Pension Fund Design in Developing Economies

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1. Introduction

The provision of income at retirement is experimenting structural changes in many developed economies around the world. Traditionally Social Security and voluntary or mandatory defined-benefit (DB) pension plans provided employees with a stable and usually generous pension income stream at retirement. In recent years, this system is being replaced by another which relies much more heavily on employees to finance their own retirement though their participation in defined-contribution (DC) pension plans. In those plans, income at retirement is typically not guaranteed; instead, employees finance their retirement from the assets they have accumulated in their pension account through their working lives. The size of those assets depends on their own lifetime contribution and investment decisions.

The U.S. is perhaps the developed economy in which the transition from DB to DC has been more pronounced. Using data from the Survey of Consumer Finances, Munnell and Sunden (2006) show that about 62% of employees with pension coverage in the U.S. in 1983 were covered exclusively by a traditional DB pension plan; an additional 25% were covered by both a traditional DB pension plan and a DC plan. By year 2004, however, the proportion of employees

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covered exclusively by a traditional DB plan had declined to only 20%, and the proportion of those covered by both a DC plan and a DB plan had declined to 17%. The remaining 63% of employees depended exclusively on a DC plan to finance their retirement, in addition to their Social Security benefits.

A number of factors explain the decline in coverage by traditional DB plans in developed economies. The “perfect storm” of the early part of the first decade of this century, with declining stock market valuations and interest rates, produced a dramatic worsening of funding ratios in most corporate and public DB pension plans, as assets declined while liabilities increased. Numerous corporate DB pension plans disappeared, while many of the remaining plans were frozen for existing participants, and closed to new participants. Increased global competition in product markets has also made expensive for corporations to sponsor traditional DB plans, especially for those with a more mature employee population. Most if not all of younger corporations do not offer DB plans, and opt instead for offering DC plans. The significant increase in dependency ratios in developed economies is also affecting the funding cost of publicly sponsored DB plans. Increased flexibility and mobility in labor markets also favor the adoption of DC plans for their portability.

Many of the factors driving the transition towards a DC system in developed economies also affect developing economies. Developing economies are generally open economies subject to global competition in product and capital markets. They typically have highly flexible labor markets too. Although demographic profiles are more favorable in many developing economies, in others such as those in Eastern and Central Europe population aging is a concern.

Thus it is perhaps not surprising that as they create pension systems for their employees in the wake of the sustained economic growth of the last decade or two, most of these economies have chosen to offer DC-based systems with mandatory participation instead of traditional DB plans.

Although DC-based pension systems offer flexibility and portability, they also present important policy challenges. Section 2 of this article discusses some of the limitations of DC-based pension systems and Section 3 discusses the current policy proposals to confront these limitations. Section 4 and Section 5 examine the economic arguments for the adoption of some of these proposals, and the design of investment options in DC pension systems in developing economies from the perspective of the theory and practice of long-term investing. Finally, Section 6 presents a simulation study of the performance of different plan designs in a realistically calibrated setting.

2. Policy Challenges of Defined-Contribution Pension Systems

DC plans are eminently self-guided. In a typical DC-based system, plan participants must decide on their own how much they want to contribute to the plan, and how they want to invest their contributions. Plan sponsors also have the option to make contributions on behalf of the participant, which commonly take the form of matching contributions, i.e., contributions that are made only if the participant decides to contribute on his own. Contributions from the participant and the plan sponsor are usually tax-exempt, up to a certain limit.

Unlike DB plans, whose assets are typically managed by a team of investment professionals hired by the plan sponsor, DC plans are not, at least not in the part that concerns the asset allocation decision. Instead, plan sponsors or regulators typically select a number of investment options to make them available to plan participants, often offer them education materials about how to make prudent investment decisions, and designate a specific investment option as the default option in the plan. This is the fund in which plan contributions are invested when the plan participant does not make an active investment choice. But, beyond that, each individual participant is responsible for deciding how to best invest his contributions.

For a self-directed DC plan to work, one needs to believe that plan participants can make sound saving and investment decisions, or at least that they can learn how to make those decisions. Unfortunately, the existing evidence in the U.S. about the behavior of plan participants regarding contribution and investment decisions suggests that too many participants do not appear to make sound saving and investing decisions (Mottola and Utkus 2009, Viceira 2007a).

Three problems are of particular concern. First, participation in these plans appear to be relatively low when it is voluntary; those who participate tend to choose relatively low contribution rates, even the plan sponsor offers matching contributions. Second, plan participants appear to suffer from inertia in their investment decisions. They tend to rebalance their portfolios very infrequently, and many simply let their contributions go into the investment default option in the plan, regardless of whether this investment option is appropriate for them or not. Third, investment portfolios are often not adequately diversified, suffer from performance chasing, or contain excessive holdings of a single investment option

such as company stock. These problems tend to be more prevalent among participants with low income and low education levels (Campbell 2006, Calvet, Campbell, and Sodini 2007, 2009).

The existing empirical evidence about participant behavior in DC pension systems in developing economies is scant. However, the limited existing evidence suggests that participants in those plans suffer from the same saving and investment maladies as plan participants in developed economies. In particular, low savings and inertia appear to be widespread in these plans.

While participation is typically mandatory in DC pension systems in developing economies, such as those in Latin America and Central and Eastern Europe, it affects only those with stable employment in the formal sector of the economy. Because the informal sector is relatively large in many of these economies, and employment tends to be less stable than in developed economies, these systems suffer from low contribution density and irregular contributions over the life cycle of a significant fraction of the working population.

The Chilean experience suggests that participants in these systems also suffer from investment inertia. The Chilean system offers a handful of investment funds, each one designed to be appropriate for participants in a particular age bracket. Participants are assigned a particular age-appropriate fund when they join, and are expected to rebalance towards other age-appropriate funds over time. In practice, a large fraction of plan participants adopt the default investment option offered by the pension fund at the time they join, and stay with this fund forever afterwards.

The experience with DC plans suggests that many DC plan participants appear to be making suboptimal savings and investment decisions. These participants might benefit from having

their assets managed professionally, as it would happen if they were in a traditional DB pension plan. Yet forces of global competition might make difficult to move back to the traditional DB-based pension system. Ideally, it would be desirable to have a pension system that preserves portability and flexibility, while minimizing the potential costs of self-directed investing and saving by individuals with lack of financial sophistication. Recent developments in pension fund design as well as in the theory of long-term asset allocation suggest that it might be possible to move in this direction. If appropriately designed, a few investment options might suffice to achieve adequate diversification and rebalancing over the life cycle of a typical employee.

3. Innovations in Pension Fund Design

In recent years, institutional investors, regulators, and academics have proposed changes to DC plans that address the problems of suboptimal contribution and diversification choices of DC plan participants. In essence, these proposals try to turn investors' inertia into a "force for good" by introducing default contribution and investment options that help participants overcome low contribution rates, lack of rebalancing and investment diversification, and other investment maladies.

Two proposals have been particularly successful, particularly after the enactment in the U.S. of the Pension Protection Act of 2006 (Viceira 2007a), which has provided a legal umbrella for their adoption by DC plans. One of them is the adoption of automatic enrollment clauses in DC pension plans along the lines proposed by Thaler and Benartzi (2004) in their "Save More Tomorrow" program.

The second one is the adoption as a default investment options in DC pension plans of investment funds that provide investors with automatic rebalancing and diversification across asset classes (Viceira 2007b). These are two main types of funds: Life-Style or Balanced Funds, and Life-Cycle Funds.

Life-style funds, also known as balanced funds, are funds which automatically rebalance their holdings towards a target asset mix that remains constant over time. For example, a fund might target a 60%-40% mix of stocks and bonds; periodically, the fund sells some of the holdings of the asset class that has outperformed over the period, and uses the proceeds to invest in the asset class that has underperformed as to keep the mix of stocks and bonds in the portfolio on target. Plan sponsors typically offer a collection of these funds, each one with a different target asset mix. Investors are expected to choose the fund that best fits their risk tolerance. These funds have been widely adopted by sponsors and regulators of DC pension plans in developing economies.

Life-cycle funds also rebalance automatically towards a target asset mix. However, this target asset mix does not stay constant over time; instead it becomes increasingly conservative over time until it reaches a certain target date, at which point the target asset mix remains constant. For example, a hypothetical life-cycle fund with a target date set in 2045 and a five-year glide path might start with an initial target mix of 90% in stocks and 10% in bonds. The fund will automatically rebalance its holdings towards that target during the first five years of life of the fund, at which point the target mix becomes 85% in stocks and 15% in bonds; every five years the stock allocation in the target mix decreases by five percentage points, and correspondingly

the allocation to bonds increases by five percentage points, until in year 2045 the target mix becomes 20% in stocks and 80% in bonds and stays there thereafter.

Plan sponsors typically offer a collection of life-cycle funds which differ on their target date, with funds with closer dates starting at more conservative allocations. Investors are expected to choose the fund whose target date is closest to their expected retirement date. These funds are becoming widely adopted by plan sponsors in DC pension plans in the U.S., particularly after the U.S. Department of Labor has granted a "safe harbor" provision for the adoption of these plans as prudent default investment options in DC plans.

4. Life-Cycle Investing

Life-style funds are based on the idea of "risk-based investing," or the advice common among professional investment advisors, that conservative investors target a lower stock-bond asset ratio than aggressive investors. Life-cycle funds on the other hand are based on the idea of "age-based investing," or the idea also common among professional investment advisors that investors should target a lower stock-bond asset ratio as they age.

Of course, conventional wisdom is not necessarily based on a solid scientific foundation. However, the modern theory of long-term asset allocation (Campbell and Viceira 2002) does provide a rationale for the asset allocation strategies pursued by both types of funds. This point is developed in Viceira (2009), which argues that life-cycle investing is a more appropriate asset allocation strategy from the perspective of working investors.

To understand why, it is useful to consider the balance sheet of a typical working investor (**Figure 1**). Working investors have two main assets in their balance sheets. One is their financial wealth, which they can easily trade and spend. The other asset is their human wealth, given by the present discounted value of their expected future labor earnings. Unlike financial wealth, human wealth is not tradable. Working investors can only monetize the dividends paid out by their human wealth, which are their labor earnings.

For a typical working investor, human wealth represents that largest fraction of his total wealth at a young working age. The reason is that the investor has an expected life-time of labor earnings ahead of him, while he has not yet had an opportunity to accumulate substantial savings. But, as the investor ages, financial wealth increases through savings and the returns on invested savings, while human wealth shrinks as there are fewer years of expected labor earnings ahead of him. Thus financial wealth represents the largest fraction of total wealth when the working investor approaches retirement.

