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Can Internal Swap Markets Enhance Welfare in Defined Contribution Plans?

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There is a worldwide trend to substitute defined contribution pension plans for defined benefit plans, which are typically indexed to wage or price inflation. A problem with this development is that participants in defined contribution plans have limited access or no access at all to inflation-linked assets, especially wage inflation-linked claims. This article demonstrates that the creation of an internal market that swaps equity-related returns for wage inflation-linked income streams helps to overcome the market incompleteness regarding wage-linked securities. The result is an improvement in the welfare of both younger and older defined contribution plan members.

Keywords: Defined Contribution Plan, Internal Swap Market, Life-Cycle Theory, Pension Fund, Wage-Return Swap, Wage-Linked Exposure

Implications of the Move to Defined Contribution Plans

The worldwide importance of individual defined contribution (DC) pension plans has grown substantially. This has come at the expense of the relative significance of social security and private sector funded defined benefit (DB) plans. DB plan benefits in retirement are based on the number of years of contribution and a reference wage, which is often related to an individual's own past wages. Moreover, during retirement, benefits may be indexed for a reference variable, for example wage growth or price inflation. Whereas DB plans are tightly linked to wages, pensions from DC plans depend on capital market returns. The sum of contributions plus investment proceeds on these contributions determines pension wealth at retirement. This pension wealth should ideally be converted into annuities (Yaari 1965; Davidoff et al. 2005).

Viewed from the perspective of life-cycle investment theory (Bodie et al., 2007), there are a number of disadvantages to this move away from wage-related pension benefits in favor of return-related benefits:

- Wage-indexed DB plans overcome the serious market incompleteness regarding the lack in supply of wage-indexed or price-indexed bonds.
- DB plans have different risk-return characteristics than DC plans, so a portfolio of retirement income provisions consisting of both DB and DC plans may be welfare-improving as retirement income does not rely on either wage growth of capital market performance but on a combination (Matsen and Thogerson, 2004).
- Wage-indexed DB plans organize intergenerational risk-sharing because pensioners can benefit from maintaining purchasing power. In funded schemes with well-organized intergenerational risk sharing, the young and the old may benefit from more risk taking in capital markets because of the extension of the investment horizon (Cui et al., 2010; Gollier 2008).

We propose the creation of an internal market of wage-linked swaps, where the aggregate growth rates of wages can be exchanged for risky (equity) returns.

The Idea of an Internal Swap Market

The traders in this swap market are young and old individuals who are saving, or have saved, for retirement income via DC plans. This internal market can be organized for workers who are covered by the same terms of employment including the pension plan, (e.g. a specific group of professionals such as physicians or lawyers). A one-year swap contract could be implemented with voluntary participation. Every year, contract terms would be renegotiable. We develop a life-cycle model to determine the risk premiums for different cohorts and consequently the optimal age-related exposure to such swaps, in addition to the conventional asset allocation.[1,2]

We show that the internal market of wage-linked swaps can be an ideal construction to achieve intergenerational risk-sharing between young and old plan members, and to simultaneously create optimal life-cycle exposures for all members. It also helps to complete the missing market of wage-linked securities, and to relax the borrowing constraints of young members. The largest welfare gains are achieved if employers require mandatory participation in these swap contracts over long periods (e.g. throughout one's career).

The remainder of this article describes a pension plan design with variable annuities. From there, it investigates whether or not the participants of different ages have incentives to engage in a return-wage swap arrangement. The conclusion is that younger and older workers likely prefer different levels of return-wage swaps, therefore creating trading possibilities for welfare improvement. A pricing protocol is developed which converts the incentives into the fair price of such a swap and the market clearing condition. The article concludes that this swap protocol could be the basis for a win-win outcome for both younger and older workers.

