving a pension income that is adjusted on a yearly basis. Pension income is adjusted so that retirees are able to maintain their level of consumption during retirement. Which measure would the retiree choose if she has the option? A retiree maximizing her intertemporal utility of consumption will choose the indexation measure that allows her to smooth consumption over time.[7] Assuming the retiree has no assets to finance consumption, pension income—her only source of income—has to be adjusted by a retiree's specific cost-of-living index in order to maintain her consumption over time. This retiree's specific cost-of-living index can be thought of as a risk-free asset, p^*.

5. Leicester, O'Dea, and Oldfield (2008); Levell and Oldfield (2011).
6. Lluberas (2018).
7. In the model, the retiree only cares about her consumption, but she could also care about her consumption relative to the rest of the population. The latter is not considered in this analysis.

The model includes two alternative indexation measures: a first one linked to a population average cost-of-living index given by the CPI, p, and a second measure linked to the ANEI, s. Assume also that the retiree is risk-averse.

Let $r_t^p = r_t^{p^*} + \varepsilon_t^p$ be the rate of return of p at time t and $r_t^s = r_t^{p^*} + \varepsilon_t^s$ the rate of return of s. These rates of return can be expressed with respect to the return of the risk-free asset given by the retiree's specific cost-of-living index, $r_t^{p^*}$. Thus the excess returns for p and s, respectively, are defined as follows:

$$\hat{r}_t^p = r_t^p - r_t^{p^*} = \varepsilon_t^p; \tag{1}$$

$$\hat{r}_t^s = r_t^s - r_t^{p^*} = \varepsilon_t^s. \tag{2}$$

The following joint distribution is assumed for the excess returns:

$$\begin{pmatrix} \varepsilon_t^p \\ \varepsilon_t^s \end{pmatrix} \left[\begin{pmatrix} \mu_t^p \\ \mu_t^s \end{pmatrix} \begin{pmatrix} \sigma_p^2 & \operatorname{cov}\left(\varepsilon_t^p, \varepsilon_t^s\right) \\ \operatorname{cov}\left(\varepsilon_t^p, \varepsilon_t^s\right) & \sigma_s^2 \end{pmatrix} \right].$$

While the expected mean excess return changes over time, both the variances and covariance are assumed to be constant. This implies that although the mean of excess returns can change, the dispersion of excess returns is assumed to remain constant during the retirement phase.

The retiree's selection problem is thus a mean-variance portfolio selection problem in which the retiree receives a lump sum at time 0 and then chooses the proportion of income to allocate to each asset.[8] The retiree chooses the proportion of income allocated to each indexation measure at the time of retirement, and that proportion is kept constant until she dies at time T. Let γ be the coefficient of relative risk aversion and $\beta = 1/(1 + \delta)$ the subjective discount factor. Then the retiree chooses w_p by solving the following optimization problem:

$$\max_{w_p} V = E_0 \left\{ \sum_{t=1}^{T} \beta^t \left[\varepsilon_t^p w_p + \left(1 - w_p\right) \varepsilon_t^s \right] \right\} - \frac{\gamma}{2} \left\{ \sum_{t=1}^{T} \beta^t \operatorname{var} \left[\varepsilon_t^p w_p + \left(1 - w_p\right) \varepsilon_t^s \right] \right\},$$

8. Defining the retiree's selection problem as depending only on the mean and the variance implicitly assumes one of the following: (1) quadratic utility; or (2) exponential utility and normal distribution of asset returns; or (3) power utility and log-normal distribution of asset returns. See Campbell and Viceira (2002) for more details.

such that $0 \leq w_p \leq 1$. Given the assumptions on the distribution of returns, the mean and variance can be expressed as follows:

$$E_0\left\{\sum_{t=1}^{T}\beta^t\left[\varepsilon_t^p w_p + \left(1-w_p\right)\varepsilon_t^s\right]\right\} = \sum_{t=1}^{T}\beta^t\left[\mu_t^p w_p + \left(1-w_p\right)\mu_t^s\right]$$

$$\sum_{t=1}^{T}\beta^t \operatorname{var}\left[\varepsilon_t^p w_p + \left(1-w_p\right)\varepsilon_t^s\right]$$

$$= \sum_{t=1}^{T}\beta^t\left[\sigma_p^2 w_p^2 + \left(1-w_p\right)^2\sigma_s^2 + 2w_p\left(1-w_p\right)\operatorname{cov}\left(\varepsilon_t^p, \varepsilon_t^s\right)\right].$$

When these expressions are plugged into the optimization problem, the retiree's problem can be expressed as

$$\max_{0\leq w_p\leq 1} V = \sum_{t=1}^{T}\beta^t\left[\mu_t^p w_p + \left(1-w_p\right)\mu_t^s\right]$$

$$-\frac{\gamma}{2}\left\{\sum_{t=1}^{T}\beta^t\left[\sigma_p^2 w_p^2 + \left(1-w_p\right)^2\sigma_s^2 + 2w_p\left(1-w_p\right)\operatorname{cov}\left(\varepsilon_t^p, \varepsilon_t^s\right)\right]\right\}.$$

The first-order condition with respect to w_p is:

$$\frac{dV}{dw_p} = \sum_{t=1}^{T}\beta^t\left[\mu_t^p - \mu_t^s\right] - \gamma w_p\left\{\sum_{t=1}^{T}\beta^t\left[\sigma_p^2 + \sigma_s^2 - 2\operatorname{cov}\left(\varepsilon_t^p, \varepsilon_t^s\right)\right]\right\}$$

$$+\gamma\left\{\sum_{t=1}^{T}\beta^t\left[\sigma_s^2 - \operatorname{cov}\left(\varepsilon_t^p, \varepsilon_t^s\right)\right]\right\} = 0.$$

Define $\tilde{\mu}_i = \sum_{t=1}^{T}\beta^t\mu_t^i$ for $i = p, s$. Then

$$w_p^* = \frac{\tilde{\mu}_p - \tilde{\mu}_s + \gamma\sum_{t-1}^{T}\beta^t\left[\sigma_s^2 - \operatorname{cov}\left(\varepsilon_t^p, \varepsilon_t^s\right)\right]}{\gamma\sum_{t-1}^{T}\beta^t\left[\sigma_p^2 + \sigma_s^2 - 2\operatorname{cov}\left(\varepsilon_t^p, \varepsilon_t^s\right)\right]}. \tag{3}$$

Equation 3 gives the expression for the optimal proportion of income allocated to the CPI indexation measure, and thus $(1 - w_p^*)$ represents the

optimal proportion of income allocated to the ANEI indexation measure. As in the standard mean-variance model, the optimal portfolio weight depends on the risk premium, the variance-covariance, and the consumer's risk aversion.