These considerations raise the question of how working investors should take into account their human wealth when deciding how to invest their financial wealth. For working investors with safe jobs, human wealth represents a buffer against adverse outcomes in capital markets: They can finance consumption out of their stable labor earnings, and they can even replace lost financial wealth by increasing their labor supply. Therefore, from a financial perspective, the human wealth of working investors with safe jobs is equivalent to holding an implicit investment in bonds. These bond-equivalent holdings are large when the investor is young, and decline as he ages (**Figure 2**).

This economic argument suggests that if this investor is willing to bear financial risk, it makes sense for him to tilt the composition of his financial wealth towards risky assets such as stocks when he is young, and tilt it away from stocks as he grows older (Bodie, Merton, and Samuelson 1992). This is precisely the type of investment strategy built into life-cycle funds.

In practice, however, working investors face uncertain life-time labor earnings. On the downside, they might experience periods of unemployment, adverse professional developments, declining real wages, or permanent disability. On the upside, they might experience unexpected positive developments such as promotions or job offers. These adverse or favorable circumstances can be due to purely individual-specific reasons or to macroeconomic conditions.

Thus from the perspective of Finance, one can think of human capital as a risky asset. As such, it is subject to both systematic or macroeconomic-related risk and idiosyncratic or individual-specific risk. Unlike tradable financial assets, individuals cannot ameliorate the idiosyncratic risk embedded in their human capital through diversification. Instead, the non-liquid nature human wealth implies that they are forced to bear their human capital risk entirely.

Viceira (2001) studies the impact of both idiosyncratic and systematically labor income risk on portfolio choice. This study finds that working investors should optimally reduce their exposure to stocks if idiosyncratic labor income uncertainty increases. However, it is still optimal for them to follow a path in which they allocate more of their financial wealth to equities when young, and less as they age.

By contrast, this study finds that asset allocation over the life-cycle is highly sensitive to the presence of systematic risk embedded in human capital, which the study measures as the correlation of labor income with stock returns. A positive correlation leads to a more conservative allocation path over the life-cycle. For a high enough correlation, it might even be optimal for younger investors to tilt their allocations towards bonds, not stocks. Intuitively, this results from the fact that a positive correlation between labor income and stocks means that human capital is more "stock-like" than "bond-like."

Figure 3 illustrates this finding. It plots the life-cycle allocation to stocks and bonds of financial wealth for an investor whose risk tolerance is such that he is comfortable holding an overall exposure to equities equal to 60% of his total wealth. When human capital is completely riskless (Panel A), the investor allocates his financial wealth to stocks for most of his working life, and starts allocating part of his financial wealth to bonds only as he approaches retirement. By contrast, when human capital is highly correlated with stocks, with an implicit exposure to stocks of 65% (Panel B), the life-cycle allocation path reverses. The investor allocates his financial wealth to bonds early in his working in life, and starts increasing his allocation to socks only as he approaches retirement. Therefore, investors whose human capital is highly correlated with the overall economy might want to follow a life-cycle path of investing which is the opposite to what standard life-cycle funds follow.

Figure 3 exemplifies two perhaps extreme characterizations of human capital. In recent work, Viceira (2001), Cocco, Gomes and Maenhout (2005), Kotlikoff, Gomes, and Viceira (2008) and others have explored whether the basic conclusions about investing over the life-cycle with safe

human capital hold under a realistic characterization of labor income (or human capital) risk. These studies find that the basic conclusions of the stylized model of life-cycle portfolio allocation with riskless human capital still hold for plausible specifications of both systematic and idiosyncratic labor income uncertainty, albeit along more conservative life-cycle paths.

Figure 4 summarizes the results from these studies. It reproduces the optimal life-cycle allocation path to stocks and bonds found in Gomes, Kotlikoff and Viceira (2008). This study presents a model of optimal life-cycle consumption, labor supply, asset accumulation, and portfolio decisions calibrated to match the typical life-cycle working hours and wage profile of a high-school/college graduate in the U.S., as well as his typical family size, housing expenditures and Social Security benefits. The allocation path shown in Figure 4 assumes a moderately risk tolerant investor who on average would like to hold exposure to stocks in his portfolio given the positive risk premium on stocks. The allocation to stocks over the life cycle is large early in the life-cycle, and declines as the investor ages. This allocation path is considerably more conservative than the allocation path for the investor with perfectly riskless human capital shown in Panel A of Figure 3. The investor starts allocating to bonds at an early age, and the allocation to bonds increases rapidly in middle age.

It is important to note that the path shown in Figure 4 also assumes that the investor will receive Social Security benefits in retirement. In the absence of such benefits, the allocation path in Figure 4 would be more conservative, though it would still have the same qualitative shape. To understand why Social Security benefits make working investors more willing to assume stock market risk in their financial portfolios, note that these benefits are functionally

equivalent to receiving a riskless stream of labor income in retirement. Using the same logic to understand human capital as a financial asset, it is immediate to conclude the Social Security benefits are "bond-like" and as such will make the investor more willing to hold stocks in his financial portfolio. Thus the optimal life-cycle allocation path for employees who expect to receive traditional pensions in addition to the assets they accumulate in their DC plan is more tilted towards equities than it would otherwise be in the absence of traditional pension benefits.

The asset allocation path shown in Figure 4 is based on the estimated labor income uncertainty faced by a high school or a college graduate in the U.S. In developing economies, income uncertainty is likely to be exacerbated. One might also expect more dispersion in income profiles as well as in income uncertainty across the population. Accordingly, the optimal life-cycle asset allocation path for a typical working investor in these economies is likely to be more conservative than the one shown in Figure 4, although it is unlikely that it will be similar to the reversed path shown in Panel B of Figure 3.

In summary, under plausible characterizations of labor income uncertainty, human capital arguments provide support for the age-based asset allocation strategies that life-cycle funds follow. It also provides a rationale for adopting these funds as default investment choices in pension plans. There remain, however, a number of important questions that need careful consideration.

First, one important question is what specific life-cycle path to adopt in life-cycle fund offerings. This should depend on a careful assessment of typical labor income profiles in each country.

Section 6 offers a simulation study for one developing economy, Chile, for which data on labor income profiles is available. A second important question is about the composition of the portfolios included in these funds and, more generally, in the investment options offered in DC plans. A third question is how many options should be offered in DC pension plans. Is it enough to offer a single life-cycle fund as the only investment option available to plan participants? A fourth question is the evaluation of performance of funds. The remaining of this article addresses those questions.

5. Pension Fund Design in Developing Economies

The theory of long-term asset allocation also provides insights for the design of investment options in DC pension plans. In the context of developing economies, pension fund design needs to address three particularly relevant issues: the composition of fixed-income portfolios, the composition of equity portfolios, and currency hedging.

5.1 Fixed Income Portfolios

Most investment choices in DC pension plans in developing economies are life-style funds which, as a result of regulatory constraints, tend to load heavily on fixed income instruments. Moreover, these large fixed income allocations tend to be highly concentrated in domestic government bonds and cash instruments (short-term government bonds, money market instruments, and deposits). **Table 1** shows the portfolio composition of a cross-section of mandatory DC pension funds in developing economies as of December 2007. With the exception of Chile and Peru, all the funds have allocations to domestic government bonds and

stable-value instruments well above 50%. In the case of Uruguay and Slovakia the allocations are as high as 95% and 85%, respectively.

This heavy allocation to cash instruments, stable value funds, and domestic government bonds is probably driven by two major factors. First, it might be rooted in the conventional wisdom in investing that regards cash instruments and stable value funds are the safest assets. Second, fiscal deficit financing considerations are most likely also at play, particularly in explaining the allocations to domestic government bonds. Unfortunately, the modern theory of long-term asset allocation suggests that the common practice of requiring pension funds to hold large holdings of domestic long-term nominal government bonds and deposits or cash-like instruments is not in the best interest of plan participants and should be reconsidered, even if the ultimate goal is to provide plan participants with safe investment options.

Cash instruments and stable value funds are not safe assets for long-term investors, because they are subject to reinvestment risk. Because of their short maturity relative to the investment horizon of most plan participants, long-term investors need to follow a strategy of rolling over these instruments as they mature. This strategy is risky, because the real rates at which investors can reinvest their cash holdings move considerably and persistently over time (Campbell and Viceira 2001, 2002, Campbell, Sunderam, and Viceira 2009). In particular, as the most recent experience suggests, low real interest rate regimes can persist for long periods of time. These instruments are also subject to short-term inflation risk. While this is not a concern in developed economies with stable inflation, it can be an important concern in developing economies with volatile inflation.

Long-term bonds protect investors from reinvestment risk, because falls in interest rates are compensated with capital gains in the value of the bond. But long-term government bonds are typically instruments whose coupons and principal are fixed in nominal terms. This makes them risky investments for long-term investors because they are subject to long-term inflation risk: If realized and expected future inflation turn out to be larger than the rate of expected inflation built into price of the bond at the time of its acquisition, the purchasing power of the coupons and principal of the bond will be eroded, and the bond will also experiment capital losses.

Unfortunately, inflation risk can be important a long horizons. Expected inflation in developed economies moves considerably over time, and experiments both temporary and highly persistent changes (Campbell and Viceira 2001, 2002, Campbell, Sunderam, and Viceira 2009). In developing economies, long-term inflation risk is likely to be exacerbated, as the inflation experiences of many of these economies suggests.

In inflationary environments, the only asset class that provides investors with protection from real interest rate uncertainty and from inflation uncertainty is inflation-linked bonds. Long-term inflation-indexed bonds (TIPS in the US) protect investors from inflation risk by providing a predictable stream of real (inflation-adjusted) income. They protect investors from falls in interest rates because their prices adjust inversely to movements in real interest rates.

An investment in nominal bonds is a bet that inflation risk will be negligible in the future or, from a speculative perspective, that the economy will go through a period of deflation. In deflationary environments, inflation-indexed bonds still protect investors because their coupons and principal are constant in real terms. While long-tem deflation is certainly a

possibility, experience suggests that inflation is probably a bigger threat in developing economies.

Inflation-linked bonds have been labeled in the popular financial press as an "alternative" or "exotic" asset class. In fact, long-term inflation-indexed bonds are neither alternative nor exotic: They are the true riskless asset for long-term investors. As such, they should be at the core of the fixed income investment options offered in any DC plan, and at the core of the fixed income allocation of life-cycle funds and life-style funds. Those plans which are oriented towards providing investors with a riskless default investment option should consider making an inflation-linked bond fund the default option for active participants in the plan.

Perhaps one reason why inflation-linked bonds are sometimes labeled as "exotic assets" is because they are not readily available in many economies, particularly in developing economies. However, the experience has been that, when issued, there is ready demand for these bonds from long-term investors such as traditional DB pension funds, endowments, and individual investors saving for retirement. Today, governments and even private issuers in many developed economies issue inflation-indexed bonds on a regular basis, making these bonds readily available to investors. Governments in some developing economies have also started to issue such bonds; in some countries like Chile, inflation-indexed instruments have a long tradition, and they are the most liquid government bonds.