Pension Plan Design

We analyze a pension plan with a variable annuity structure that is offered to a group of employees. The plan members contribute a fraction of their wage income into the plan for every year of service. Contributions are used to acquire deferred variable annuities paying out during retirement. If the contributions are invested only in (nominal) risk-free assets, then effectively each unit of contribution buys a certain quantity of deferred annuity at the market nominal rate of interest.

Let $P_{t,x}$ stand for the contribution made at time t when a plan member is of age x, R^f for the nominal risk-free rate, and ${}_kp_x$ the survival probability. The equation below relates the contribution to the present value of a deferred annuity with a payment level of $\overline{\Delta B_t}$:

$$P_{t,x} = \sum_{k=1}^{100-x} \left(\exp\left(-kR_k^f\right)\left({}_k p_x\right)\overline{\Delta B_t} \right) \tag{1}$$

When the contributions for each year are invested in nominal riskfree assets, then income upon retirement is equal to the fixed amount of $\sum_{25}^{64}\left(\overline{\Delta B_t}\right)$.

In practice, the assets backing these acquired deferred annuities are often invested in the risky assets, so that the participants have prospect on earning (equity) risk premiums, given their risk appetite. We capture this by adjusting yearly the benefits from the variable annuities for the excess return of realized investment return over the risk-free rate. Let $\Delta\tilde{B}_{t,T}$ reflect the benefits with adjustments, at retirement T the bought deferred annuity in year t, $\overline{\Delta B_t}$ which amounts to:

$$\Delta\tilde{B}_{t,T} = \overline{\Delta B_t} \exp\left(\sum_{s=t}^{T} \left(R_s^{\,P} - R_s^{\,f} \right) \right) \tag{2}$$

where R_s^P is the return on the portfolio. Upon retirement, the total benefit paid out is:

$$B_T = \sum_{t=x}^{64} \Delta B_{t,T}, \qquad (T > t) \tag{3}$$

Investments are held in a broadly diversified portfolio of stocks and nominal bonds. Only plan members are exposed to investment risk. They are insured for diversifiable mortality risk (on an intra-cohort base).

Internal Swap Incentives

The collective portfolio of stocks and bonds may not be the optimal portfolio when one takes into account wage growth uncertainty. Life-cycle theory indicates that the total wealth of the younger cohorts consists primarily of human capital, whereas the older cohorts have a relatively large position in financial capital and a decreasing value of human capital. Adding wage-linked assets to the portfolio may be better from the perspective of risk diversification and wage inflation protection.

Young and old likely have opposite preferences as to wage-linked assets where they are available. The younger cohorts will probably prefer a short position in wage-linked assets as they are overexposed to wage growth risk, whereas the older cohorts will look for a long position in wage-linked assets to offset the high exposure to financial market risk. However the supply of the price inflation-linked assets is limited in financial markets and wage-linked securities are not yet available.

As younger workers are natural suppliers of wage-linked securities, older workers are natural demanders of these assets. In the next section we test whether young and old employees have incentives to trade wage-linked return for capital market return. We construct an internal market which is accessible to employees covered by the plan and these individuals trade wage-linked swaps.

We derive the preferred wage-linked positions by the various cohorts with help of the expression below, wherein α_x is the preferred holding of financial wealth in the available portfolio

of stocks and bonds, the complement $1-\alpha_x$ the preferred holding in wage-linked assets, and w_s denotes the rate of wage inflation.

$$\Delta\tilde{B}_{t,T} = \overline{\Delta B}_t \exp\left(\sum_{s=t}^{T} \alpha_x \left(R_s^{\ P} - R_s^{\ f}\right) + \left(1-\alpha_x\right) w_s\right) \quad (4)$$

Note when $\alpha_x=1$, then the adjustment in the value of the deferred annuities is purely driven by financial returns and when $\alpha_x=0$, then the adjustments are purely linked to wage growth. For the younger cohorts it might be that the preferred α is larger than one, $\alpha_x>1$, meaning they wish to acquire extra financial returns by shorting the wage growth exposure.