The Case of Uruguay

Pension income in Uruguay is indexed to the ANEI. According to Article 67 of the constitution and Law No. 17,687, pension income in Uruguay is adjusted by the previous year's increase in the official ANEI. A key question then is whether the ANEI is a good measure of retirees' cost of living. In general, for the average household, indexing income to the CPI insures consumption, but it might result in lower growth than wages—or the general cost of living.

This section uses the theoretical model to assess the superiority of adjusting pension income using either the ANEI or the CPI, from the perspective of the retirees. The retirees are then assumed to have access to two alternative assets and have to decide the proportion of income allocated to each of them.

Preliminaries: Household inflation

As the excess returns are expressed with respect to retirees' cost of living, the first step is to compute a retiree-specific inflation index (p^*). The inflation rate for household i at time t is

$$p_{it}^* = \sum_{j=1}^{J} s_i^j \pi_t^j, \tag{4}$$

where

$$s_i^j = \frac{p_i^j q_i^j}{p_i q_i}$$

is the share of good j in the expenditures of household i, and π_t^j is the year-over-year inflation rate of good j at time t. For Uruguay, inflation rates for different goods are available only at the national level from the National Statistics Institute (INE), so variation in the inflation experienced by different households is due to differences in expenditure shares. To compute the household-specific inflation rate, I consider eighty sections of

TABLE 1. Consumption Basket
Percent of total expenditures

Item	*Worker*	*Retiree*
Food and nonalcoholic drinks	23.9	23.4
Alcoholic drinks and tobacco	1.6	1.2
Clothing and footwear	4.9	2.8
Housing	30.4	35.4
Furniture and household appliances	4.3	4.0
Health care	6.4	12.2
Transportation	9.0	5.7
Communications	4.1	4.2
Leisure	5.4	4.4
Education	1.7	0.4
Restaurants and hotels	3.5	1.8
Other goods and services	4.8	4.6

the CPI ($j = 1, \ldots, 80$) and compute s_i^j for each household in the sample using the 2005–06 Uruguay National Household Income and Expenditure Survey. Household inflation depends, then, on each of the eighty CPI section inflation rates and on the basket of goods consumed by each household.

Table 1 shows the consumption basket, as a share of total expenditure, for workers and retirees. Similar to previous studies, I find that retirees spend a smaller proportion of their budget on education and work-related goods, such as clothing and footwear, transportation, and eating out, than workers. On the other hand, the share of total expenditure that retirees allocate to health care is almost double that of workers (6.4 percent versus 12.2 percent). Finally, retirees spend a larger proportion of their budget on housing.

These differences in the consumption bundle translate into differences in the inflation rate experienced by the different types of households. Figure 2 shows the inflation rate of workers and retirees and also the CPI inflation rate calculated by the NSI. As the figure shows, the two inflation measures track the official inflation rate quite closely. The small differences are due to the fact that the official calculation makes use of additional data sources to complement the household survey. The figure also reveals that there are no substantial differences in the inflation experienced by workers and retirees in the period under analysis.

Figure 3 shows the difference in the inflation rate experienced by retirees relative to the general population and the change in the ANEI. In general, retirees experience slightly higher inflation rates in periods of economic

FIGURE 2. Average Household Inflation versus CPI: 1998–2012

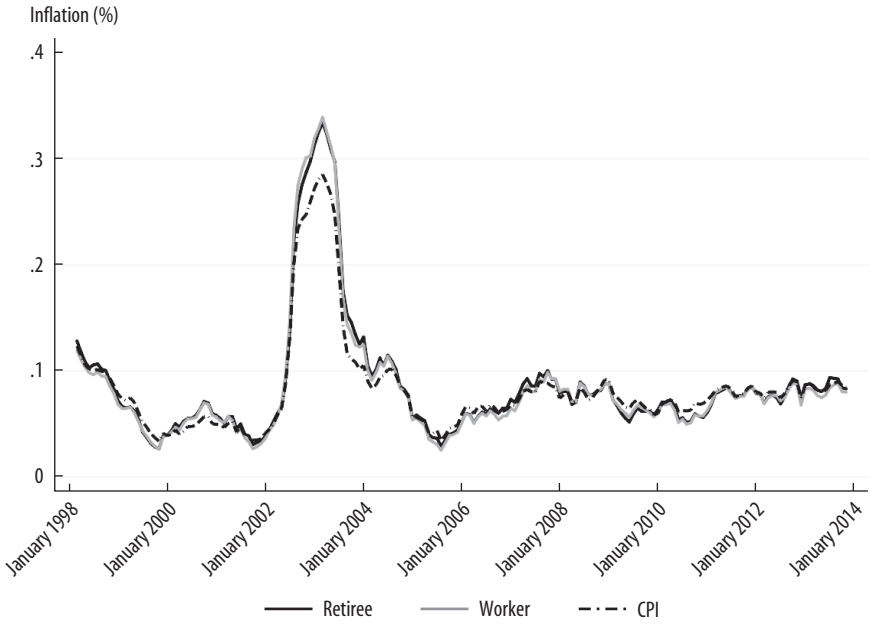
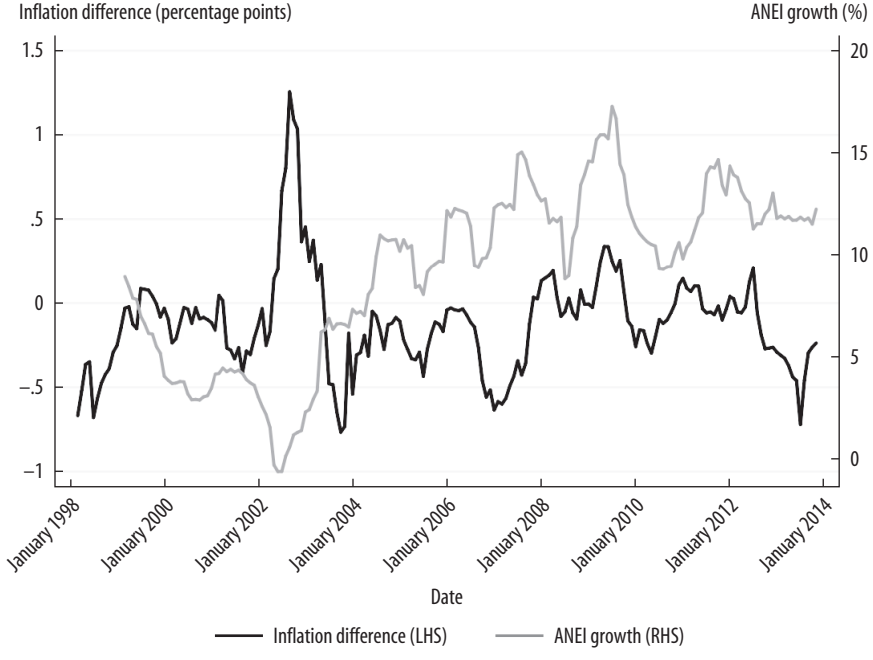