From the perspective of long-term investors, particularly working investors saving for retirement through DC pension plans, the issuance of inflation-indexed bonds by governments is welfare improving. Issuance of these bonds should also help governments reduce the cost of

public deficit financing, since these bonds do not require compensation for inflation uncertainty. Of course, by eliminating the ability to inflate away government debt, these bonds are in some ways akin to foreign-currency denominated debt, in the sense that straight default is the only possible way of reducing payments on these bonds.

In the absence of local inflation-linked bonds, Campbell, Viceira, and White (2003) show that investors in countries with volatile inflation at short- and at long-horizons can still gain inflation protection. They can do so by holding short-term bonds denominated in foreign currencies with stable inflation and real interest rates. Section 5.3 below discusses this strategy in more detail.

Inflation-indexed bonds provide the safest investment option for working investors. However, older investors face longevity risk in addition to real interest rate risk and inflation risk. Standard inflation-indexed bonds do not protect investors from longevity risk. However, inflation-indexed annuities can, and they should be at the core of the options offered to plan participants about to retire or already retired.

5.2 Equity Portfolios

In most developing economies, pension fund regulations limit the exposure to equities, and particularly the exposure to international equities, of DC pension plans. While limiting overall equity holdings make sense if the plan regulator wants to set limits to the maximum risk exposure in the plan—though it should never be an excuse to implicitly make pension funds finance domestic fiscal deficits by forcing them to increase their holdings of government bonds—, limiting international equity exposure might not be in the best interest of plan participants.

International diversification, with currency risk appropriately hedged, should have a first order positive impact on improving the risk-return tradeoff in equity allocations. In their classical study on the benefits of portfolio diversification, French and Poterba (1991) found substantial gains for U.S. investors from international equity diversification. These gains came from the historical imperfect correlation across international equity markets.

Although correlations of global stock markets have increased in recent times (**Figure 5**), recent studies confirm the benefits of international diversification in equity portfolios, and show that these benefits extend to investors in most developed economies (Dimson, Marsh, and Staunton 2002). Campbell, Serfaty-de Medeiros, and Viceira (2009) also find benefits to international diversification in bond portfolios. Goetzmann, Li, and Rouwenhorst (2004) take the long view, and show that the correlations of international equity markets vary considerably over time. This variation appears to be related to varying global economic and financial integration, with greater average correlation at times of increased integration. To the extent that globalization might not be a permanent phenomenon, the current lower (but still substantive) gains from international equity diversification might underestimate the long-run gains.

The benefits of international equity diversification are most likely to be even greater for investors based in developing economies. Developing economies are typically characterized by small national stock markets subject to significant country-specific risk. For example, many of these economies do not have a widely diversified productive sector and instead are heavily concentrated in specific industries or services. This risk can be ameliorated through international diversification.

Equity allocations in investment options in DC plans in developing economies should be held in the form of internationally diversified portfolios, with benchmarks oriented to reflect the performance of the world stock market portfolio rather than the local stock market.

5.3 Currency Hedging

An important decision for internationally diversified equity and bond investors is to decide how much to hedge of the currency exposure implicit in their portfolios. A conventional practice among institutional investors in developed economies is to fully hedge the currency exposure of their international holdings of equities. This practice is optimal when equity excess returns are uncorrelated with currency excess returns (Solnik 1974). Indeed, Perold and Schulman (1988) find that US investors can reduce volatility by fully hedging the currency exposure implicit in internationally diversified equity portfolios.

However, if equity (or bond) returns and currency returns are correlated, full currency hedging will not be the best approach to reduce portfolio risk. For example, if investors hold a portfolio of international equities, and excess returns on foreign equities are negatively correlated with foreign currency returns, holding currency exposure can help investors reduce the volatility of their speculative portfolio. Thus not hedging rather than hedging is what helps investor reduce portfolio risk.

Campbell, Serfaty-de-Medeiros, and Viceira (2009) examine whether currency returns are in fact correlated with the returns on portfolios of international equities and bonds over the period 1975-2005, and derive the optimal risk-minimizing currency hedging policy for internationally diversified bond and equity investors implied by those correlations.

They find that currencies traditionally considered as reserve currencies by international investors such as the US dollar, the Euro, and the Swiss franc tend to be negatively correlated with global stock markets. These currencies tend to appreciate when global stock markets fall, and tend to depreciate when global stock markets rise. An immediate implication of this finding is that investors seeking to minimize the currency risk of their portfolios should not hedge their exposure to those currencies in global equity portfolios.

By contrast, they find that commodity-based currencies such as the Australian dollar or the Canadian dollar tend to be positively correlated with global stock markets, while other major currencies such as the British pound or the Japanese yen are largely uncorrelated with global stock markets. Thus investors should fully hedge the exposure to those currencies in equity portfolios in order to minimize portfolio risk. In the case of commodity-based currencies, it is even optimal to hold short positions in them that go beyond those required by full hedging.

In summary, they find that it is not optimal for internationally diversified equity investors to apply a single hedging policy across all major currencies to reduce risk. Rather, they should preserve their exposure to reserve currencies, while hedging their exposure to all other major currencies. Their study shows that investors based in developed economies can achieve highly economically and statistically significant gains relative to standard currency policies such as full hedging, no hedging, or half-hedging.

The recent financial crisis of 2008 has provided an informal corroboration of their findings, as reserve currencies have tended to strengthen, while commodity currencies such as the Australian dollar or the Chilean peso have strongly depreciated.

Investors in developing economies holding internationally diversified equity portfolios are likely to hold a very high proportion of their portfolios in the stock markets of developed economies. As such, the conclusions from the Campbell-Serfaty-de-Medeiros-Viceira study apply to them. In fact, Walker (2008) finds that reserve currencies tend to appreciate with respect to emerging market currencies when global stock markets fall.

Interestingly, Campbell, Serfaty-de-Medeiros, and Viceira (2009) find that global bond market returns are mostly uncorrelated with currency returns. They show that currency exposures in internationally diversified bond portfolios should be close to full hedging, with a modest long exposure to the US dollar.

There is an additional argument for long-term investors in developing economies to hold exposure to reserve currencies. It is well known that holding foreign currency exposure may help reduce total portfolio volatility when there is no domestic asset that is riskless in real terms (Adler and Dumas 1983). At short-horizons, this effect is unlikely to be important for investors in developed economies with stable inflation, but it can be important for investors in developing economies with volatile inflation.

At long horizons, Campbell, Viceira, and White (2003) show that investors interested in minimizing real interest rate risk can do so by holding portfolios of short-term government bonds denominated in euros and US dollars, because these two currencies have had relatively stable interest rates. In other words, in the absence of inflation-indexed bonds denominated in local currency, bills denominated in reserve currencies can help long-term investors mimic the properties of those bonds.

The ability of reserve currencies to hedge long-term real interest risk and inflation risk should be especially attractive to long-term investors in developing economies for at least two reasons. First, inflation-indexed bonds do not exist in many of these economies, and it has been argued that the inflation protection and interest rate risk protection they provide is important for long-term investors. Second, bonds in those currencies are unlikely to default.

In summary, all these results suggest that reserve currencies—the US dollar and the euro—can help long-term investors in developing economies to reduce short-term and long-term portfolio volatility. These currencies can provide an attractive and stable store of value for these investors, particularly for DC plan participants.

6. Performance Evaluation of Investment Options

The distribution of wealth at retirement accumulated under different fund designs in DC plans is of interest to sponsors, participants, regulators, and policy makers. This distribution depends on two key factors: The income profile over the life-cycle of the plan participant, which determines contributions to the plan, and the risk and return of the asset classes included in the fund.

Following Poterba, Rauh, Venti, and Wise (2005, 2009), this section follows a simulation approach to obtain this distribution for a base country, Chile, for which there is ready availability of data on life-cycle earnings for plan participants, and relatively long data series for domestic interest rates and stock returns. This exercise provides a sense of the performance of

different funds over the working life-cycle of a plan participant facing realistic life-cycle earnings growth, earnings uncertainty, and capital markets expected return and risk.

6.1 Labor Income Profile

Studies of labor income profiles over the life-cycle (Carroll 1997, Gourinchas and Parker 2002, Hubbard, Skinner and Zeldes 1995) find that the typical earnings profile is hump-shaped, subject to random shocks. On average labor earnings tend to grow in the early part of the life-cycle of the employee, reach a maximum around mid-life, and experiment a decline afterwards. This shape is driven by a combination of increasing wages and labor supply early in life, and a decline in labor supply late in life (Low 2005, French 2005, Gomes, Kotlikoff, Viceira 2008).

In their study of plan participants in the Chilean pension system, Berstein, Larraín, and Pino (2006) find a similar inverted-U shape for a typical contributor to the system. **Figure 6** reproduces their estimated life-cycle earnings profile for a typical Chilean male participant in constant Chilean pesos of 2004. This profile is the basis for the simulation of labor income histories in this study.

Of course, as noted in Section 4, labor earnings are not deterministic. They are subject to random shocks that make future labor income uncertain for individuals, and result in considerable dispersion in the realized labor income profiles of working populations (Mitchell and Turner, 2008). Labor earnings are subject to random shocks which have a permanent effect on the level of earnings achieved by the individual, and shocks whose effect on earnings is only transitory.

Formally, labor economists find that empirically labor earnings over the life cycle can be modeled as

$$y_t = f(t) + v_t + \varepsilon_t$$

$$v_t = v_{t-1} + u_t$$

where *f(t)* describes the deterministic age-dependent component of earnings with an inverted-U shape (Figure 6), u_t describes the permanent shock to labor earnings, and ε_t describes the transitory shock. Both shocks are assumed to be uncorrelated both longitudinally and temporally, and normally distributed.

There are currently no studies about the size of these shocks for plan participants in mandatory pension funds in developing economies. However, there is empirical evidence available about their size for U.S. workers. Cocco, Gomes and Maenhout (2005) estimate the annual standard deviation of these shocks at 10.95% and 13.89%, respectively, though half of that is attributed to measurement error. The simulations included in this study use these magnitudes with no downward correction for measurement error as estimates of the volatility of the shocks to working investors in developing economies. Thus the simulations assume effectively that labor income uncertainty is much more pronounced in developing economies. This might be in practice a prudent assumption, given the more precarious nature of employment in these economies.

Figure 7 shows the impact of this uncertainty on the distribution of annual labor income the final year of employment before retirement. This simulation is based on 100,000 replications of

the labor income process with the age-profile *f(t)* shown in Figure 6, assuming that the individual joins the labor force (and starts contributing to the plan) at age 21 with a starting salary of Ch$62,500 per annum, and retires at age 65.