Employee Preferences

In order to explore the existence of incentives, we use a welfare measure, which is defined by the preferences of individuals. The benefits are in nominal terms. However, the participants have preferences in real benefits. During the working period, net-income is gross wage minus pension contributions $(Y_n^x - P_v)$. Upon retirement, income is equal to the payout of the benefits (B_{65}). The preference of the employee is defined by the expected utility of wage-deflated income. Individuals evaluate retirement income in a real framework deflated by wage growth.

$$U_{x\in[25,64]} = \max_{\alpha}\left[E_0\left[\sum_{n=1}^{65-x} e^{-\beta n} u\left(\frac{Y_n^{\ x} - P_n}{W_n}\right)\right] + E_0\left[e^{-\beta(65-x)} u\left(\frac{B_{65}}{W_{65}}\right)\right]\right]$$

where W_T denotes wage inflation index upon retirement:

$$W_T = \exp\left(\sum_{k=t}^{T} w_k\right)$$

Since the choice of the values of α has no impact on the before-retirement net-income, the preference can be simplified to the expected utility over retirement income. The optimization problem is equivalent to:

$$U_{x\in[25,64]} = \max_{\alpha} E_0\left[e^{-\beta(65-x)} u\left(\frac{B_{65}}{W_{65}}\right)\right] \quad (5)$$

The welfare level is measured by real certainty equivalent benefit (CEB). For employees, it is calculated by solving the following equation:

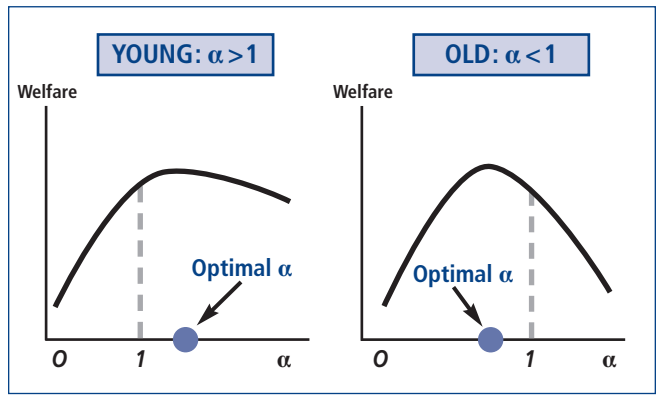
$$U_{x\in[25,64]} = e^{-\beta n} u\left(CEB^x\right) \quad (6)$$

Hence,

$$u\left(CEB^x\right) = \frac{CEB^{1-\gamma}}{1-\gamma} \quad \Rightarrow \quad CEB = \left(\left(1-\gamma\right)\frac{U}{e^{-\beta n}}\right)^{\frac{1}{1-\gamma}} \quad (7)$$

The illustrative CEB-α curve below illustrates the incentives of different age cohorts to swap. Younger workers do hold variable annuities in market portfolio ($\alpha=1$) but they might prefer more of them ($\alpha>1$). That is, they want to sell wage growth risk in order to buy additional asset returns. At the same time, older workers also hold variable annuities in market portfolio ($\alpha=1$), but they might prefer to hold less ($\alpha<1$). Thus they want to buy wage growth risk and to sell asset return.

