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Abstract

In this paper, we propose a theoretical framework to study pension income indexation from the pensioners' point of view. We then use the theoretical model to calculate the optimal indexation measure for di erent cohorts of pensioners using historical data from Uruguay. Our 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 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, we present two alternative criteria to assess the convenience of each indexation measure and arrive to similar results.

JEL: G11,D12, D60
Keywords: cost of living, pension income, indexation, mean-variance portfolio choice

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The opinions are my own and do not represent those of the Banco Central del Uruguay. I thank Gerardo Licandro, Jorge Ponce, Jose Licandro and Alvaro Forteza for comments and suggestions. All remaining errors are my own.

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1 Introduction

The choice of the best indexation measure to adjust pension income is of particular importance in periods of high inflation. Several countries have adopted automatic indexation either using the Consumer Price Index (CPI) or the Average Nominal Earnings Index ($ANEI$) or even a combination of both. Our interest is in understanding what income path best matches consumption needs during retirement years. From a policy perspective, this is a highly important question due to the increasing number of retirees. In particular, recent reforms in pension systems that replaced defined benefit with defined contribution schemes, generally imply the transfer of risks from employers to employees. In this new setting, the availability of annuities linked to indexes that well capture the changes in the cost of living of retirees is of great importance.

The contribution of this paper is twofold. First, we propose a theoretical framework to study pension income indexation from the point of view of the pensioner. We model pensioner's indexation choice using a mean-variance optimal portfolio framework. Similarly to the standard mean-variance portfolio choice problem, the optimal choice of the indexation measure depends not only on the return but also the associated consumption risk. We consider two alternative risky assets, the CPI and the $ANEI$, and a risk free asset given by the pensioner's cost of living index. We 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 consumer's risk aversion. This allows us to decide what indexation measure best suits consumption needs during retirement. Moreover, given the close form solution of the model it is straightforward to use it as a tool to analyze the different policies at hand when thinking about pension income indexation in any country.

Second, we take the model to the data using historical information for Uruguay. According to article 67 of the Constitution and Law No. $17,687$, pension income in Uruguay is adjusted by the previous year increase in the official $ANEI$ or *Indice Medio de Salarios Nominales.* We first approximate changes in the cost of living of pensioners by computing household specific inflation rates. We then compute the optimal portfolio in terms of $ANEI$ and CPI for different generations of pensioners using historical data. In the long-run it is expected that wages will grow faster than prices however, given that on average person lives for 20 years after retirement, the time of retirement is of main importance to assess the convenience, from the point of view of the pensioner, of the $ANEI$ or CPI to adjust pension income. In the particular case of Uruguay, analyzing if the $ANEI$ or the CPI are better measures of the cost of living of retirees is key in order to design a well functioning annuities market.

The rest of the paper is organized as follows. The literature is summarized in Section 2. Section 3 present the mean-variance portfolio choice model and the model is taken to the data in Section 4. Finally, Section 5 concludes.

2 Literature Review

A strand of literature in the UK has focused on the inflation experience of different household types: Crawford (1994), Crawford and Smith (2002), Leicester et al. (2008) and Levell and Oldfield (2011). Crawford (1994) estimates Tornqvist type price indexes for 74 commodities to study changes in the cost of living of different household types during the period 1978 to 1992. He finds small differences in the inflation rate experienced by the different types of households. In particular, richer households experienced higher inflation than poorer during this period due to the fall in relative prices of necessities and the corresponding increase of luxuries.

Crawford and Smith (2002) study the inflation experience of different types of households during the period 1976 to 2000. 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 then study how representative is the average rate of inflation finding that, between 1976 and 2000, only 35 percent of the households experience inflation within 1 percentage point of the average. They also study the inflation experience of different types of households finding that, on average, inflation is higher for high income households, non-pensioners, mortgagors, employed, single adults and the younger. Finally, they show the importance of allowing differential effects of inflation in studying inequality over time.