This figure illustrates that the impact of labor income uncertainty on final salary is highly significant. The median of the distribution of final salary is about Ch$107,000, and the mean is about Ch$140,000. The standard deviation of the distribution is, at Ch$116,500, larger than the median, and it implies a large dispersion in potential outcomes. The fifth percentile of the distribution is about Ch$32,500 and the first percentile is about Ch$20,000, or less than one third and one fifth of the median final salary, respectively. At the right side of the distribution, the 95 percentile and the 99 percentile are Ch$356,600 and Ch$585,200 respectively.

Since pension plan contributions are typically proportional to earnings, this implies that the range of potential outcomes in pension assets at the end of the working life is going to be very large, even if these contributions are invested with no risk at all. Thus income uncertainty will generate sizable uncertainty about asset accumulation in retirement, regardless of whether the plan takes investment risk or not.

6.2 Capital Markets

The simulations consider four asset classes. The first one is domestic stocks, which in the simulations is proxied by the MSCI Chile Total Return Stock Index. The second one is the world stock market portfolio which, consistent with the discussion about currency hedging in Section 5.3, is proxied by the MSCI World Total Return Stock Index in dollar terms and unhedged. The

third one is domestic government inflation-linked bonds (ILB) , and the fourth one is domestic nominal government bonds (Nom Bonds).

The simulation of the performance of these asset classes assumes that their returns are uncorrelated over time and lognormally distributed. The assumption of temporal independence is a conservative assumption, because it ignores the possibility that stock returns might be predictable or mean-reverting (Campbell and Viceira, 1999). Mean reversion in returns implies that risk is smaller at long investment horizons than at short horizons, while temporal independence means that risk is independent of investment horizon (Campbell and Viceira 2005).

Table 2 presents the capital market assumptions of the simulation exercise. Specifically, it presents the mean, standard deviation and correlation structure of continuously compounded (or log) real returns on the four asset classes. These moments are consistent with the historical experience.

The mean and standard deviation of returns in the MSCI World unhedged portfolio correspond to the period January 1984- April 2008, while the moments for the MSCI Chile portfolio correspond to a somewhat shorter period, January 1993-April 2008. This period excludes the the Pinochet regime and the period of high inflation Chile lived in the 1980's but it still includes events of extreme volatility such as the emerging markets crisis at the end of the 1990's, the global stock market crash early in this century, and important capital markets reforms in Chile. The mean log real return on the world stock market portfolio and the domestic stock market portfolio are very similar at 7.7% and 7.6% respectively. However, at 22% the volatility of the

domestic stock portfolio is about 30% higher than the volatility of the world stock market portfolio, with a correlation with the world stock market portfolio of 34%.

The higher volatility of the domestic stock market portfolio relative to the world stock market portfolio implies that, while the mean log returns are about the same for both stock portfolios, the expected mean simple real return on the domestic portfolio is larger than the expected return on the world stock market portfolio. Specifically, the capital market assumptions in Table 2 imply that the expected simple real return on the domestic portfolio is 10%, while the expected return on the world stock market portfolio is 100 basis points lower at 9%.[2]

The average log real return on inflation-indexed bonds is assumed to be 2.8%, roughly the current yield on Chilean long-term inflation indexed bonds. The simulations assume that investors can get this return with zero volatility. Of course, in practice inflation-indexed bonds have non-zero volatility at short horizons. Since we are interested only in the long-run performance of the asset class, this assumption is a simple way of capturing the fact that inflation-indexed bonds are riskless at long horizons.

The historical average real return on nominal bond instruments in Chile has been negative in most periods, reflecting large inflationary surprises. However, it is unlikely that investors expected a negative real return at issuance of these bonds. Consistent with the idea that investors should demand a positive risk premium on long-term nominal bonds, the simulations assume an mean log real return on nominal bonds of 3% per annum, with a standard deviation

[2] Mean simple returns and mean continuously compounded returns are different when returns are volatile. Under the assumption of lognormality, the mean simple return is equal to the mean log return plus one-half the variance of the log return, and approximately equal at small intervals otherwise. The mean simple return determines the expected future return.

of 10%, zero correlation with the world stock market, and a 25% correlation with the domestic stock market.

6.3 Investment Strategies

To understand the implications of labor income uncertainty and capital market risk for asset accumulation over the life-cycle, this study considers sixteen different investment strategies or hypothetical funds. The first four strategies consider pure investments in each asset class: government nominal bonds, government inflation-indexed bonds, domestic stock market portfolio, and the world stock market portfolio (unhedged).

The next four strategies are life-style or balanced funds, each one investing 60% in bonds and 40% in stocks. The bond portfolio is either 100% invested in nominal bonds, or 100% invested in inflation-indexed bonds. The stock portfolio can be either the domestic stock market portfolio or the world stock market portfolio.

The next eight strategies are life-cycle funds, with two main life-cycle investing strategies. Lifecycle 1 considers a stock-bond portfolio which is invested in a 90%-10% stock-bond portfolio for the first twenty years of the fund, and gradually changes this mix until it reaches a 50%-50% stock-bond portfolio at retirement age. Lifecycle 2 considers a strategy that starts with 90%-10% stock-bond portfolio and starts immediately reducing the stock allocation until it reaches a 50%-50% stock-bond portfolio at retirement. All life-style and life-cycle funds are rebalanced on an annual basis.

The investment strategies are simulated under three assumptions about labor earnings. First, labor income is assumed to be non-stochastic, so that $y_t = f(t)$. Second, labor income is assumed

to be stochastic, and subject to permanent and transitory shocks which are uncorrelated with stock market returns and nominal bond returns. Third, labor income is assumed to be stochastic, and subject to permanent and transitory shocks, with permanent shocks to income exhibiting a 50% correlation with domestic stock returns and uncorrelated with world stock returns and domestic bond returns.

In each case, the contribution rate is set at 10% of the monthly salary. Setting the contribution rate as a percentage of labor income reflects the standard practice in mandatory pension plans. When labor earnings are stochastic, it also helps capture in the simulations the impact on asset accumulation of episodes of low or extremely low labor earnings of varying length.

Table 3 presents a summary of the main results of the simulation exercise, with a focus on the pure strategies and the life-style and life-cycle strategies that use inflation-indexed bonds as the basis for the fixed income allocation. To facilitate interpretation, the table reports the mean and the standard deviation of accumulated assets at retirement under each investment strategy as a multiple of the final annual salary expected at the time the participant starts working and joins the plan at age 21. The expected final salary is also reported in the bottom row of the table. **Tables 4, 5, and 6** present the full distribution of expected final salary multiples for all sixteen strategies.

The first two rows of Table 3 show the results generated by the pure bond strategies. The first row of the table shows that investing on an inflation-indexed bond fund leads on average to an asset accumulation equal to about 13 times expected final salary when labor earnings are non-stochastic, and about 11.5 times when they are. This implies that a plan participant with mean

realized earnings in his final year of work, and a life expectancy of 15 years at retirement, would have accumulated under this option enough assets to finance annual spending during retirement equal to about 70% of his final salary. With a life expectancy of 20 years, the assets accumulated at retirement would be enough to finance spending equal to about 50% of his final salary.

Interestingly, despite this being a fully riskless strategy, assets at retirement exhibit considerable dispersion in the case of uncertain labor income. The standard deviation of asset accumulation as a multiple of the expected final salary is slightly above 5. Of course, this dispersion is entirely attributable to uncertainty in labor income outcomes, not to investment outcomes, and it is consistent with the dispersion of final salary shown in Figure 6. Table 5 shows that this standard deviation implies that the 5th percentile of the distribution is 5.5 times the expected final salary. This is about 24 times the 5th percentile of the final salary distribution (Ch$32,555). Therefore, a plan participant who ends up in the left tail of the distribution in labor income outcomes would still have accumulated enough assets to finance annual consumption equal to 100% of his final salary for 24 years.

A strategy of investing contributions in nominal bonds leads to a slightly higher average multiple of expected final salary (13.6x in the case of stochastic labor income) but at the cost of a much larger standard deviation of outcomes (8.7x). Of course, this is the result of the assumption that the expected return on nominal bonds is larger than the expected return on inflation-indexed bonds, with a much larger standard deviation. This higher volatility tries to capture the fact that nominal bonds are subject to inflation risk, which in developing economies

can be significant. Episodes of large unexpected inflation may result in very low or even negative realized returns on nominal bonds. For example, as it has already been noted, in the case of Chile nominal instruments with maturities above one year have delivered average negative returns during most periods in the last 30 years.

All other strategies under consideration include investments in stocks, either the domestic stock market or the unhedged world stock market. In general, every strategy involving the domestic stock market results in an average asset accumulation which is larger than the twin strategy that replaces the domestic stock market component of the strategy with the unhedged world stock market portfolio.

However, this comes at a significant cost in terms of higher volatility. The increase in volatility is particularly significant in the case when labor income is positively correlated with the domestic stock market, which arguably is the most plausible characterization of labor income uncertainty in developing economies. This is the case where deterioration in local macroeconomic conditions leads to both a fall in domestic stock market valuations, and a fall in individual labor earnings. This results in both lower returns and lower contributions, which together have an important negative compounding effect on asset accumulation.

The third and fourth rows of Table 3 help illustrate the impact of international diversification on asset accumulation. These two rows report the outcomes of investment funds fully invested in either the domestic stock market, or the unhedged world market portfolio. A strategy fully invested in the domestic stock market results in the largest average asset accumulation of all strategies under consideration, which stands at 79 times the expected final salary in the case of

stochastic labor income. Of course, this higher mean asset accumulation is a direct effect of the assumption that the domestic stock market has the largest expected return of all four asset classes. The fund which is 100% invested in the world stock market portfolio also produces a large average asset accumulation at 58.5 times expected final salary.

However, the strategy of investing in the domestic stock market comes at the cost of a very high dispersion in outcomes. The standard deviation of asset accumulation at retirement is almost 145 times the expected final salary with correlated labor income. By contrast, by investing instead in an internationally diversified portfolio of equities, plan participants can reduce the volatility of asset accumulation at retirement more than 55% (61.5 times versus 145 times), while still achieving significant average asset accumulation.

Interestingly, the benefits of international diversification are most apparent in life-style and in life-cycle funds, where equity portfolios are combined with fixed income portfolios. In those funds, replacing domestic equities with the unhedged world stock market portfolio leads to a significant reduction in the volatility of asset accumulation (about 30%), with a proportionally much smaller reduction in expected asset accumulation.