Figure 1: Incentives of Swapping: Young and Old Members' Perspectives



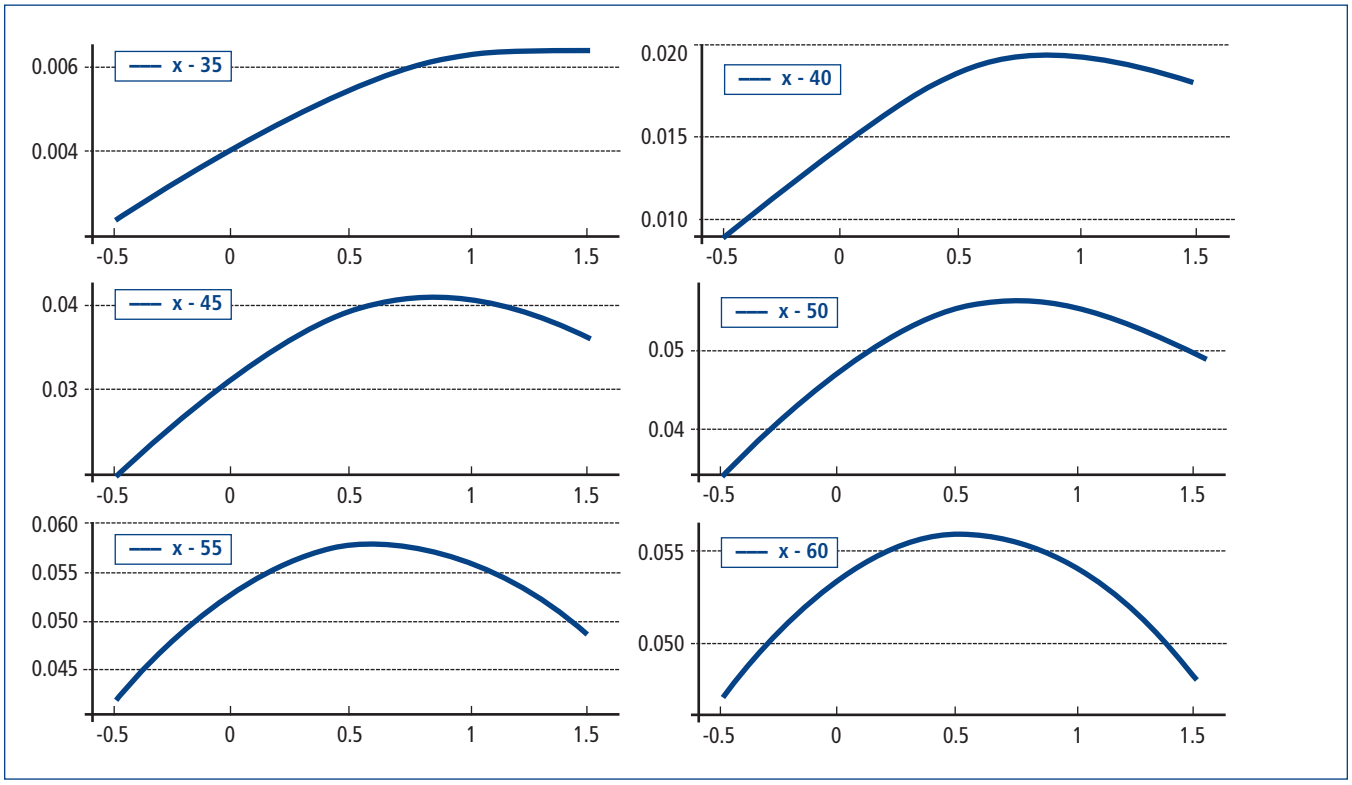
Source: Authors' illustration.

Actual Results

The results discussed below assume an economy with an equity premium of 5%, average nominal risk-free rate of 3%, average portfolio (60% in equities) excess return of 3%, and average wage growth of 2%. The volatility of equity returns is set at 15% per year and wage growth volatility at 1.5% per year. The correlation between wage growth and equity returns is a small but positive 0.1 With these assumptions, do participants have different preferences regarding their exposure to financial returns and wage growth? If so, do they have incentive to swap the financial returns and wage growth exposures with each other?