More recently, Leicester et al. (2008) study the inflation experience of older households and Levell and Oldfield (2011) the inflation experience of low-income households in the UK. Of particular interest for this study is the analysis of Leicester et al. (2008). They use data from the UK FES to compute household specific inflation between 1977 and 2008 and find that, albeit substantial differences in given years, during the whole period there is no difference in the average inflation rate of pensioners (5.8%) and non-pensioners (5.9%). They then study how inflation varies within pensioners and find that those aged 75 or above suffered more from the rapid increase in fuel and food prices than younger pensioners.

From a theoretical perspective, Lluberas (2013) studies the welfare consequences of cost of living adjustments for a consumer that buys an annuity in order to finance consumption during retirement. 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.

3 Model: mean-variance portfolio choice

Assume a worker retires at time $t = 0$ and starts receiving her pension income that is adjusted on a yearly basis. The aim of adjusting pension income is so pensioners' are able to maintain their level of consumption. If the pensioner has the option, which measure would she choose? A pensioner maximizing her intertemporal utility of consumption will choose the indexation measure that allows her to smooth consumption over time [1]. Assuming the pensioner has no assets to finance her consumption, pension income - her only source of income - has to be adjusted by a pension specific cost of living index in order to maintain her consumption over time. This pensioner specific cost of living index can be thought of as the risk free asset. Lets call it p^*.

[1] Note that we assume the pensioner only cares about her consumption but it could be the case that she also cares about her consumption relative to the rest of the population. The latter is not considered in this analysis.

Lets further define two alternative indexation measures; a first one based on a population average cost of living index given by the CPI that we call p, and a second measure based on the $ANEI$ that we call s. Assume also that the pensioner is risk averse.

Let $r_t^p = r_t^{p^*} + \epsilon_t^p$ be the rate of return of p at time t and $r_t^s = r_t^{p^*} + \epsilon_t^s$ the rate of return of s. We can express these rate of returns with respect to the return of the risk free asset given by the pension specific cost of living index, $r_t^{p^*}$. Thus, we define the excess returns for p and s respectively as:

$$\widehat{r}_t^p = r_t^p - r_t^{p^*} = \epsilon_t^p \tag{3.1}$$

$$\widehat{r}_t^s = r_t^s - r_t^{p^*} = \epsilon_t^s \tag{3.2}$$

We assume the following joint distribution for the excess returns:

$$\begin{pmatrix} \epsilon_t^p \\ \epsilon_t^s \end{pmatrix} \sim \left[\begin{pmatrix} \mu_t^p \\ \mu_t^s \end{pmatrix} \begin{pmatrix} \sigma_p^2 & Cov(\epsilon_t^p, \epsilon_t^s) \\ Cov(\epsilon_t^p, \epsilon_t^s) & \sigma_s^2 \end{pmatrix} \right]$$

Note in particular that whilst the expected mean excess return changes over time, both the variances and covariance are assumed to be constant. This implies that whilst the mean of excess returns can change, the dispersion of excess returns are assumed to remain the same during the period of retirement.

We can think of the pensioner selection problem as a mean-variance portfolio selection problem in which the pensioner receives a lump sum at time 0 and then chooses the proportion of income to allocate to each asset [2]. We then assume that the pensioner 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 $\beta = \frac{1}{1+\delta}$ the subjective discount factor, then, the pensioner chooses w_p by solving the following optimization problem:

$$\underset{w_p}{\text{Max}} \quad V = E_0 \left[\sum_{t=1}^{T} \beta^t [\epsilon_t^p w_p + (1-w_p)\epsilon_t^s] \right] - \frac{\gamma}{2} \left[\sum_{t=1}^{T} \beta^t Var[\epsilon_t^p w_p + (1-w_p)\epsilon_t^s] \right]$$

$$\text{st} \qquad 0 \leq w_p \leq 1$$

Given the assumptions on the distribution of returns, the mean and variance can be expressed as follows:

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

$$\left[\sum_{t=1}^{T} \beta^t Var[\epsilon_t^p w_p + (1-w_p)\epsilon_t^s] \right] = \sum_{t=1}^{T} \beta^t [\sigma_p^2 w_p^2 + (1-w_p)^2 \sigma_s^2 + 2w_p(1-w_p) Cov(\epsilon_t^p, \epsilon_t^s)]$$