The rows in the bottom half of Table 3 allow for a comparison of life-style funds and life-cycle funds from the perspective of asset accumulation at retirement. Both types of funds provide plan participants with a vast reduction in the volatility of assets at retirement relative to the pure equity strategies, while providing plan participants with substantial expected assets relative to their expected final salary. Life-cycle funds provide plan participants with higher expected assets at retirement, and thus with the possibility of having higher replacement ratios

for their earnings once they retire. However, they do so at the cost of increased dispersion of the possible outcomes. Note however that the higher volatility and higher expected asset accumulation of life-cycle funds relative to life-style funds is driven to a large extent by the specific portfolio mix and glide paths for these funds considered in the simulations. At 40%, the equity allocation of the life-style funds is more conservative than the average equity allocation of the life-cycle funds, which starts at 90% and converges to 50% in the final year before retirement.

Interestingly, Table 3 shows that whether the life-cycle fund starts de-investing in equities uniformly from the first year of contributions or after 20 years does not appear to make a significant difference in the distribution of assets accumulated at retirement.

Portfolio optimization considerations of the sort explained in Section 4 strongly favor the adoption of life-cycle funds for DC plan participants. This section illustrates through simulation that these funds do not perform worse and in most cases perform better than other plausible alternatives in terms of the expected asset accumulation at retirement and its volatility that they can provide. This is particularly true when they are properly structured with inflation-indexed bonds and an internationally diversified equity portfolio.

In practice, policymakers need to consider which life-cycle structure is more appropriate for the population of participants in the fund. Kotlikoff, Gomes and Viceira (2008) examine the welfare implications of adopting life-style funds and life-cycle funds in DC pension plans. They find that, controlling for risk tolerance, life-cycle funds dominate life-style funds in the sense that they

are closest to the optimal portfolio strategy a rational expected utility maximizing working investor would choose.

However, they also find that the optimal design of the glide path for life-cycle funds is sensitive to the risk tolerance of the plan participant. In particular, plan participants with very low risk tolerance experiment significant welfare losses if they are forced to adopt life-cycle funds with the average high equity allocations which are standard in the industry, which are optimal for participants with medium risk tolerance. For plan participants with low risk tolerance, life-cycle funds with allocations heavily tilted toward inflation indexed bonds are optimal. Bodie and Treussard (2007) find similar results, although they focus only on the expected utility of wealth at retirement instead of expected life-time utility.

7. Concluding remarks

Global competition and aging demographic trends are leading to the widespread adoption of DC plans as the most important vehicle for retirement savings in both developed and developing economies. However, the experience of how plan participants choose to save and invest through these plans has been mixed. Plan participants, particularly those at the lower end of the distribution of education and income levels, appear to make poor saving and investing choices.

This article argues that mandatory participation with appropriately designed default investment options in these plans can go a long way to help DC plan participants improve

expected asset accumulation at retirement, and consequently their ability to spend in retirement.

The theory of long-term asset allocation provides guidance for the design of saving and investing vehicles that can help investors save for retirement, and save themselves from their own "investing maladies" or psychological biases. In particular, it provides support for the adoption of age-based and risk-based investing strategies as the basis for the construction of default investment options in DC plans. Simulations show that life-style funds and life-cycle funds help improve average asset accumulation at retirement relative to pure bond funds, while drastically reducing the dispersion of outcomes relative to pure stock funds.

This theory also provides strong support for tilting fixed income allocations in DC plans towards inflation-indexed bonds, and equity allocations towards internationally diversified stock portfolios. Empirical research on the correlation of global stock markets and currencies shows that reserve currencies such as the U.S. dollar, the euro, and the Swiss franc tend to be negatively correlated with global stock markets, implying that exposures to those currencies in equity portfolios should not be hedged from a portfolio risk minimizing perspective.

For plan participants whose labor earnings are not too volatile and not highly correlated with stock returns, life-cycle funds are better default investment choices than life-style funds, money market funds, or pure stock funds. However, making a single life-cycle fund for each retirement horizon the only choice available to plan participants might not be optimal if there is heterogeneity in the risk tolerance or in the human capital characteristics among plan participants. In particular, participants with very low risk tolerance or highly uncertain labor

earnings are likely to be better off with life-cycle funds which are heavily tilted toward inflation-indexed bonds. Thus offering two sets of life-cycle funds, one with more aggressive equity allocations and another one with more conservative equity allocations might improve the overall welfare of the population of plan participants.

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Figure 1. Balance Sheet of Typical Plan Participant

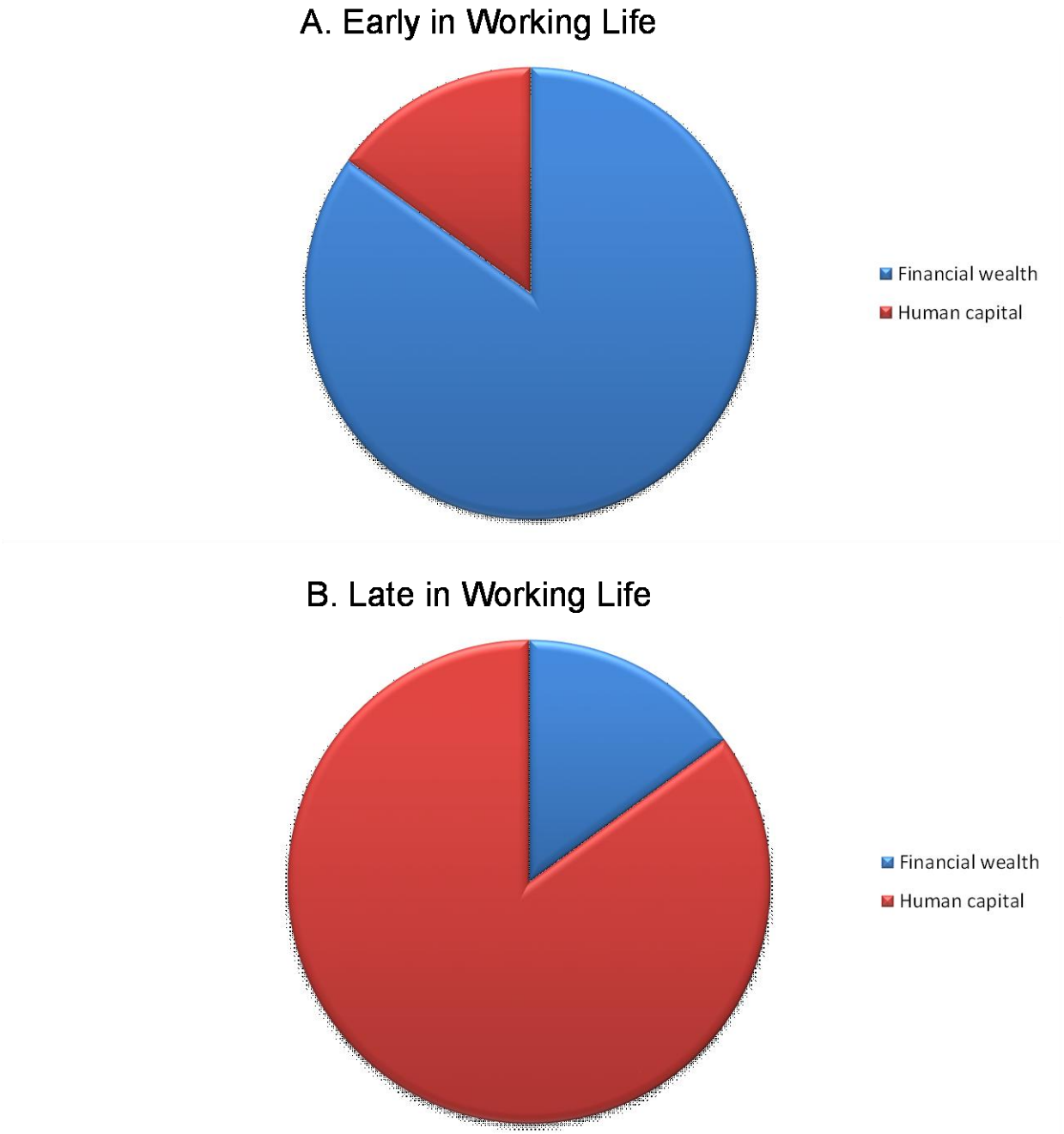
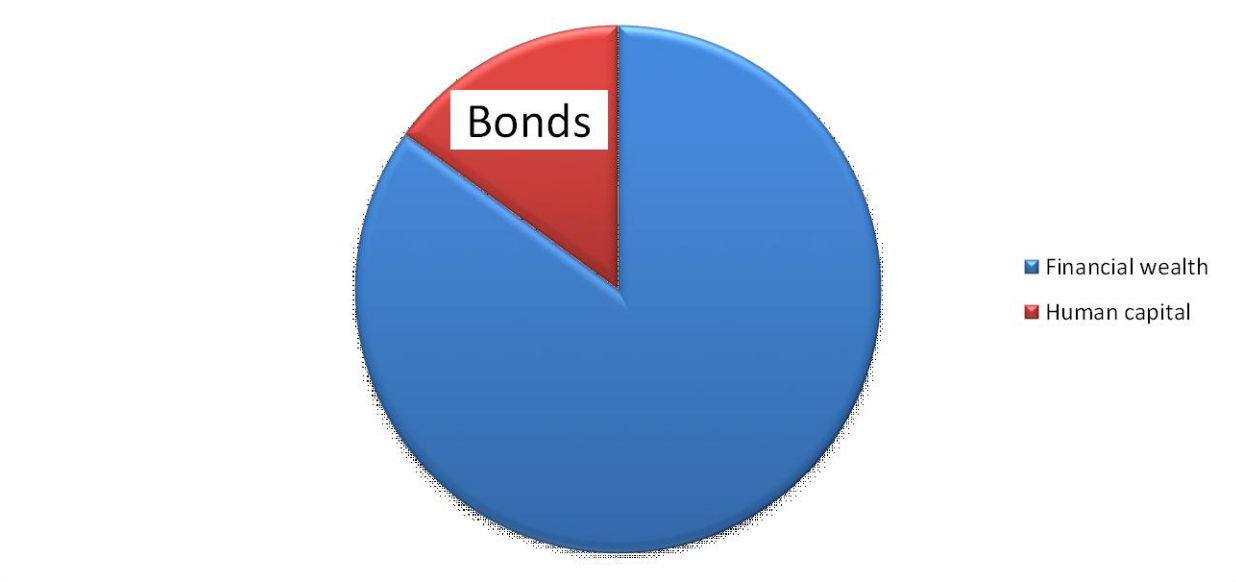