Figure 2 shows the different return exposures and the calculated welfare improvements for employees aged 35 to 60; the CEB-α curves are hump shaped. We see clearly the most preferred return exposure of the young is larger than that of the older cohorts. For instance, the 35-year-old prefers $\alpha=130\%$ exposure to return indexation and hence negative 30% in wage indexation. The 60-year-old and retirees prefer about 50% exposure to

Figure 2: The CEB-α Curve for Employees of Age 35, 40, 45, 50, 55 and 60*



Source: Authors' calculations.
** With assumed risk aversion γ=10. The maturity of the swaps equals the remaining working life (n=65-x).*

return indexation and 50% in wage indexation. This result is consistent with the life-cycle theory: younger cohorts prefer to be overexposed to financial returns because of their human capital. This can be seen from the benefit equation (4). Part of young employees' benefit accruals come from the to-be-earned salary incomes and therefore have a large position in wage growth and wage risk.

Older workers have a relatively small position in wage growth exposure compared to their financial wealth and they may benefit from selling return risk in order to increase wage growth return and risk exposure. For example, the 60-year-old individual prefers a portfolio of 50% in financial return exposure and 50% in wage return exposure. These figures indicate that it is possible to improve the exposures of different cohorts by setting up an internal swap market, which results in age-dependent indexation policy.

A Market-Clearing Mechanism

Although the above results are intuitive, a drawback is that the α parameter is fixed during the remaining working period of the young. With this condition, in a certain period of time, all future cohorts and current young members would demand more financial returns, but there will be little or no supply. Therefore, a scheme with fixed α is not sustainable. Thus we must make α age-dependent: making it decline with age. Our previous results will still hold in that there will still be incentives to swap. However, we now incorporate a market clearing condition to equalize the supply and demand.

Consider the case, for example, where there is more demand for wage-linked claims from the older cohorts than the total supply from the younger cohorts. To clear the market, younger workers must be compensated to motivate them to provide more wage-linked claims in exchange of extra financial risks. There are several ways of providing such compensation. One possibility is that the net suppliers invest the cash compensation into risky assets in order to boost their future retirement benefit payments.[3] We have shown above that, if wage-linked claims were available, the benefits could be:

$$\Delta B_{x,65} = \overline{\Delta B}_x \exp\left[\sum_{t=x}^{65}\left(\alpha_t r_t^e + (1-\alpha_t) w_t\right)\right] \qquad (8)$$

With positive compensation per unit of risk-taking (c>0) to boost future benefit payments, the risk exposure can be modified as follows:

$$\Delta B_{x,65} = \overline{\Delta B}_x \exp\left[\sum_{t=x}^{65}\left(\alpha_t r_t^e + (1-\alpha_t)w_t + (\alpha_t - 1)c\right)\right] \quad (9)$$

When α_t-1>0 the person acts as a net supplier and is compensated, and when α_t-1<0 the person is a net demander and pays for it. The compensation, c, is determined by a numerical grid search, jointly with the shape of α_x, so that the preference of each cohort is optimized, and the optimized welfare level is higher than, or equal to, the case with pure financial exposures.

We also incorporate a market clearing condition so that the sum of the total wage-linked claims offered by the younger cohorts equal the total wage-linked claims demanded by the older cohorts, in each period for the coexisting working participants.

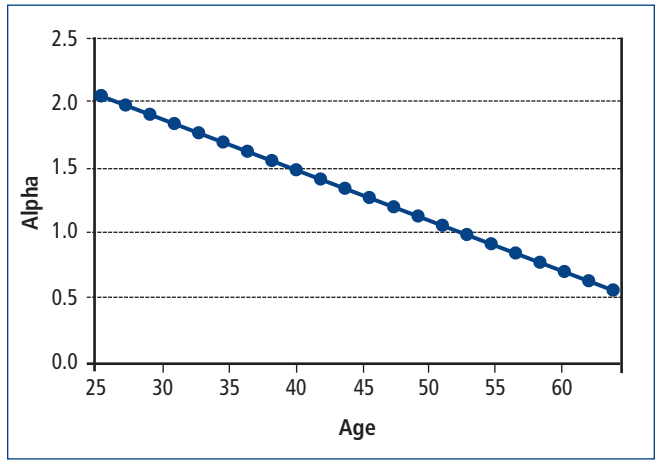
$$\sum_{x\in\{\alpha_x>1\}} L_x N_x (\alpha_x - 1) w_t = \sum_{x\in\{\alpha_x<1\}} L_x N_x (1-\alpha_x) w_t \quad (10)$$

where L_x denotes the asset under management per age cohort, and N_x denotes the population size of each cohort. Here we study a stationary situation where the cohorts are of equal size.