Plugging in these expressions, the pensioner problem can thus be expressed as:

$$\begin{aligned} \underset{0 \leq w_p \leq 1}{\text{Max}} \quad V = & \sum_{t=1}^{T} \beta^t [\mu_t^p w_p + (1-w_p)\mu_t^s] \\ & - \frac{\gamma}{2} \left[\sum_{t=1}^{T} \beta^t [\sigma_p^2 w_p^2 + (1-w_p)^2 \sigma_s^2 + 2w_p(1-w_p) Cov(\epsilon_t^p, \epsilon_t^s)] \right] \end{aligned}$$

The first order condition with respect to w_p is:

[2]When we think of the pensioner's selection problem as depending only on the mean and the variance, we are, implicitly, assuming one of the following: (i) quadratic utility, (ii) exponential utility and normal distribution of asset returns, or, (iii) power utility and log-normal distribution of asset returns. See Campbell and Viceira (2002) for more details.

$$\begin{aligned}\frac{dV}{dw_p} = & \sum_{t=1}^{T} \beta^t [\mu_t^p - \mu_t^s] \\ & - \gamma w_p \left[\sum_{t=1}^{T} \beta^t [\sigma_p^2 + \sigma_s^2 - 2Cov(\epsilon_t^p, \epsilon_t^s)] \right] \\ & + \gamma \left[\sum_{t=1}^{T} \beta^t [\sigma_s^2 - Cov(\epsilon_t^p, \epsilon_t^s)] \right] = 0\end{aligned}$$

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

$$w_p^* = \frac{\widetilde{\mu_p} - \widetilde{\mu_s} + \gamma \sum_{t=1}^{T} \beta^t [\sigma_s^2 - Cov(\epsilon_t^p, \epsilon_t^s)]}{\gamma \sum_{t=1}^{T} \beta^t [\sigma_p^2 + \sigma_s^2 - 2Cov(\epsilon_t^p, \epsilon_t^s)]} \tag{3.3}$$

Equation 3.3 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.

In the following sections we use the theoretical model to calculate the optimal portfolio using historical data from Uruguay.

4 The case of Uruguay

Pension income in Uruguay is indexed to the $ANEI$. Indeed, according to article 67 of the Constitution and Law No. 17,687, pension income in Uruguay is adjusted by the previous year increase in the official average nominal earnings index or *Indice Medio de Salarios Nominales*. A key question then is whether the $ANEI$ is a good measure of the cost of living of retirees. In general, indexing income to the CPI insures one's own consumption but might result in lower growth than wages - or the general cost of living.

In this section we assess, based on the theoretical model, the convenience, from the point of view of the pensioners, of adjusting pension income using either the $ANEI$ or the CPI. We then assume that the pensioners have access to two alternative assets and have to decide the proportion of income allocated to each of them.

4.1 Preliminaries: household inflation

As the excess returns are expressed with respect to the cost of living of pensioners, we first have to compute a pensioner's specific inflation index (p^*). Define inflation rate for household i at time t as:

$$p_{it}^* = \sum_{j=1}^{J} s_i^j \pi_t^j \tag{4.1}$$

Where: $s_i^j = \frac{p_i^j q_i^j}{p_i q_i}$, is the share of expenditure of household i in good j and π_t^j is the year-on-year inflation rate of good j at time t. Inflation rates for the different goods are only available at a national level from the National Statistics Office (INE) and thus variation in the inflation experienced by different households is due to differences in the expenditure shares. To compute the household specific inflation rate we consider 80 sections of the CPI (j=1,...,80) and compute s_i^j for each household in the sample using the *2005/06 Encuesta de Gastos e Ingresos de los Hogares*. Household inflation depends then, on the CPI section inflation rate and on the basket of goods consumed.

Table 1 shows the consumption basket, as a proportion of total expenditure, for workers and retirees. Similar to previous studies, we find that pensioners spend a smaller proportion of their budget in work related goods, such as clothing and footwear, transport and eating out. We also find, as expected, that pensioners spend less in education than workers. On the other hand, the share of total expenditure that pensioners spend in healthcare almost doubles that of workers (6.4% vs 12.2%). Finally, pensioners also spend a larger proportion of their budget in housing.