FIGURE 3. Average Household Inflation Difference and ANEI



distress, as occurred after the Argentina devaluation of 2001–02. In that case, real GDP dropped 9 percent between 2001 and 2002, causing the annual inflation rate of retirees to spike to almost 30 percent by the end of 2002. Consequently, use of the ANEI as the pension indexation measure does not insure retirees' consumption during recessions or periods of low economic growth. Indeed, the purchasing power of ANEI-linked pension income declined by about 28 percent during the 2001–02 economic crisis.

Cohorts

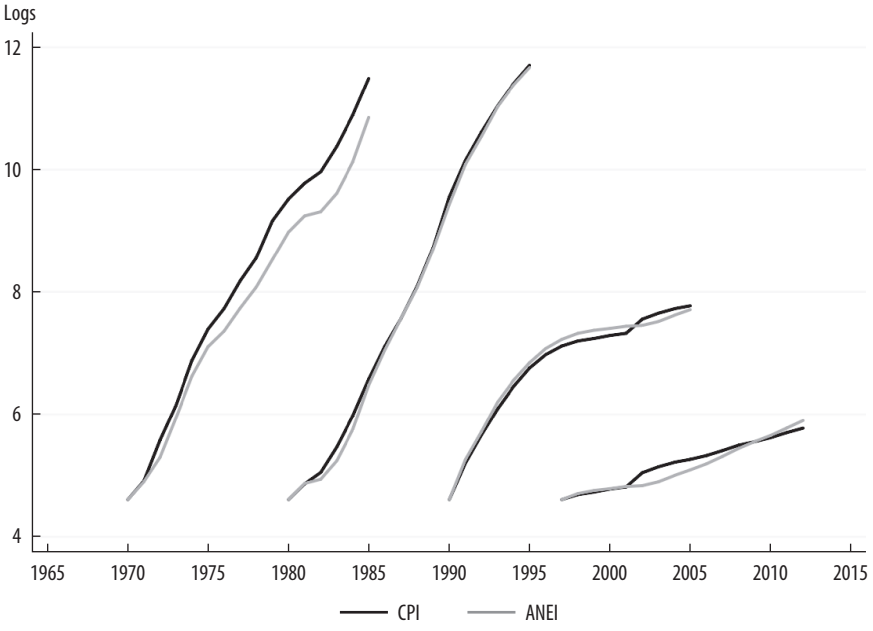
This section uses the model described above to explore retirees' optimal portfolio choices, using historical data for Uruguay. The empirical analysis draws on thirty cohorts of retirees. The data cover the dynamics of the CPI, the ANEI, and the retirees' specific inflation for the period 1968–2012. The cohorts are defined based on the year of retirement. The length of retirement (T) is assumed to be fifteen years.[9] Thus, someone who retired in 1970 is assumed to have lived and earned pension income until 1985. Given that the data run through 2012, the last cohort considered is the one retiring in 1997.

Figure 4 shows pension income dynamics using either the CPI or the ANEI as the indexation measure for four cohorts of retirees: 1970, 1980, 1990, and 1997. Based just on pension income obtained in the last year of retirement, it is clear that the year of retirement is highly important in terms of which indexation measure makes the retiree better off. The 1970 cohort is better off during the whole retirement period when pension income is adjusted by the CPI. In contrast, the 1997 cohort is better off at the beginning of the retirement period if pension income is adjusted by the ANEI, but the CPI is preferred after the 2002 crisis. At the end of the retirement period, again the ANEI would be preferred. The theoretical model presented above can thus be used to summarize the trajectory of pension income dynamics in a single measure that considers not only mean income but also its volatility. Alternative measures are presented as robustness checks later in the paper.

The following section presents the data inputs required for the computation of w_p^*.

9. Life expectancy at sixty years of age, which is the normal retirement age in Uruguay, is about sixteen years for men and eighteen years for women. However, similar results are obtained for longer retirement periods. See figures A1, A2, and A3 in the appendix for graphs of $T = 18$, $T = 19$, and $T = 20$, respectively.

FIGURE 4. Pension Income Dynamics under Alternative Indexation Measures (in Logs)



Return and Risk

Having computed retirees' specific inflation rate (p^*), the next step is to calculate the excess returns given in equations 1 and 2, which serve as inputs for the computation of the optimal proportion of income allocated to the CPI, w_p^*, given in equation 3.

Figure 5 shows the expected returns—μ_t^p and μ_t^s—calculated as the annual percentage change in the CPI and ANEI, respectively. As expected, the general population CPI is closer to the retirees' inflation rate than ANEI growth. However, because of the reinstallation of collective wage bargaining in 2005, together with steady economic growth after the 2001–02 economic crisis, nominal wages grew faster than prices. From 2000 until the last year of the data sample, retirees would be better off if their income was linked to the ANEI, with the exception of the drop in real wages in 2002 and without considering income risk. This result could change, however, once the variance of returns and retirees' level of risk aversion are taken into account, as shown in the next section.