Figure 2. Balance Sheet of Typical Plan Participant with a Safe Job

A. Early in Working Life



B. Late in Working Life

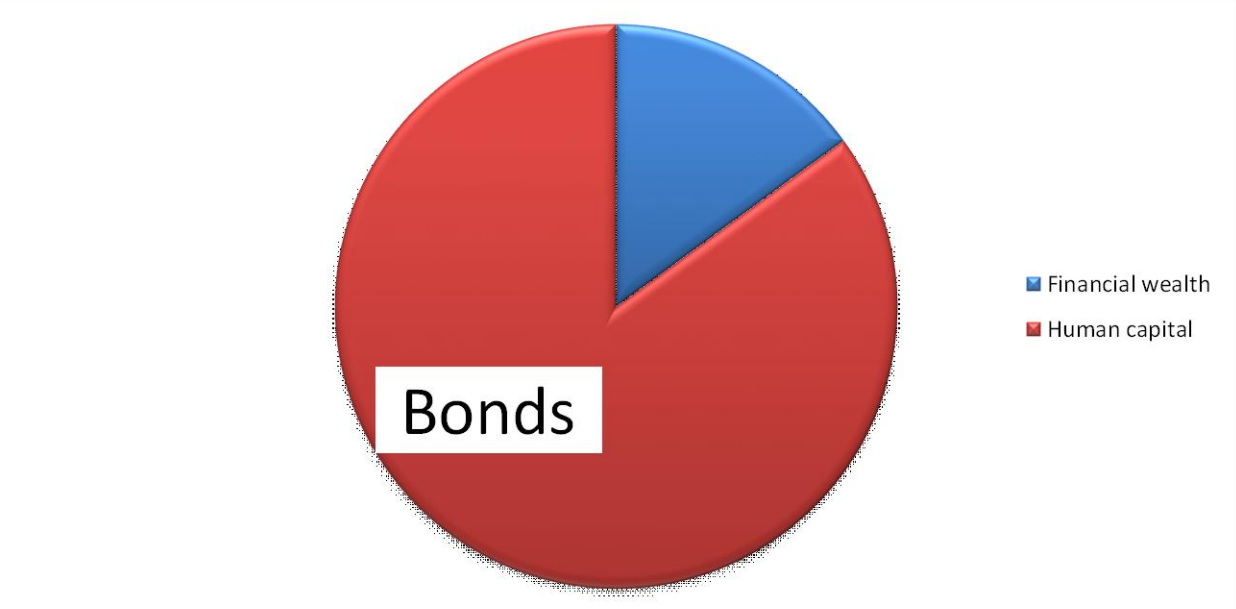
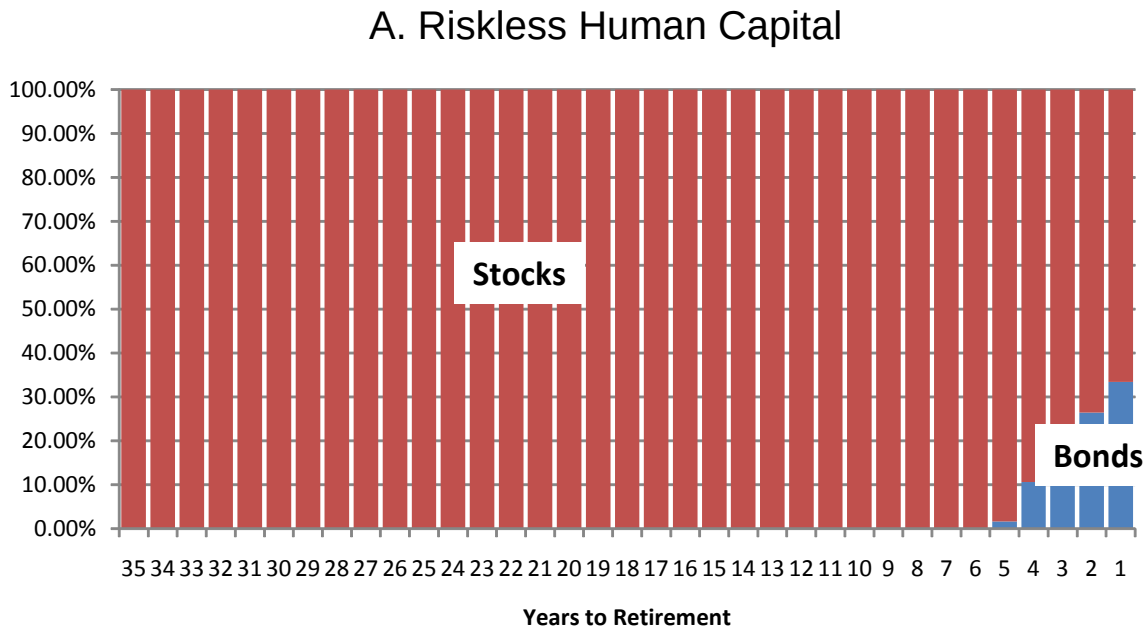