These differences in the consumption bundle translate into differences in the inflation rate experienced by the different types of households. Figure 1 shows the inflation rate of workers and retirees and also the CPI based inflation rate calculated by the Office for National Statistics. First, we find that our inflation measures follow quite closely the officially calculated inflation rate. The small differences are due to the fact that the official calculation make use of additional data sources

Table 1: *Consumption basket (in % of total expenditure)*

	Worker	Retiree
Food and non-alcoholic 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
Healthcare	6.4	12.2
Transport	9.0	5.7
Communications	4.1	4.2
Leisure	5.4	4.4
Education	1.7	0.4
Restaurant and hotels	3.5	1.8
Other goods and services	4.8	4.6

besides the budget survey we use. A second feature that arises from the graph is the fact that there are no substantial differences in the inflation experienced by workers and retirees in the period under analysis.

Figure 1: *Average household inflation vs CPI: 1998-2012*

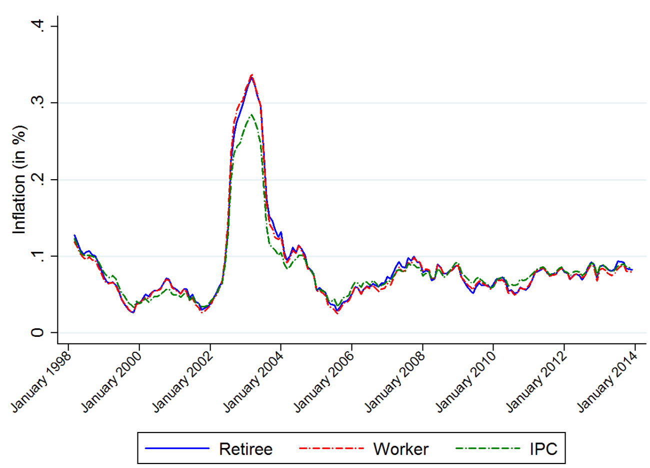
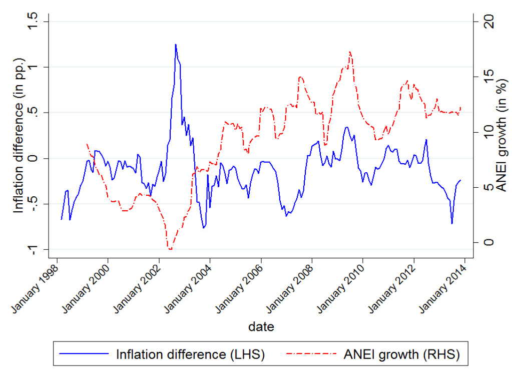


Figure 2 shows the difference in the inflation rate experienced by pensioners relative to the general population and the change in the $ANEI$. In general, pensioners experience slightly higher inflation rates in periods of economic distress such as the one experienced after the Argentina devaluation of 2001-2002. With a drop of 9% in real GDP between 2001 and 2002, pensioners annual inflation rate reached almost 30% by the end of 2002. As it is also clear from the graph, the use of the $ANEI$ as the pension indexation measure does not insure pensioners consumption during recessions or periods of low economic growth. Indeed, pension income - adjusted by the $ANEI$ - purchasing power declined by about 28% during the 2001-2002 economic crisis.

Figure 2: *Average household inflation difference and ANEI*



In the next section we take the model to the data and show pensioners optimal portfolio choices using historical data series for Uruguay.