FIGURE 5. Expected Returns: μ_t^p and μ_t^s

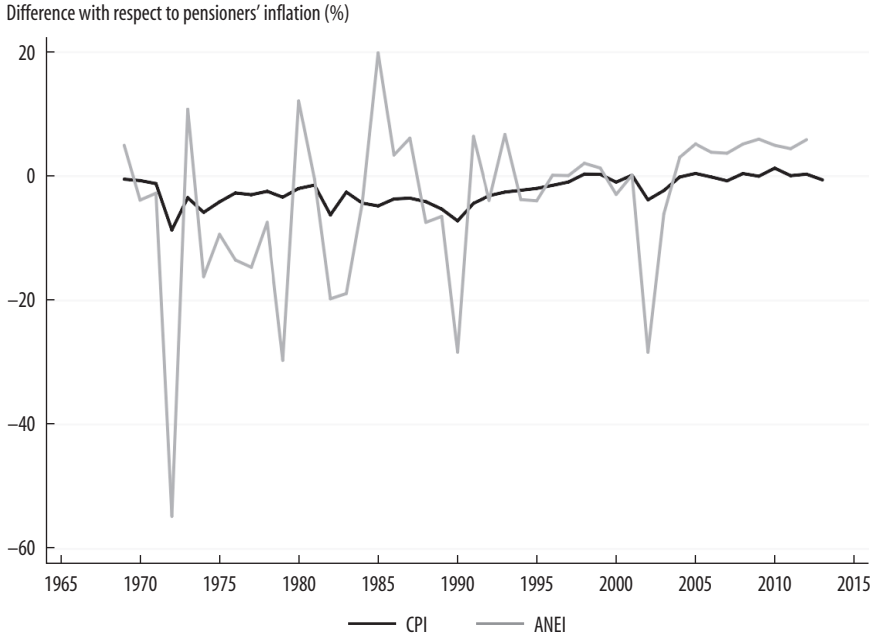


Figure 6 shows the discounted accumulated expected returns for each cohort of retirees. For those retiring between 1969 and 1978 and those retiring between 1987 and 1994 (with the exception of 1990), $\tilde{\mu}_p > \tilde{\mu}_s$. In contrast, for those retiring between 1979 and 1986, in 1990, and between 1995 and 1997, $\tilde{\mu}_p < \tilde{\mu}_s$. The figure also shows that the discounted accumulated return increases over time for both assets, but more so for the ANEI. Moreover, $\tilde{\mu}_s > 0$ only for those retiring in 1997, the last cohort considered in the empirical analysis.

Figure 7 shows the implied income risk, measured by the variance of returns, under the two indexation measures. The risk associated with the ANEI is, on average, about fifty-five times that of the CPI, ranging from a minimum of fifteen times for the 1986 cohort to 108 times for the 1972 cohort. This implies that investing in an ANEI-linked asset involves substantially more risk, in terms of consumption, than investing in a CPI-linked asset. The risk associated with the ANEI-linked asset declines over time, however, while the expected return increases.

FIGURE 6. Discounted Accumulated Expected Returns: $\tilde{\mu}_p$ and $\tilde{\mu}_s$

