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# Private versus Public Risk Sharing

## Should Governments Provide Reinsurance?

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# Private versus public risk sharing: Should governments provide reinsurance?

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**Abstract**

The paper examines alternative arrangements for intergenerational risk sharing in a small open economy subject to macroeconomic disturbances. Under certain conditions, private pension funds can provide substantial risk sharing across generations. Private risk sharing alleviates the burden on governments to provide insurance, but it is limited by mobility in the labor market and by the ability of corporate plan sponsors to default. Government has a role in correcting these limitations by providing reinsurance and it can enter insurance arrangements on behalf of future generations. Optimal reinsurance includes bonds indexed to longevity and to productivity.

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## 1. Introduction

While markets dealing with financial risks are well developed, markets for dealing with demographic risks and productivity risks are generally lacking. Pension funds play an important role in filling this gap. Defined benefit (DB) and hybrid DB/DC type occupational pensions can be regarded as insurance mechanisms that deal with just these types of risk. However, as corporations are increasingly exposed to competition nationally and internationally, their ability to make credible long-term pension promises may be declining.

What are the options for reform while maintaining the beneficial aspects of such pension contracts? Should the government take over some of the risks by providing insurance against long-term risks? One option is for the government to issue issuing index-linked bonds that have payoffs linked to longevity or to wage growth. Another option is to provide reinsurance to pension funds, either through customized contracts or insurance agencies, or through index-linked bonds. What forms of indexing are desirable or optimal? What are the consequences for the government portfolio?

The paper examines alternative arrangements for sharing risks is a stylized small open economy, which is subject to a range of macroeconomic disturbances. Labor productivity, the return to capital, and longevity are generally stochastic at the individual, national, and global level. The integration of capital markets and the mobility of labor may also vary, creating additional uncertainty. In principle, private pension funds can provide substantial risk sharing across generations and across countries (Ponds 2003; Teulings and de Vries 2006, Bovenberg et al. 2007; Gollier 2008; Cui et al 2009). Such private risk sharing alleviates the burden on governments to provide insurance.

However, governments have a role in allocating large long-run risks, in effect supplementing private risk sharing. The ability of traditional corporate pension plans to reallocate risk has declined as mobility and financial engineering erodes firms' and workers' ability to enter long-term contracts. Sectoral and industry pension funds face similar pressures

as mobility across industries is increasing. Efficient risk sharing then calls for a greater role of government. In summary, private and public risk sharing are complementary in a given setting, but substitutes when there are variations in the scope for private contracts.

A challenge for the future is that as international labor mobility is increasing, governments are less and less able to tie future generations into "social contracts" that share risk. This challenge increases the importance of finding efficient mechanisms that are based on voluntary agreements and not primarily on large tax-financed transfers, and it may shift the public-private tradeoff back towards private pension funding.

The analysis is tailored to the pension arrangements in the Netherlands, which has a three-pillar system with strong industry and sectoral pension funds (Bovenberg and Nijman 2008; Ponds and van Riel 2007). Pillar one is a basic subsistence benefit provided by government and financed on a pay-as-you-go basis. Pillar two consists of industry pension schemes, which are negotiated by employers and unions and are mandatory for all employees and employers in the relevant sector.[1] Such plans cover than 90 percent of the work force and are crucial for most middle-class pensioners to obtain an adequate income replacement in retirement. These occupational pensions are supported by independent funds that invest in capital markets. Pillar three refers to private savings, which has received relatively little attention and seems most important at the upper end of the wealth distribution.

The direct role of government pensions in the Netherlands is remarkably limited, both as compared to other countries and in relation to industry pension funds. Because the government's role is viewed as supplemental, a case for government reinsurance must rest on an argument that private pension funds cannot efficiently provide such insurance on their own. A central question of this paper is therefore under what conditions current Dutch pension arrangements are efficient, and under what condition additional government support may be appropriate or even necessary.

[1] For brevity, I will refer to independent multi-employer pension funds as industry pension funds. This includes sector and occupational funds. Many findings also apply to single-employer funds, which are regulated to provide at least the same benefits.