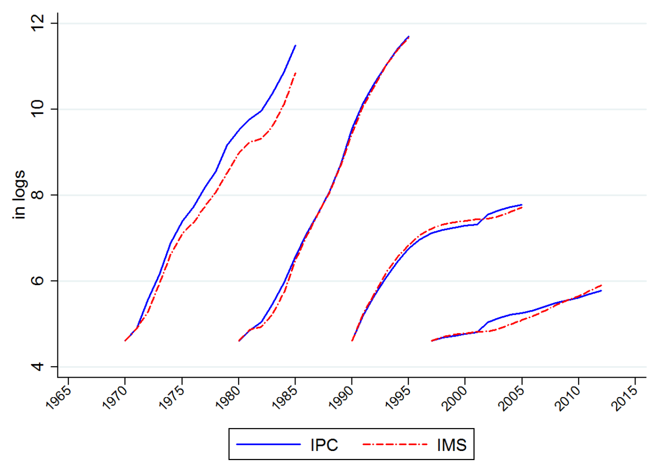
4.2 Cohorts

For the empirical analysis we work with 30 cohorts of retirees. We have data on the dynamics of the CPI, the $ANEI$ and the pensioners specific inflation for the period 1968 to 2012. We then define a cohort based on the year of retirement. The length of retirement (T) is assumed to be 15 years[3]. Then, someone retired in 1970, for instance, is assumed to live and earn pension income until 1985. Similarly, someone retired in 1980 is assumed to live and earn pension income until 1995. Given we have data until 2012, the last cohort we consider is the one retiring in 1997.

[3]Similar results are obtained if we consider, for instance, T=18, T=19 or T=20 shown in the Appendix. Note that life expectancy at 60, the normal retirement age, is about 16 years for men and 18 years for women.

Figure 3 shows pension income dynamics using either the CPI or the $ANEI$ as indexation measures for four cohorts: 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 of major importance to choose which indexation measure makes the pensioner better off. The 1970 cohort is better off during the whole retirement period by having its pension income adjusted by the CPI. On the other hand, the 1997 cohort is better off at the beginning of retirement with the $ANEI$, with the CPI after the 2002 crisis and then with the $ANEI$ by the end of the retirement period. The theoretical model presented above is one way to summarize the trajectory of pension income dynamics in one measure. Alternative summary measures are presented as robustness checks in Section 5.1.

Figure 3: *Pension income dynamics under alternative indexation measures (in logs)*



In the following section we present the inputs for the computation of w_p^*.

4.3 Return and risk

Having computed pensioners specific inflation (p^*), we can calculate the excess returns given in equations 3.1 and 3.2 that serve as inputs for the computation of the optimal proportion of income allocated to the CPI, w_p^*; given in equation 3.3.

Figure 4 shows the expected returns - μ_t^p y 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 pensioners inflation rate than the $ANEI$. However, due to the re-installation of the collective wage bargaining in 2005 together with the steady economic growth after the 2001-2002 economic crisis, nominal wages grew faster than prices. Focusing on the period from 2000 until the last year of the series, it is clear that, with the exception of the drop in real wages in 2002 and without considering income risk, the pensioners would be better off investing in the $ANEI$. We show in the next sections that once we consider the variance of returns and the pensioners level of risk aversion this result can change.

Figure 4: *Return:* μ_t^p *y* μ_t^s

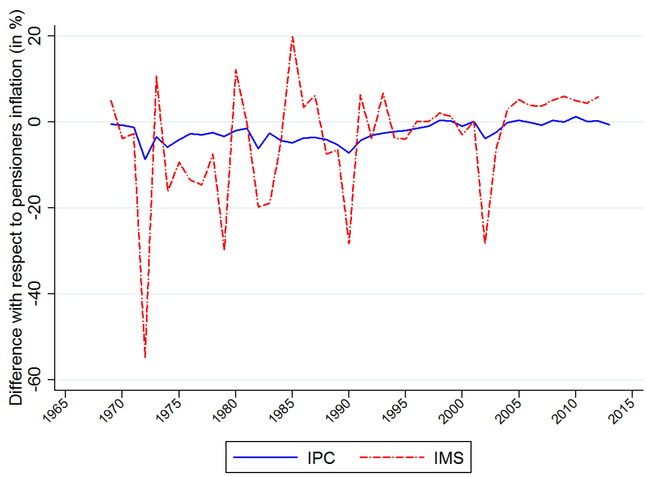
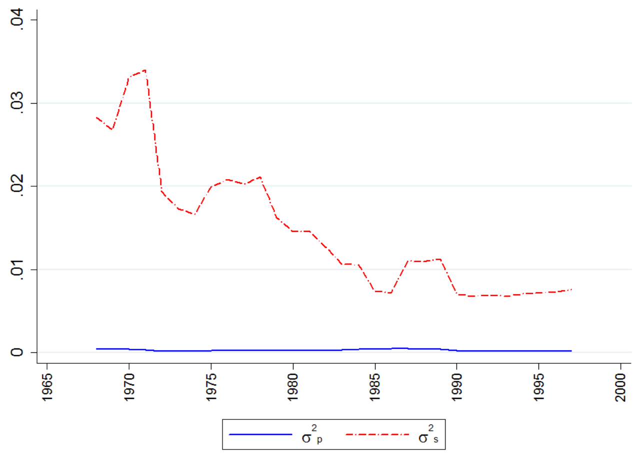