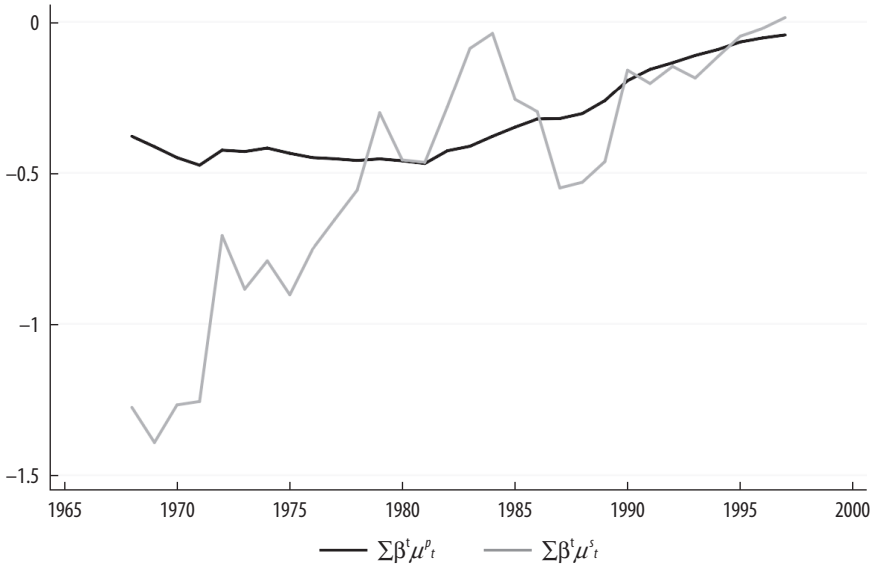


FIGURE 7. Pension Income Risk: σ_p^2 and σ_s^2

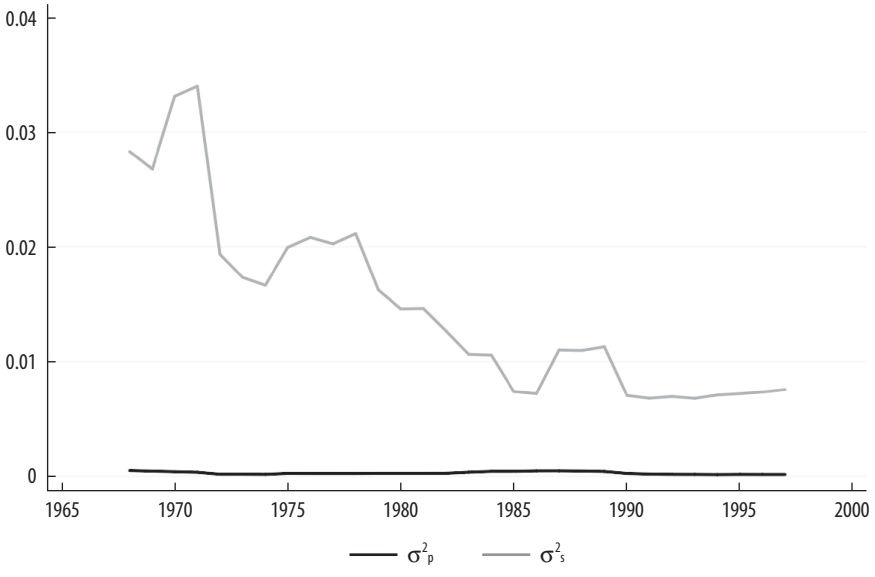
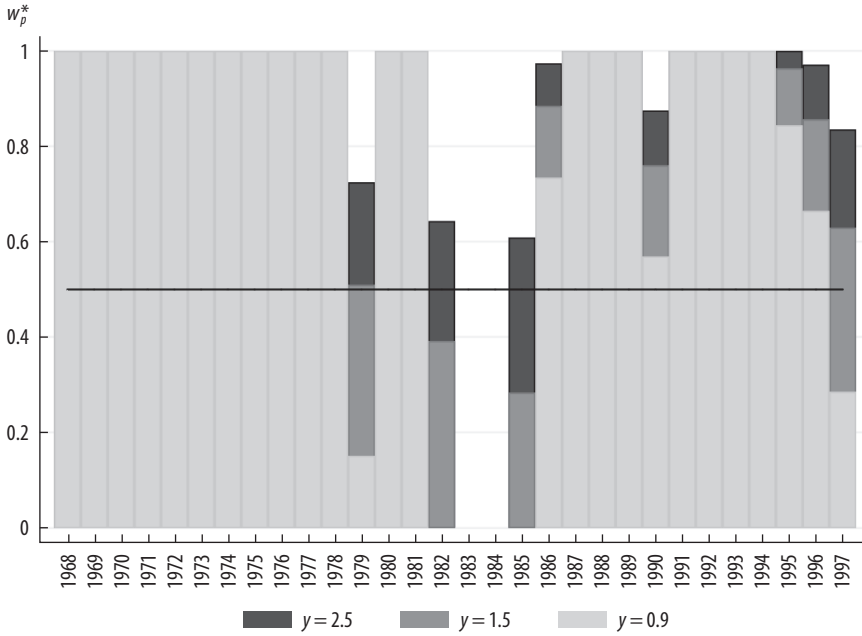


FIGURE 8. Optimal w_p^*: Sensitivity to Risk Aversion



Note: The figure shows the optimal share of income to allocate to the CPI versus the ANEI. A value of one implies that all the income should be invested in the CPI, while a value of zero implies that all the income should be invested in the ANEI.

Optimal w_p

Based on the inputs described above, this section computes the optimal proportion of income to allocate to the CPI. Figure 8 shows the results for each of the cohorts retiring between 1968 and 1997. A value of one implies that all the income should be invested in the CPI, while a value of zero implies that all the income should be invested in the ANEI.

The results are shown for coefficients of risk aversion (γ) equal to 0.9, 1.5, and 2.5. These values were taken from Friedberg and, in particular, Chetty, who estimate implied coefficients of relative risk aversion for men aged sixty-three to seventy-one years.[10] According to both sources, the implied coefficient of relative risk aversion for older men is between 0.93 and 1.46.[11]

10. Friedberg (2000); Chetty (2006).
11. See Chetty (2006, table 1).

TABLE 2. Excess Return Needed to Compensate for ANEI Volatility

	Average return	
Cohort	$w_p^* = 0$	$w_p^* = 0.5$
1970	1.14	0.98
1975	0.67	0.56
1989	0.31	0.26
1992	0.08	0.09

There are many estimates of risk aversion for the working-age population, but there is very limited empirical evidence on the risk aversion coefficient of the elderly. A relatively well established empirical fact is the decline of risk tolerance with age. One recent study shows that risk tolerance decreases linearly until age sixty-five, after which it flattens out.[12]

In light of the much smaller risk associated with investing in the CPI, w_p^* increases with γ for a given level of return. This implies that if $w_p = 1$ for $\gamma = 0.9$, then $w_p = 1$ for $\gamma = 1.5$ and $\gamma = 2.5$, as well. The figure also shows the increase in w_p^* for higher levels of risk aversion. The 1979 cohort may be used as an example. For a pensioner with a low level of risk aversion, the optimal strategy would be to invest the total pension income in an ANEI-linked asset. As risk aversion increases, w_p^* also increases, and w_p^* is 0.4 for $\gamma = 1.5$ and 0.6 for $\gamma = 2.5$.

These results suggest that for most of the cohorts, but particularly for those retiring in the 1970s and 1990s, the optimal strategy is to choose the CPI as the pension income indexation measure. Even for cohorts retiring after the 1989 constitutional reform that established the ANEI as the indexation measure, the CPI is the preferred indexation measure.

The better performance of the CPI as an indexation measure is mostly driven by the high volatility of ANEI growth. Then an interesting question is what level of return would compensate retirees for the high volatility of the ANEI.[13] Table 2 shows the additional average return of the ANEI needed to compensate for its high volatility for four cohorts of retirees and for two alternative cases. In the first case, the optimal income allocated to the CPI, w_p^*, is 0.0; in the second case, w_p^* is equal to 0.5. The cohorts comprise retirees

12. Dohmen, Falk, Golsteyn, and others (2017).
13. Thanks to one of the referees for suggesting this analysis.

FIGURE 9. Difference in Pension Income by Cohort: ANEI – CPI (in Logs)

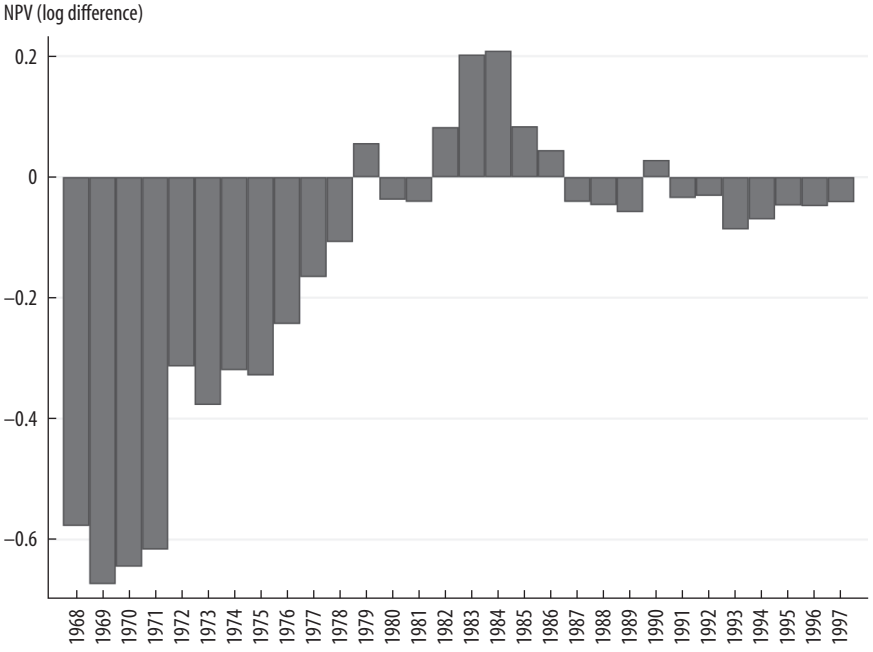
leaving the labor market in 1970, 1975, 1989 (the year of the constitutional reform), and 1992.