Three fundamental arguments justify government insurance or reinsurance. The first is based on a mobility constraint, which refers to the ability of workers to exit a pension plan that tries to collect payments from workers in excess of future benefits. Settlement is essential for insurance. But ex post, a demand for settlement acts like tax and induces avoidance. Given laws against forced labor, private plans cannot contractually prevent employees from leaving. Hence their ability to "tax" members is limited by the opportunity cost of exit. The government can overcome this limitation by making the young responsible, through the tax system, for insurance contracts or contingent bonds sold to older generations. Because optimal retirement benefits are partially indexed to wages and longevity, optimal insurance takes the form of wage- and longevity-indexed contracts or bonds.[2]

A second argument is based on incomplete markets. Though the merits of completing incomplete markets seem obvious, the underlying issues are default and the cost of collateral. Pension promises must be backed by assets or by a plan sponsor—a firm or industry. Incomplete markets are unproblematic if a plan sponsor can fill the gaps between optimal pensions and available assets. However, corporate backing is credible only if the plan sponsor is adequately capitalized or if the promises are sufficiently collateralized. Rapid technical change, industrial restructuring, and advances in financial engineering have eroded the ability of firms to offer their equity capital as collateral; dedicated collateral is costly. Wage- and longevity-indexed bonds would help because a reduced mismatch between typical plan assets and liabilities would reduce a plan's dependence on corporate sponsors.

A third argument is based on imperfections in risk sharing abroad. If most foreign countries fail to integrate young and unborn generations into risk sharing arrangements—through pension plans or by their governments—the systematic risk that priced in world financial markets largely reflect risks facing the old generation. Capital and longevity risks

[2] Note that this policy is optimal even if financial markets are complete. Though retirees can then find insurance in the market, the inability of workers to participate implies, in the absence of policy intervention, a welfare loss for workers and an inefficiently low private supply of insurance desired by retirees. Put differently, the problem can be interpreted as resulting from the limited liability of the young, who do not own financial collateral and cannot commit to provide future labor effort (see Bovenberg and van Ewijk, 2010).

are priced, but not wage risk. This suggests that protection against longevity risk would sell at a premium and protection against wage risk could be purchased at low cost. Both should be welfare improving for government acting in the interest of future generations.

Government intervention in risk sharing can in principle take many forms. In the Netherlands, where insurance through private pension plans is well established and generally well-working, interventions most practical and cost effective if they occur through the regular tax system and by providing suitable financial instrument to industry pension plans. The latter is reinsurance in the sense that the government provides instrument for funds to insure themselves, which enables them to provide optimal insurance to their members; but (apart from regular taxes) government does not directly insure employees.[3]

The paper is organized as follows. Section 2 introduces alternative arrangements of public and private risk sharing and identifies key issues for the analysis. Section 3 presents a stylized model of pension funding that provides conditions for efficient intergenerational risk sharing and discusses conditions under which young and future generation can be included in private risk sharing. Section 4 examines limitations to private risk sharing due to increasing labor mobility and financial engineering, and how government reinsurance can alleviate these problems. Section 5 comments on limitations to government risk sharing in a world with increasing international mobility, and on potential remedies. Section 6 concludes.

## 2. Public and Private Risk Sharing: The Role of Private Pension Funds

Pension financing everywhere faces two principal challenges. The first one is to ensure a sufficient level of funding for retirement. In all developed economies, this is accomplished at least in part though a public pension system. The second challenge is to deal efficiently with the unavoidable economic and demographic risks. The two challenges are linked because lack

[3] By comparison, the U.S. government guarantees certain individual pensions through the PBGC. There is no comparable agency in the Netherlands. The U.S. arrangement seems much less efficient; it is activated only in case of insurer default, it provides insurers no help in managing aggregate risks, and the pricing does not adequate adjust for risk.

of insurance jeopardizes funding adequacy and because public tax-transfer systems invariably reallocate risk between contributors and recipients.[4]

Three fundamental risks are the focus of this paper: shocks to productivity, which are reflected in wages; shocks to the return on capital—reflecting mainly obsolescence but also shocks to productivity—and shocks to longevity (or life expectancy).[5]

A simple intuition about the optimal allocation of risk is that Pareto efficiency calls for risk pooling, which means that aggregate risks should be shared by everyone (Bohn 2006b). Without insurance, workers would exposed to labor productivity risk. Retirees would exposed to return and longevity risks. Hence efficient risk sharing means shifting wage risk from workers to retirees; shifting rate of return risk from retirees to workers; and shifting longevity risk from retirees to workers.