Figure 5 shows the discounted accumulated expected returns for each cohort of retirees. For the cohorts retiring between 1969 and 1978 and those retiring between 1987 and 1994 - with the exception of 1990 -, $\widetilde{\mu_p} > \widetilde{\mu_s}$. On the other hand, for those retiring between 1979 and 1986, in 1990 and between 1995 and 1997, $\widetilde{\mu_p} < \widetilde{\mu_s}$. A second important feature of the graph is the fact that for both assets but in particular for the $ANEI$, the discounted accumulated return increases over time. Morevoer, $\widetilde{\mu_s} > 0$ only for those retiring in 1997, the last cohort considered in the empirical analysis.

Figure 5: *Return:* $\widetilde{\mu_p}$ *y* $\widetilde{\mu_s}$

Figure 6 shows the implied income risk, measured by the variance of returns, under the two indexation measures. The risk associated to the $ANEI$ is on average, about 55 times that of the CPI and ranges from a minimum of 15 times for the 1986 cohort to 108 times for the 1972 cohort. This implies that investing in the $ANEI$ involves substantially more risk than investing in the CPI. An important point to highlight is the fact that, together with the increase in the expected return over time, the risk associated with the $ANEI$ declines over time.

Figure 6: *Pension income risk:* σ_p^2 *y* σ_s^2



5 Optimal w_p

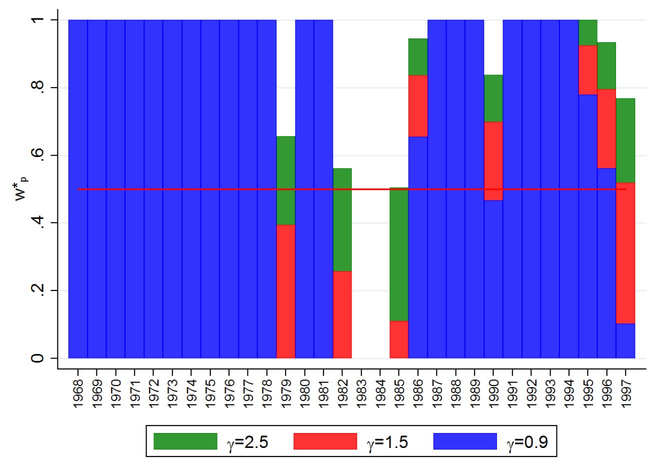
Having presented the inputs to compute the optimal proportion of income to allocate to the CPI, we show in Figure 7 the results for each of the cohorts retiring between 1968 and 1997. A value of 1 implies that all the income should be invested in the CPI whilst a value of 0 implies that all the income 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 [4]. Note that given the much smaller risk associated with investing in the CPI, for a given level of return, w_p^* increases with γ. This implies that if w_p=1 for γ=0.9, then it is also 1 for γ=1.5 and γ=2.5. The graph then shows in red and green the increase in w_p^* due to an increase in the pensioner risk aversion. Take the case of the 1979 cohort. For a low level of risk aversion, the optimal strategy would be to invest all the income in the $ANEI$. As risk aversion increases, w_p^* also increases and thus w_p^* is 0.4 for γ=1.5 and 0.6 for γ=2.5.

Our 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.

[4]These values were taken from Friedberg (2000) and particularly Chetty (2006) who estimates implied coefficients of relative risk aversion for older men aged 63 to 71.

Even for cohorts retiring after the 1989 constitutional reform that established the $ANEI$ as the indexation measure, the CPI is the preferred indexation measure.