For those retiring in 1970, an increase of between 0.98 and 1.14 percentage points in average ANEI growth is needed to compensate for its excess volatility. For the more recent cohorts of retirees, the return that would compensate for the high variability of ANEI declines, in line with the reduction in the volatility of ANEI growth over time (see figure 7). For the 1992 cohort, for instance, an increase of 0.09 percentage points in ANEI growth would compensate for its volatility.

Robustness Check

In the previous sections, I presented a framework to analyze the advantages of the CPI or the ANEI as pension income indexation measures. This section shows that the results from the theoretical model are robust to alternative criteria. In particular, figure 9 shows the log difference between pension income adjusted by the ANEI and the CPI. A negative value implies that the

FIGURE 10. Net Present Value: ANEI – CPI (in Logs)



CPI is preferred to the ANEI. Most of the cohorts in most years are better off if their pension income is adjusted by the CPI as opposed to the ANEI. Even some of the cohorts whose retirement covers the years after the 2001 crisis, when the ANEI increased faster than the CPI, are better off with the CPI. This is due to the negative effect that the 2001 crisis had on the real growth of wages. It suggests that extreme events have profound effects on the benefits, from the retirees's viewpoint, of one or the other pension income indexation measure.

A second criterion to assess the advantageousness of the CPI vis-à-vis the ANEI is the net present value (NPV). Figure 10 shows the log difference of the NPV using the ANEI and the CPI, assuming a discount rate of 3 percent. Again, a negative value implies that the retiree is better off with her pension income indexed to the CPI as opposed to the ANEI. With the exception of the cohorts retiring in 1979, between 1982 and 1986, and in 1990, the CPI is preferred to the ANEI as the pension income indexation mechanism.

Sustainability of the Pension System

Based solely on the welfare of retirees, the preferred indexation mechanism depends on the time of retirement. Some cohorts would be better off if the CPI is used as their income indexation measure, while other cohorts, particularly those retiring at the end of the 1990s, would be better off with the ANEI as the indexation measure. This section looks at another dimension of the problem, namely, how the choice of the indexation mechanism could affect the sustainability of the pension system.

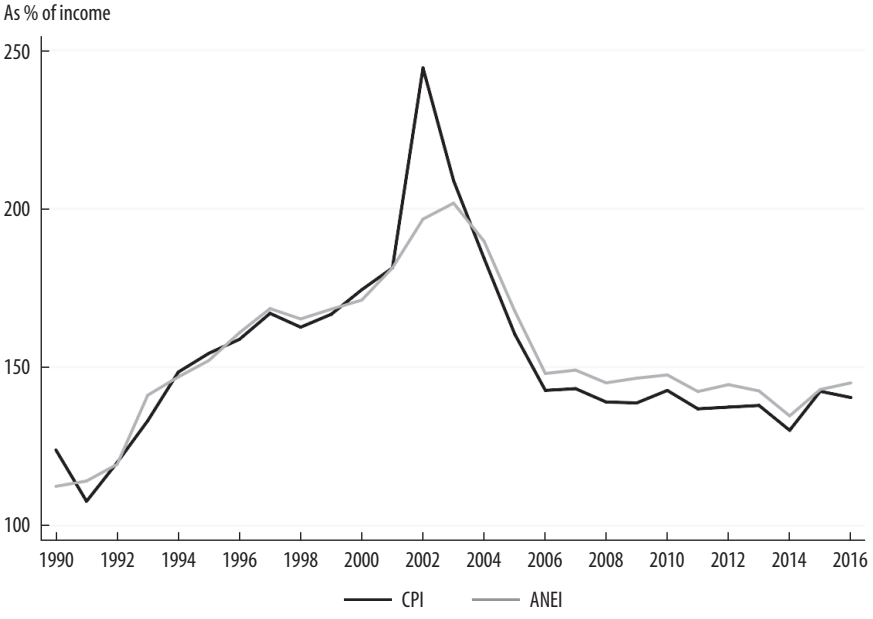
Real wages can be expected to grow in line with productivity in the long run. Therefore, a social security system in which pension income is linked to wage growth should put more pressure on its finances in the long run than a system in which pension income is adjusted by inflation. However, given the cyclical crises that countries regularly face, there might be periods of low or null wage growth and high inflation. An inflation-linked pension system would then put more pressure on its finances in periods of low economic growth when resources are scarce.

Uruguay has a history of relatively high and volatile inflation and, like many countries in Latin America and the Caribbean, has suffered recurrent economic crises in the last decades. I used the social security agency's financial statements to compute total pension payments under two alternative scenarios.[14] The first is the scheme that is currently in place, in which pension income is adjusted by the evolution of the ANEI. The second scenario links pensions to inflation or CPI growth. All the figures shown in this section are expressed as a proportion of the social security agency's resources.

Figure 11 shows total pension payments by the social security agency as a share of its resources under the two alternative scenarios. Historically, economic crises are associated with high inflation and low earnings growth. This translates into very different dynamics of pension income depending on whether the CPI or the ANEI is used as the indexation mechanism, which in turn affects the sustainability of the pension system finances. The Uruguayan economy grew more than 40 percent in real terms between 1990 and 1998, the year before the start of the deep recession that ended with a banking and exchange rate crisis in 2002. That year, GDP fell more than 7 percent, and unemployment reached 17 percent. The crawling peg that was in place since the early 1990s was abandoned, and the peso depreciated around 100 percent

14. Banco de Previsión Social (BPS). The analysis considers only resources and payments for disability and old-age pensions, which are classed together as pensions.

FIGURE 11. Pension System: Payments under Alternative Indexation Mechanisms
Percent of resources



against the U.S. dollar, resulting in annual inflation of almost 30 percent. With high unemployment and a stagnated economy, nominal labor earnings stopped growing.