Findings

Figure 3 shows the pattern of α_x, which decreases with age. Prior to age 52, workers are suppliers of wage-linked claims and after age 52, they are receivers of wage-linked claims. The magnitude of the compensation is approximately five basis points per one percentage point increase of extra risk taking.

Figure 3: Degree of Swap



Source: Authors' calculations.

The resulting pay-off scheme is summarized in Table 1. Because of the decline of α_x with age, the expected total excess return from the variable annuity also declines with age. After age 52, the expected excess return is lower than the excess return of the financial assets. However, the older employees receive the desired less volatile wage growth. The last column shows the average supply (-) or demand (+) of wage-linked claims per age cohort, relative to the size of the total assets under management. Each year, the variable annuity participants have the opportunity to renegotiate whether to extend the internal swap for the next year.[4]

If the internal swap is able to continue operating, then the resulting welfare improvements for some age cohorts, relative to the welfare levels obtained without any swap (i.e., α=1 in Figure 2), are shown in Table 2. With appropriate compensation for risk, the internal swap market improves the welfare of the participants, especially the younger members. The older cohorts reach break-even at a reduced level of demand for wage-linked claims. These welfare gains could be reached through mandatory participation in the swap contract over extended periods of time (e.g. throughout workers' careers).

Table 1: The Pay-Off Scheme

Age	α	$\alpha * E[R^e]$	$(1-\alpha)E[w]$	$(\alpha-1)c$	E[Return]	Supply (-) or Demand (+)
25	2.1	6.2%	- 2.1%	0.53%	4.6%	- 0.001%
35	1.7	5.0%	- 1.3%	0.33%	4.0%	- 0.014%
45	1.3	3.8%	- 0.6%	0.14%	3.4%	-0.013%
50	1.1	3.3%	- 0.2%	0.04%	3.1%	- 0.005%
55	0.9	2.7%	0.2%	- 0.05%	2.8%	+ 0.008%
60	0.7	2.1%	0.6%	- 0.15%	2.6%	+ 0.029%

Source: Authors' calculations.

Table 2: Welfare Improvements at Implementation of a Swap Market with Continued Operation

Age	35	40	45	50	55	60
△ Welfare at implementation	9.2%	4%	2.5%	1.1%	0.4%	0%

Source: Authors' calculations.

A Win-Win Solution

There is a global trend to substitute funded DC pension plans for price-indexed and wage-indexed DB plans. However participants in DC plans have limited, or no access to inflation-linked assets, especially wage inflation-linked claims. But different age cohorts have different exposure to the wage growth potential captured in their human capital position. This creates the opportunity to trade wage growth for financial returns.

We show that the creation of an internal swap market helps to overcome the market incompleteness regarding wage-linked securities, and hence improves welfare for DC scheme members. We find the young are able to offset their high exposure to wage growth and increase their exposure to capital market return, and older workers replace full exposure to financial markets by a combination of wage and capital market returns. This reallocation of risk exposures over the ages is in line with the recommendations of life-cycle theory of personal finance.

Endnotes

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2. The valuation of wage-linked claims in incomplete market setting is discussed in De Jong (2008).

3. Another possibility is that the *net demanders* (e.g. older cohorts) pay a certain amount of cash to the *net suppliers* (e.g. the younger cohorts) up front for the future wage-linked claims. The net suppliers consume the cash compensation immediately.

4. The internal market might break down if certain cohorts do not have sufficient incentive to participate (e.g. due to mismatch between supply and demand, varying sizes of cohorts, etc).

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