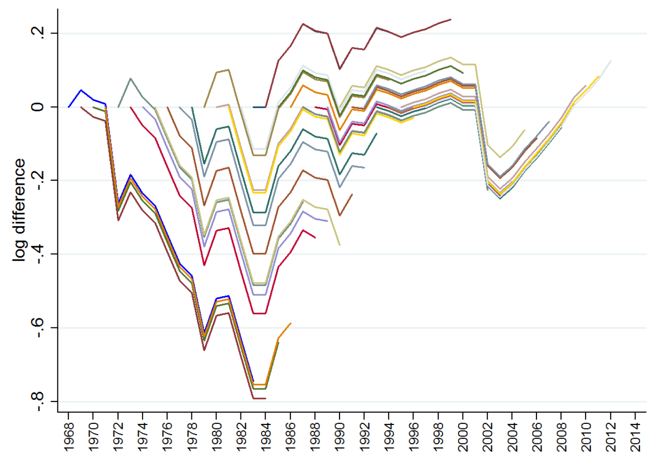
Figure 7: *Optimal* w_p^**: sensitivity to risk aversion*



5.1 Robustness check

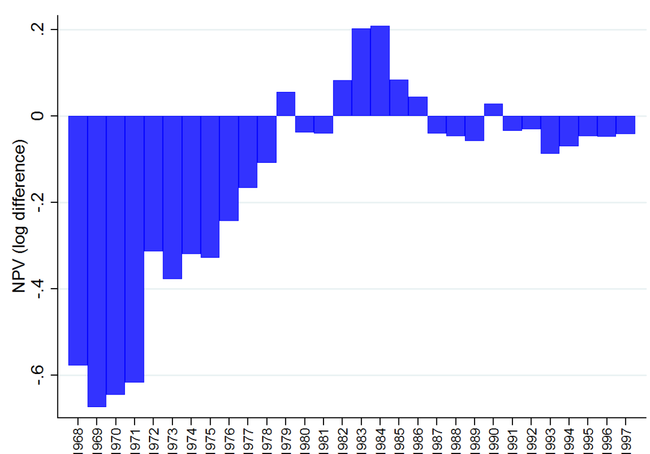
In the previous sections we presented a framework to analyze the convenience of the CPI or the $ANEI$ as pension income indexation measures. In this section we show that the results using the theoretical model presented in Section 3 are robust to alternative criteria. In particular, Figure 8 shows the log difference between pension income uprated by the $ANEI$ and the CPI. Negative values implies that the CPI is preferred to the $ANEI$. Most of the cohorts in most of the years are better off if their pension income is adjusted by the CPI as opposed to the $ANEI$. Even for some of the cohorts that experience the years after the 2001 crisis in which 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 and suggest that extreme events have profound effects in the convenience, from the point of view of the pensioner, of one or other pension income indexation measure.

Figure 8: *Difference in pension income: ANEI-CPI (in logs)*



A second criterion to assess the convenience of the CPI and $ANEI$ is the Net Present Value (NPV). We assume a discount rate equal to 3% and show in Figure 9 the log difference of the NPV using the $ANEI$ and the CPI. Again, negative values implies that the pensioner is better off with the CPI as opposed to the $ANEI$. With the exception of the 1979 cohort, cohorts between 1982 and 1986 and the 1990 cohort, the CPI is preferred to the $ANEI$.

Figure 9: *Net Present Value: ANEI-CPI (in logs)*



6 Conclusion

We propose a theoretical framework to study pension income indexation from the point of view of the pensioner. We model pensioner's indexation measure choice in a mean-variance optimal portfolio framework. Similarly to the standard mean-variance portfolio choice problem, the optimal choice of the indexation measure depends not only on the return but also the associated consumption risk. We consider two alternative risky assets and a risk free asset given by the pensioner specific inflation rate.

We then use the theoretical model to calculate the optimal portfolio using historical data from Uruguay. We first approximate changes in the cost of living of pensioners by computing household specific inflation rates. We then compute the optimal portfolio in terms of $ANEI$ and CPI for different generations of pensioners using historical data. We document two important empirical facts. First, the implied income risk associated to the $ANEI$ is substantially higher than that of the CPI. It is on average, about 55 times that of the CPI and ranges from a minimum of 15 times for the 1986 cohort to 108 times for the 1972 cohort. This results in making the $ANEI$ a less attractive indexation measure even in periods of real wage growth.