Under a CPI-linked pension system, payments would have climbed to more than 240 percent of resources in 2002, versus 196 percent for an ANEI-linked system. After the 2002 crisis, and in particular since 2004, average earnings grew more than inflation. A similar pattern is found for cumulative payments under the two schemes: cumulative payments grew at a similar rate under the two indexation measures until the 2002 crisis, after which CPI-linked pensions would have put more pressure on public finances than earnings-linked pensions. Insofar as earnings grew in real terms after 2005, cumulative payments under an earnings-linked pension system represent 150 percent of cumulative resources in 2016, compared with 147 percent for CPI-linked pensions.[15]

15. See figure A4 in the appendix.

FIGURE 12. Pension System: Difference in Payments under ANEI versus CPI
Percent of resources

Figure 12 shows the difference in resources needed in an ANEI-linked pension system vis-à-vis a pension system in which payments are linked to inflation. There are no substantial differences in the financial needs under the two indexation mechanisms in the 1990s. However, as a result of the high inflation and nil earnings growth experienced during the economic and financial crisis of 2002, an inflation-linked pension system would have needed about 2.4 percent of GDP in additional resources compared to a pension system in which payments were adjusted by ANEI growth. Thus a CPI-linked pension system would put even more pressure on public finances in periods of low economic growth, when public resources are scarce. To sum up, although it is welfare improving for retirees to have their pension income linked to inflation during economic crises, this can have a profound effect on the sustainability of the pension system, at least in the short and medium terms.

Conclusion

This paper has proposed a theoretical framework for studying pension income indexation from the point of view of the retiree. The retiree's choice of the indexation measure was modeled in a mean-variance optimal portfolio framework. As in the standard mean-variance portfolio choice problem, the optimal choice of the indexation measure depends not only on the return but also on the associated consumption risk. The model considers two alternative risky assets and a risk-free asset given by the retiree's specific inflation rate.

The theoretical model was then used to calculate the optimal portfolio, using historical data from Uruguay. Changes in retirees' cost of living were approximated by computing the household-specific inflation rates, and historical data were used to compute the optimal portfolio allocated to ANEI-linked and CPI-linked assets for different generations of retirees. I documented two important empirical facts. First, the implied income risk associated with the ANEI is substantially higher than that of the CPI—about fifty-five times higher, on average, ranging from a minimum of fifteen times for the 1986 cohort to 108 times for the 1972 cohort. Its high volatility makes the ANEI a less attractive indexation measure, even in periods of real wage growth.

A second empirical finding is that for most cohorts, but particularly for those retiring in the 1970s and 1990s, the optimal strategy is to choose the CPI as the pension income indexation measure. Even for cohorts retiring after the 1989 constitutional reform that established the ANEI as the pension income indexation measure, the CPI is the preferred indexation measure.

The focus of this paper was to study the best indexation mechanism from the perspective of the retiree, but the indexation mechanism also has important implications for the sustainability of the pension system. There are minor differences in the long run for public finances between the two indexation mechanisms, but the choice could affect sustainability in the short run. The model showed that CPI-indexed pension income is much more volatile than the alternative, so a CPI-indexation pension system may require a well-funded pension stabilization fund to cope with these fluctuations. Moreover, that pension scheme would be under financial stress in periods of low economic growth, which are often accompanied by high inflation and which generally provide no room for tax increases to fund pensions. From a policy perspective, the design of a pension system and, in particular, the choice of the indexation mechanism should consider not only what is best for the retirees but also how the alternative indexation measures affect the sustainability of the system in the short, medium, and long run.

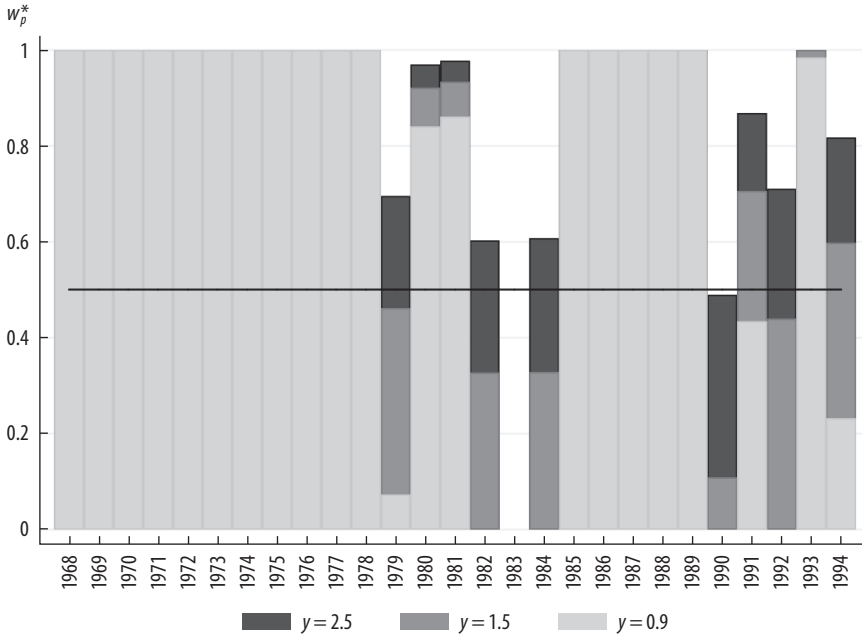
A potential avenue for future research is to consider intrahousehold risk sharing. This paper considered the retiree as a single unit; the results would probably be stronger if intrahousehold risk sharing were incorporated into the model. In a household composed of both retirees and workers, and with the high correlation between the workers' income and the ANEI, the household would be better off allocating a larger fraction of its income to a CPI-linked asset in order to diversify the risk of the ANEI.