Figure 3. Stylized Life-Cycle Asset Allocation



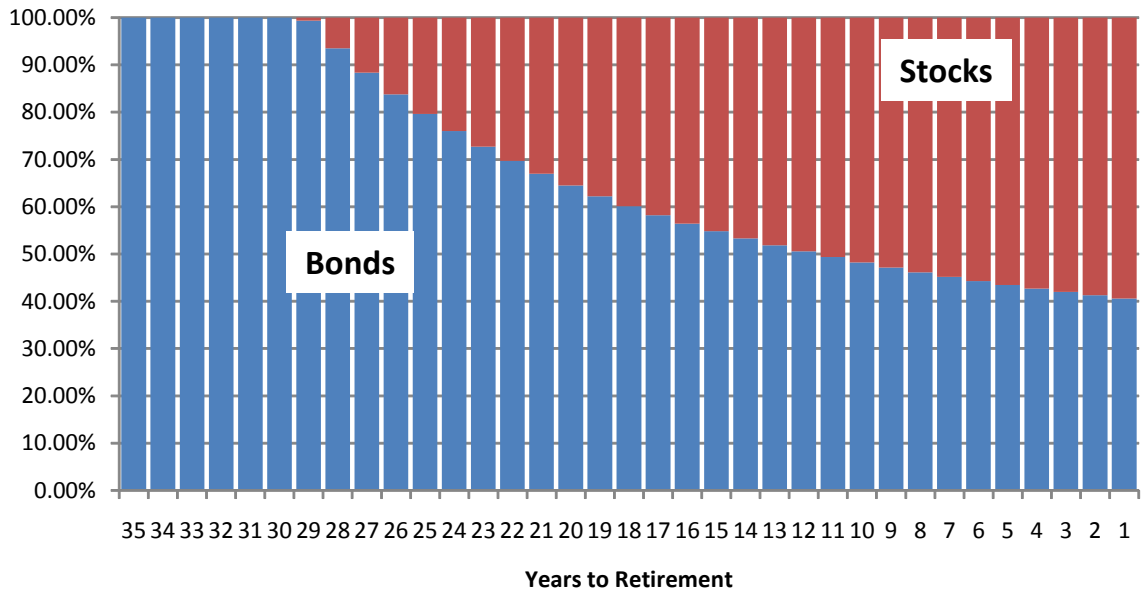


Figure 4. Realistically Calibrated Life-Cycle Portfolio Allocation

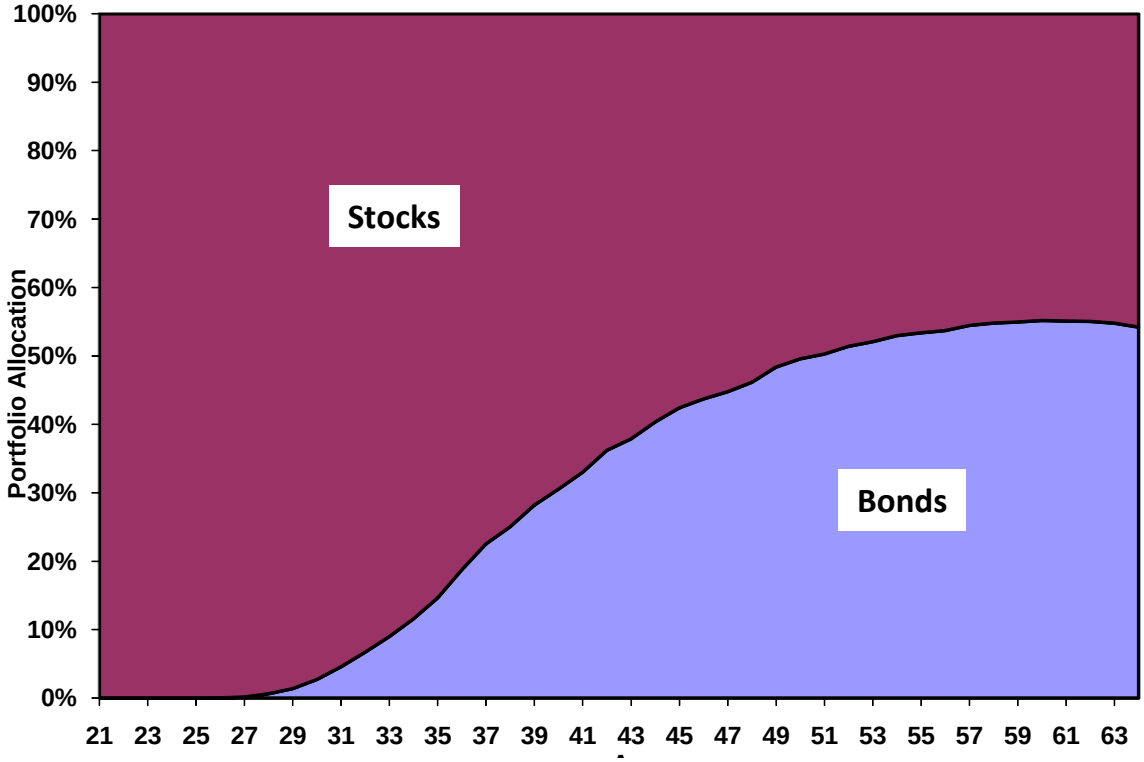


Figure 5. Correlations Across International Equity Markets

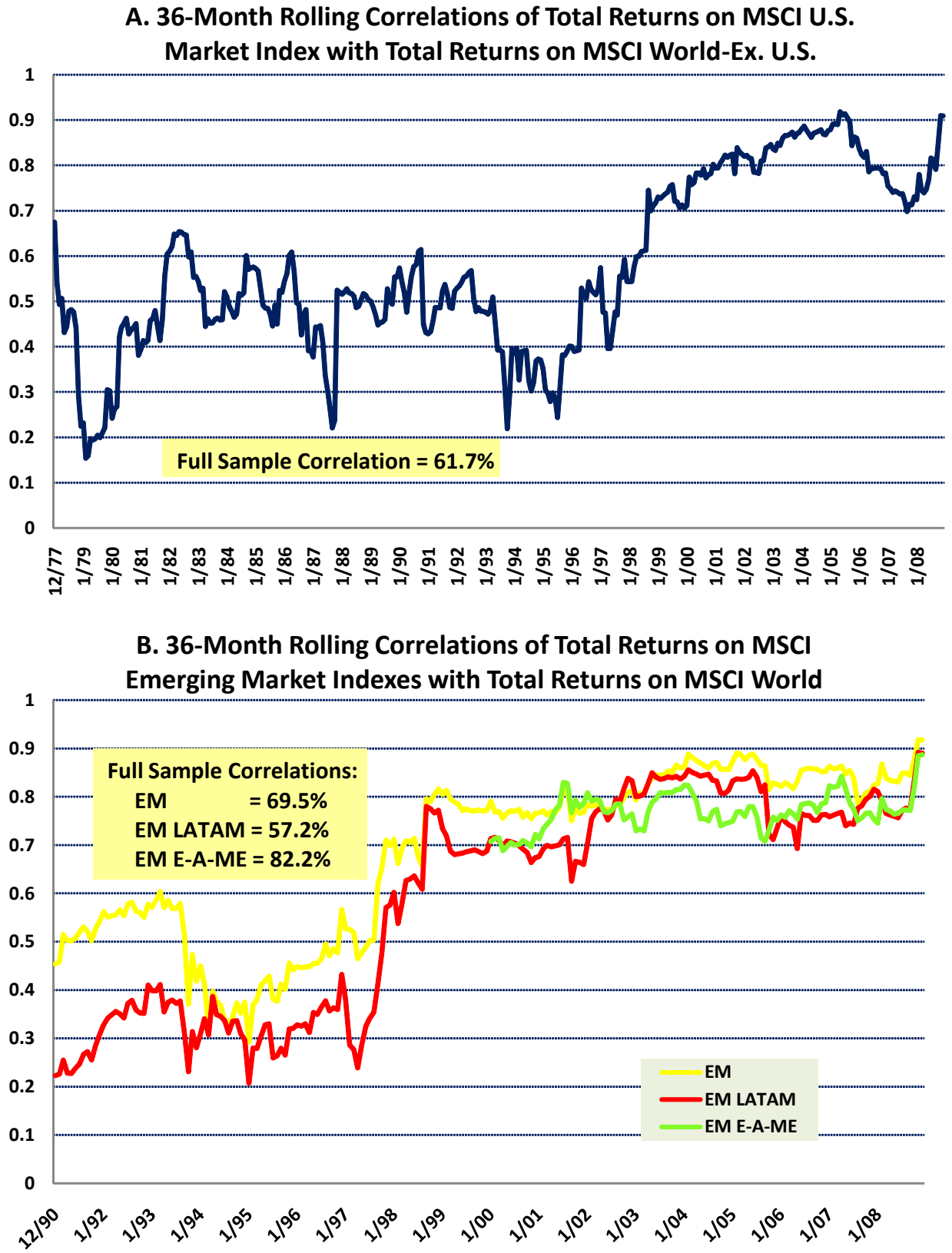


Figure 6. Estimated Live-Cycle Labor Earnings of Chilean Males

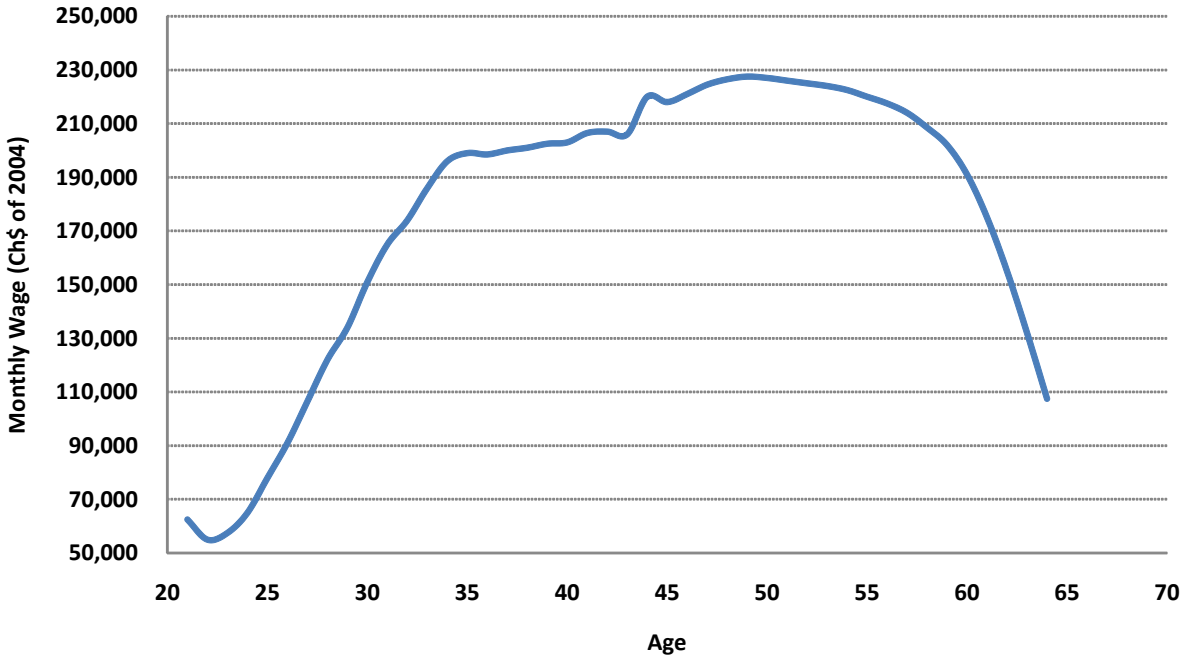


Figure 7. Distribution of Labor Earnings in Final Working Year

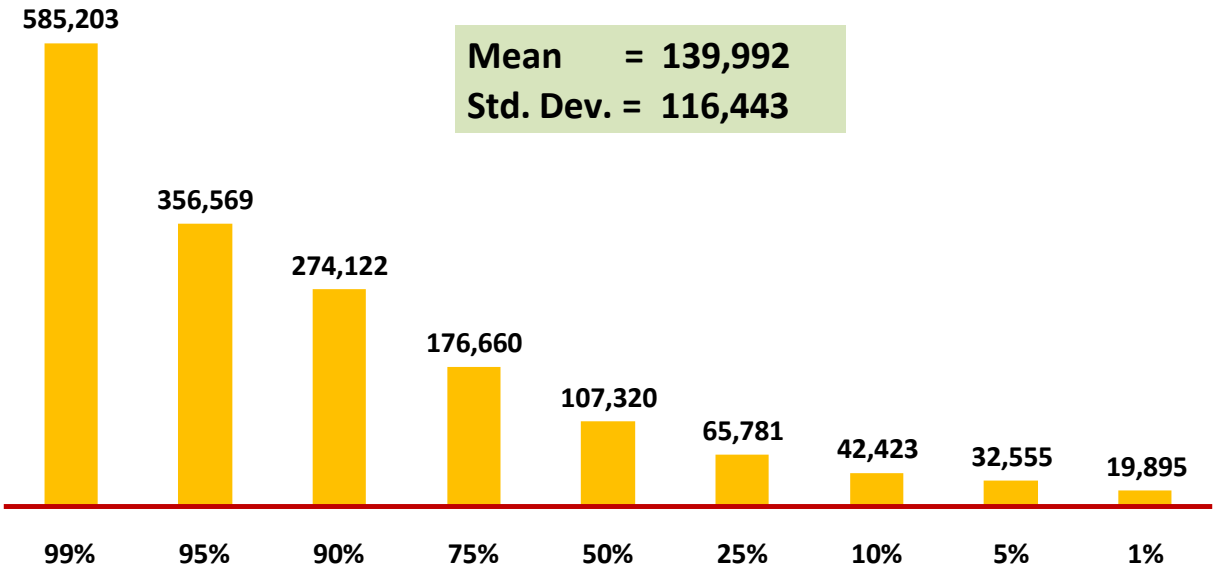


Table 1. Portfolio Composition in Mandatory Pension Funds (December 2007)

	Total Fixed Income (1)	Government (2)	Total Equity (3)	Foreign Instruments (4)	Cash and CDs (5)	Government Instruments+CDs (6) = (2)+(5)
Colombia	70	48	28	10	2	50
Argentina	52	51	33	8	4	55
Chile	27	8	54	36	18	26
Uruguay	87	87	0	0	8	95
Peru	44	22	54	13	2	24
Mexico	80	69	4	0	6	76
Hungary	64	61	30	0	1	62
Poland	62	60	35	1	3	63
Slovakia	38	38	10	10	48	85
Croatia	66	63	31	4	2	66
Average	59	51	28	8	10	60
Average (ecl Peru)	61	54	25	8	10	64

Source: World Bank

Table 2. Capital Markets Assumptions

Asset Class	Mean	Std.Dev.	Correlations		
MSCI World	7.70	16.16	1.00	0.34	0.00
MSCI Chile	7.58	22.08	0.34	1.00	0.25
Nominal Bonds	3.00	10.00	0.00	0.25	1.00
Inflation-Indexed Bonds	2.80	0.00	-	-	-

Table 3. Summary Table of Simulation Results

Strategies	Labor Income Process					
	Non-Stochastic		Uncorrelated		Correlated	
	Mean	Std.Dev.	Mean	Std.Dev.	Mean	Std.Dev.
100% ILB	13.2	0.0	11.6	5.2	11.5	5.2
100% Nom Bond	15.7	7.0	13.6	8.7	13.6	8.7
100% MSCI Chile	95.0	158.4	79.0	135.1	79.0	144.6
100% MSCI World no-hedge	69.9	67.5	58.6	61.5	58.5	61.4
40% MSCI Chile - 60% ILB	23.4	9.7	20.1	11.9	20.1	13.1
40% MSCI World no-hedge - 60% ILB	22.6	6.7	19.4	10.0	19.4	9.9
Lifecycle 1 (90-10 to 50-50 MSCI Chile-ILB starting after 20 years)	38.3	30.7	32.5	29.6	32.5	32.0
Lifecycle 1 (90-10 to 50-50 MSCI World-ILB starting after 20 years)	34.2	18.4	29.1	19.8	29.1	19.7
Lifecycle 2 (90-10 to 50-50 MSCI Chile-ILB starting immediately)	38.3	29.5	32.3	27.9	32.3	30.9
Lifecycle 2 (90-10 to 50-50 MSCI World-ILB starting immediately)	34.1	17.6	28.9	18.7	28.9	18.6
Final Income (Monthly)	107,500	-	140,260	117,068	139,992	116,443

Statistics Presented as Multiple of Expected Income In Final Year

Table 4. Simulation Results for Investment Strategies When Labor Income Is Non-Stochastic
A. Inflation-Indexed Fixed Income Portfolio