Second, our results suggest 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.

A potential avenue for future research is to consider intrahousehold risk-sharing. In this paper we consider the pensioner as a single unity; the results would probably be stronger if we add intrahousehold risk-sharing to the model. Thinking of a household containing both pensioners and workers, given excess returns and variances, the portfolio share allocated to the CPI would be higher in order for the household to diversify risks. Given the high correlation of the worker income and the $ANEI$, it would be better for the household to allocate a larger fraction of its income to the CPI in order to diversify the risk of the $ANEI$.

References

Campbell, J. Y. and L. M. Viceira (2002). *Strategic Asset Allocation: Portfolio Choice for Long-Term Investors*. Oxford University Press.

Chetty, R. (2006, December). A New Method of Estimating Risk Aversion. *American Economic Review 96*(5), 1821–1834.

Crawford, I. (1994, Jan). Uk household cost-of-living indices, 1979-92. *Fiscal Studies 15*(4), 1–28.

Crawford, I. and Z. Smith (2002, Jun). Distributional aspects of inflation. Technical report.

Friedberg, L. (2000, February). The Labor Supply Effects of the Social Security Earnings Test. *The Review of Economics and Statistics 82*(1), 48–63.

Leicester, A., C. O'Dea, and Z. Oldfield (2008, Oct). The inflation experience of older households. Technical report.

Levell, P. and Z. Oldfield (2011, Jun). The spending patterns and inflation experience of low-income households over the past decade. Technical report.

Lluberas, R. (2013). Life-cycle expenditure and retirees cost of living. *Documento de Trabajo 2013-007, Banco Central del Uruguay*.

7 Appendix

Figure 10: *Optimal w_p^* with T=18: sensitivity to risk aversion*

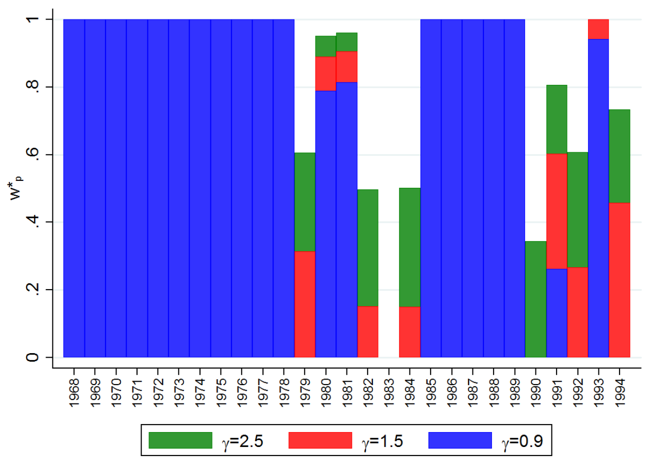


Figure 11: *Optimal w_p^* with T=19: sensitivity to risk aversion*

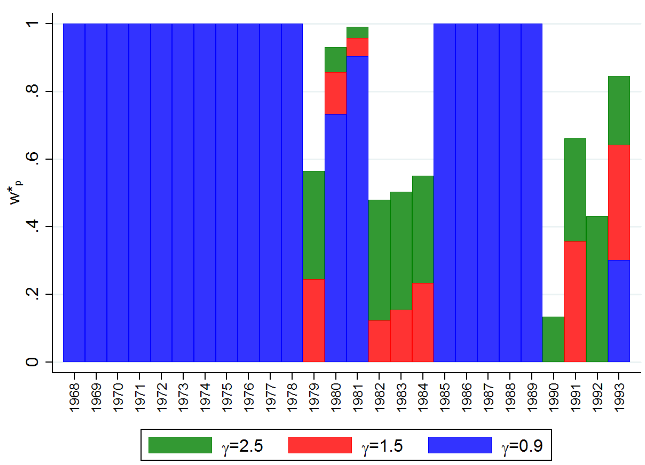


Figure 12: *Optimal w_p^* with T=20: sensitivity to risk aversion*