Appendix

Sensitivity of w_p^* to Alternative Assumptions

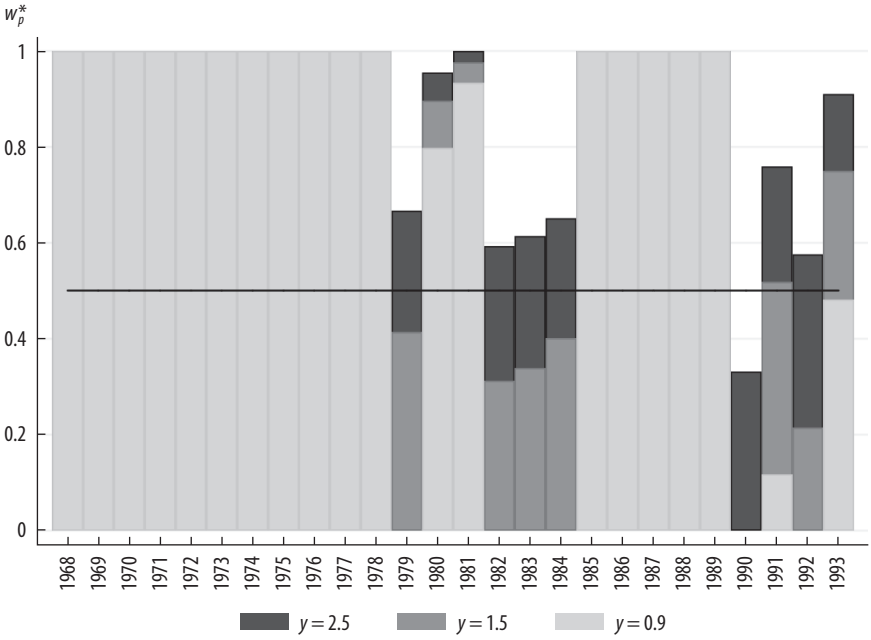
This section presents the sensitivity of the results to alternative assumption on the length of the retirement period and the level of risk aversion of the retiree.

FIGURE A1. Optimal w_p^* with $T = 18$: Sensitivity to Risk Aversion



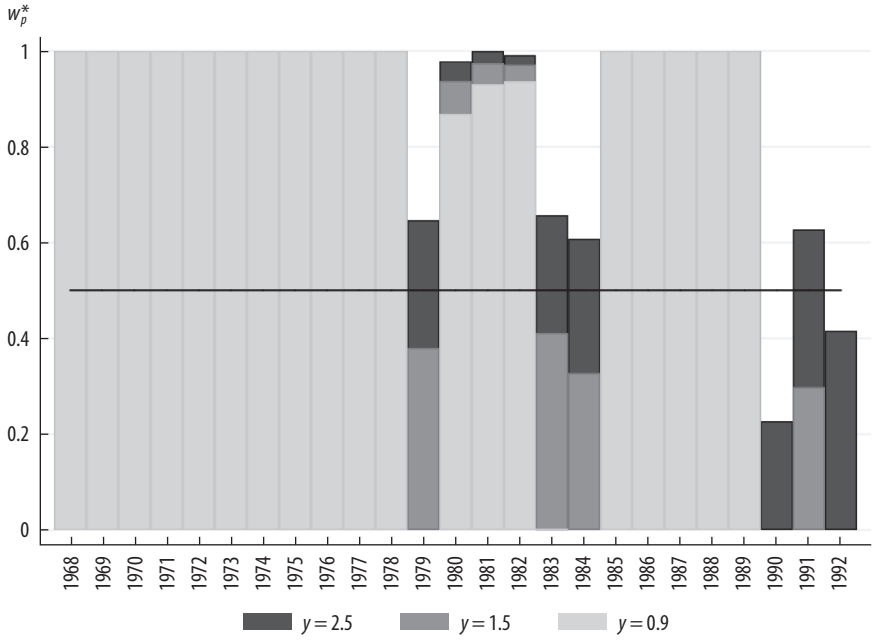
Note: The figure shows the optimal share of income to allocate to the CPI versus the ANEI. A value of one implies that all the income should be invested in the CPI, while a value of zero implies that all the income should be invested in the ANEI.

FIGURE A2. Optimal w_p^* with $T = 19$: Sensitivity to Risk Aversion



Note: The figure shows the optimal share of income to allocate to the CPI versus the ANEI. A value of one implies that all the income should be invested in the CPI, while a value of zero implies that all the income should be invested in the ANEI.

FIGURE A3. Optimal w_p^* with $T = 20$: Sensitivity to Risk Aversion

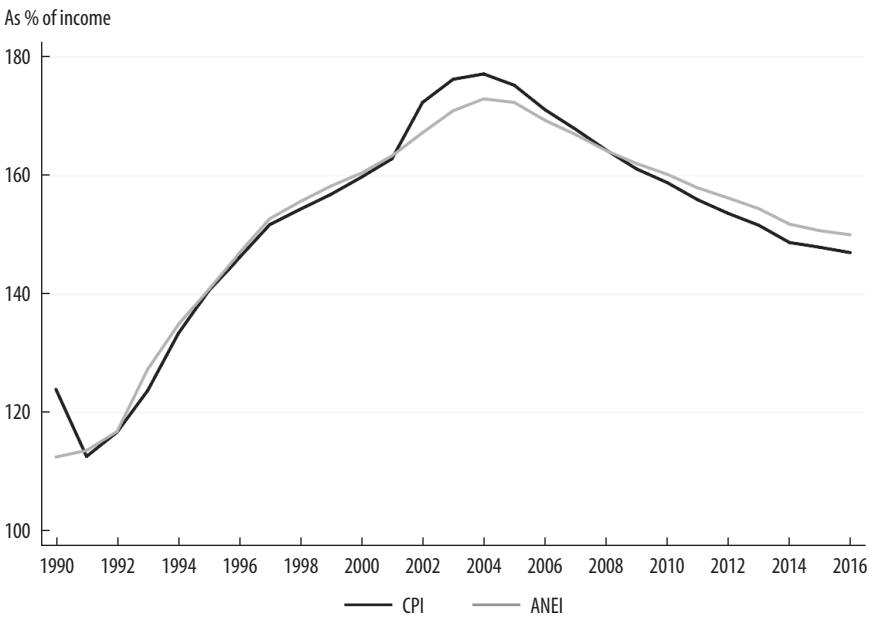


Note: The figure shows the optimal share of income to allocate to the CPI versus the ANEI. A value of one implies that all the income should be invested in the CPI, while a value of zero implies that all the income should be invested in the ANEI.

Sustainability of the Pension System: Cumulative Payments

The figure shows cumulative payments as a proportion of cumulative resources under the two alternative pension systems: inflation-linked and earnings-linked.

FIGURE A4. Cumulative Payments as a Proportion of Cumulative Resources: CPI versus ANEI



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