	Mean	Std.Dev.	Max	99%	95%	75%	50%	25%	5%	1%	Min
Presented as Multiple of Expected Income In Final Year											
100% ILB	13.2	0.0	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
100% MSCI Chile	95.0	158.4	7252.8	691.2	317.0	105.4	50.5	25.3	10.2	5.6	1.3
100% MSCI World no-hedge	69.9	67.5	1409.0	335.9	189.3	85.8	50.1	30.0	15.0	9.4	2.6
40% MSCI Chile - 60% ILB	23.4	9.7	122.8	55.0	41.6	28.1	21.5	16.6	11.6	9.1	4.3
40% MSCI World no-hedge - 60% ILB	22.6	6.7	73.7	42.8	34.9	26.3	21.6	17.8	13.7	11.4	6.7
Lifecycle 1 (90-10 to 50-50 MSCI Chile-ILB starting after 20 years)	38.3	30.7	778.0	154.7	94.7	47.2	29.7	19.2	10.7	7.3	2.4
Lifecycle 1 (90-10 to 50-50 MSCI World-ILB starting after 20 years)	34.2	18.4	253.8	98.8	69.2	41.9	29.9	21.6	13.9	10.3	4.7
Lifecycle 2 (90-10 to 50-50 MSCI Chile-ILB starting immediately)	38.3	29.5	730.1	148.9	92.0	46.9	30.2	19.9	11.4	8.0	2.8
Lifecycle 2 (90-10 to 50-50 MSCI World-ILB starting immediately)	34.1	17.6	246.5	95.4	67.3	41.5	30.1	22.0	14.6	11.0	5.2
Final Income (Monthly)	107,500	-	107,500	107,500	107,500	107,500	107,500	107,500	107,500	107,500	107,500

Table 4. Simulation Results for Investment Strategies When Labor Income Is Non-Stochastic
B. Nominal Fixed Income Portfolio

	Mean	Std.Dev.	Max	99%	95%	75%	50%	25%	5%	1%	Min
Presented as Multiple of Expected Income In Final Year											
100% Nom Bond	15.7	7.0	110.2	39.5	29.0	18.8	14.2	10.8	7.4	5.7	3.1
40% MSCI Chile - 60% Nom Bond	26.2	15.4	253.7	81.4	55.1	32.1	22.5	15.9	9.9	7.2	3.1
40% MSCI World no-hedge - 60% Nom Bond	24.4	10.2	148.8	58.1	43.7	29.3	22.4	17.3	12.1	9.5	5.0
Lifecycle 1 (90-10 to 50-50 MSCI Chile-Nom Bond starting after 20 years)	41.2	37.1	1133.4	184.2	107.2	50.5	30.6	19.0	10.1	6.6	2.3
Lifecycle 1 (90-10 to 50-50 MSCI World-Nom Bond starting after 20 years)	35.6	20.6	312.8	110.1	74.4	43.8	30.6	21.6	13.6	9.9	4.4
Lifecycle 2 (90-10 to 50-50 MSCI Chile-Nom Bond starting immediately)	41.2	36.3	1138.6	180.6	105.2	50.4	31.0	19.5	10.6	7.1	2.6
Lifecycle 2 (90-10 to 50-50 MSCI World-Nom Bond starting immediately)	35.5	19.9	336.6	106.4	73.0	43.5	30.7	22.0	14.1	10.4	4.6
Final Income (Monthly)	107,500	-	107,500	107,500	107,500	107,500	107,500	107,500	107,500	107,500	107,500

Table 5. Simulation Results for Investment Strategies When Labor Income Stochastic and Uncorrelated with Stock Returns
A. Inflation-Indexed Fixed Income Portfolio

	Mean	Std.Dev.	Max	99%	95%	75%	50%	25%	5%	1%	Min
Presented as Multiple of Expected Income In Final Year											
100% ILB	11.6	5.2	88.3	29.3	21.4	13.9	10.4	7.9	5.5	4.3	2.2
100% MSCI Chile	79.0	135.1	5798.1	593.1	267.7	86.9	40.6	19.6	7.2	3.7	0.6
100% MSCI World no-hedge	58.6	61.5	1746.0	298.3	166.1	71.7	40.3	22.8	10.4	5.9	1.2
40% MSCI Chile - 60% ILB	20.1	11.9	212.2	62.5	42.5	25.0	17.3	12.0	7.1	4.9	1.8
40% MSCI World no-hedge - 60% ILB	19.4	10.0	141.1	53.3	38.2	23.9	17.2	12.5	7.9	5.7	2.4
Lifecycle 1 (90-10 to 50-50 MSCI Chile-ILB starting after 20 years)	32.5	29.6	788.3	145.5	86.0	40.2	24.0	14.5	7.1	4.4	1.0
Lifecycle 1 (90-10 to 50-50 MSCI World-ILB starting after 20 years)	29.1	19.8	409.6	100.3	66.5	36.4	24.1	15.9	8.8	5.9	2.0
Lifecycle 2 (90-10 to 50-50 MSCI Chile-ILB starting immediately)	32.3	27.9	685.8	139.0	83.3	40.1	24.4	15.1	7.5	4.8	1.2
Lifecycle 2 (90-10 to 50-50 MSCI World-ILB starting immediately)	28.9	18.7	330.4	95.6	64.3	36.1	24.2	16.3	9.3	6.2	2.3
Final Income (Monthly)	140,260	117,068	2,840,192	585,203	356,569	176,660	107,320	65,781	32,555	19,895	3,730

Table 5. Simulation Results for Investment Strategies When Labor Income Stochastic and Uncorrelated with Stock Returns
B. Nominal Fixed Income Portfolio

	Mean	Std.Dev.	Max	99%	95%	75%	50%	25%	5%	1%	Min
Presented as Multiple of Expected Income In Final Year											
100% Nom Bond	13.6	8.7	166.6	44.8	30.0	17.0	11.4	7.7	4.4	3.0	1.0
40% MSCI Chile - 60% Nom Bond	22.4	16.4	341.7	83.0	53.1	28.0	18.1	11.7	6.3	4.1	1.1
40% MSCI World no-hedge - 60% Nom Bond	21.0	12.5	240.1	65.0	44.5	26.1	18.0	12.5	7.3	5.1	2.0
Lifecycle 1 (90-10 to 50-50 MSCI Chile-Nom Bond starting after 20 years)	34.9	34.9	951.9	169.4	96.7	42.8	24.7	14.4	6.8	4.0	0.9
Lifecycle 1 (90-10 to 50-50 MSCI World-Nom Bond starting after 20 years)	30.3	21.5	495.0	109.5	70.7	37.8	24.6	16.0	8.7	5.7	1.8
Lifecycle 2 (90-10 to 50-50 MSCI Chile-Nom Bond starting immediately)	34.8	33.5	902.1	164.0	94.3	42.8	25.1	14.9	7.1	4.3	1.0
Lifecycle 2 (90-10 to 50-50 MSCI World-Nom Bond starting immediately)	30.1	20.6	484.5	105.1	69.2	37.6	24.7	16.3	9.0	6.0	1.9
Final Income (Monthly)	140,260	117,068	2,840,192	585,203	356,569	176,660	107,320	65,781	32,555	19,895	3,730

Table 6. Simulation Results for Investment Strategies When Labor Income Stochastic and Correlated with Stock Returns
A. Inflation-Indexed Fixed Income Portfolio

	Mean	Std.Dev.	Max	99%	95%	75%	50%	25%	5%	1%	Min
Presented as Multiple of Expected Income In Final Year											
100% ILB	11.5	5.2	83.4	29.1	21.3	13.9	10.4	7.9	5.5	4.3	2.1
100% MSCI Chile	79.0	144.6	7654.6	625.1	275.9	85.5	38.4	17.7	5.9	2.9	0.4
100% MSCI World no-hedge	58.5	61.4	1960.5	298.8	165.9	71.7	40.4	22.8	10.4	6.0	1.2
40% MSCI Chile - 60% ILB	20.1	13.1	280.5	67.6	44.9	25.1	16.8	11.2	6.3	4.2	1.4
40% MSCI World no-hedge - 60% ILB	19.4	9.9	169.6	53.6	37.9	23.9	17.2	12.5	7.9	5.8	2.5
Lifecycle 1 (90-10 to 50-50 MSCI Chile-ILB starting after 20 years)	32.5	32.0	1001.2	156.5	89.9	40.1	23.1	13.4	6.1	3.6	0.8
Lifecycle 1 (90-10 to 50-50 MSCI World-ILB starting after 20 years)	29.1	19.7	464.4	99.6	66.2	36.3	24.0	15.9	8.9	5.9	2.0
Lifecycle 2 (90-10 to 50-50 MSCI Chile-ILB starting immediately)	32.3	30.9	979.9	153.2	88.0	39.9	23.3	13.7	6.3	3.8	0.9
Lifecycle 2 (90-10 to 50-50 MSCI World-ILB starting immediately)	28.9	18.6	374.7	94.8	64.0	36.1	24.2	16.3	9.3	6.2	2.0
Final Income (Monthly)	139,992	116,443	2,451,932	575,713	355,055	176,025	107,368	66,123	32,499	19,801	4,124

Table 6. Simulation Results for Investment Strategies When Labor Income Stochastic and Correlated with Stock Returns
B. Nominal Fixed Income Portfolio

	Mean	Std.Dev.	Max	99%	95%	75%	50%	25%	5%	1%	Min
Presented as Multiple of Expected Income In Final Year											
100% Nom Bond	13.6	8.7	163.6	44.6	30.0	16.9	11.4	7.7	4.4	3.0	0.7
40% MSCI Chile - 60% Nom Bond	22.4	17.6	376.1	88.2	55.1	28.1	17.7	11.1	5.7	3.6	0.9
40% MSCI World no-hedge - 60% Nom Bond	20.9	12.4	217.2	64.9	44.2	26.0	18.0	12.4	7.4	5.1	1.8
Lifecycle 1 (90-10 to 50-50 MSCI Chile-Nom Bond starting after 20 years)	34.9	37.4	1143.1	181.7	100.2	42.7	23.8	13.4	5.9	3.3	0.7
Lifecycle 1 (90-10 to 50-50 MSCI World-Nom Bond starting after 20 years)	30.2	21.5	572.1	109.4	70.3	37.9	24.6	16.1	8.7	5.7	1.9
Lifecycle 2 (90-10 to 50-50 MSCI Chile-Nom Bond starting immediately)	34.7	36.6	1214.9	178.1	98.9	42.5	24.0	13.6	6.0	3.5	0.7
Lifecycle 2 (90-10 to 50-50 MSCI World-Nom Bond starting immediately)	30.0	20.5	462.7	104.7	68.4	37.6	24.7	16.4	9.0	6.0	1.9