Efficient risk sharing is more complicated when aggregate disturbances are correlated over time and across variables. Permanent shocks impact current and future generations equally whereas temporary shocks have a direct impact only on the living generations. Moreover, if labor and capital are complements in production, workers and retirees start off with correlated exposures to the underlying dynamics of total factor productivity. Empirical work suggests that wages and capital incomes are unit root processes with a common stochastic trend. (See Baxter and Jermann 1997; Bohn 1999; Benzoni et al. 2007.) This is consistent with balanced growth models where stochastic productivity growth generates a common stochastic trend in wages and capital incomes. However, the value of capital fluctuates relative to capital income, so there are independent fluctuations in asset returns

[4] One should also keep in mind that risk is reallocated through the general tax system, and that a robust risk sharing mechanism must not create additional risks through instabilities in the risk sharing mechanism itself (discontinuity risks).

[5] This follows Ponds (2003) and Bohn (2006b). Ponds identifies the same three risks as the main sources of uncertainty. Bohn considers uncertainty about birth rates and about medical spending needs in addition. Birth rate uncertainty is a main driver of fluctuations in capital-labor ratios, wages, and returns to capital. But in an open economy, factor returns are determined by the world capital-labor ratio, which is exogenous to a small economy. For this paper, wages and returns are simply treated as considered exogenous, without attempting to investigate the sources of their fluctuations. Because in Europe universal health insurance is well established, medical expense risk is deserves less emphasis than in the U.S; one may reasonably assume that medical risk is shared efficiently by the government. An extension to signals about future productivity might be interesting for future work. Anticipated longevity shocks are examined in Bohn (2001) and disregarded here for simplicity.

relative to the productivity trend—valuation risk for short (see Bohn 1999, 2009), which may be interpreted more fundamentally as stochastic obsolescence. In this setting, efficient risk sharing still calls for shifting wage risk from workers to retirees, but only to the extent that workers' initial exposure exceeds retirees' exposure through capital income. Also, the efficient allocation of return risk requires a separation of capital income risk and valuation risk. Because the former is highly correlated with wages, only the latter should be shifted from retirees to workers.[6] To streamline the discussion of alternative risk sharing mechanisms, I will use the simple terms wage risk and return risk to refer to workers' and retirees' principal risk exposures.

To understand the value of risk sharing institutions, it is instructive to start with an economy where the government does not intervene in retirement savings, and then add relevant institutions. In a purely private system, everyone would have to save for his or her own retirement. The government would not be involved. An immediate problem is that those too poor to save and those unlucky in their investment strategies would be destitute in old age. A natural response is a basic means-tested welfare benefit in old age. However, such a benefit would likely destroy saving incentives for workers with low earning. Low earners would be better off by saving nothing and relying on welfare than to save for retirement. This logic justifies mandatory contributions. A Beveridge-type pension system with mandatory contributions to finance a flat, subsistence-level retirement pension is arguably the minimal government intervention in a civilized society.[7]

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[6] Note that Benzoni et al. (2007) come to different conclusions about workers' optimal exposure to stock market risk—notably, that young workers should have zero exposure of to the stock market. Whereas Bohn (1999) estimates a cointegrated system with capital income, stock prices, and wages, Benzoni et al. (2007) estimate only capital income and wages and they *assume* a stable price-dividend ratio. The latter is grossly inconsistent with empirical data, casting doubt on the conclusions. Bohn (1999) shows that valuation risk—the risk generated by fluctuations in equity prices relative to capital income—is a major source of volatility of equity returns, and this should be shared with workers. Implicitly, all disturbances are treated as unanticipated. These assumptions are reasonable at a generational time scale (see Bohn 2009) and convenient to avoid a proliferation of state variables.

[7] In comparison, means testing would raise much broader issues of optimal taxation. Mandatory savings are simpler and they correct the moral hazard problem that motivates the intervention.

In an economy with such minimal public intervention, individuals at the bottom end of the income distribution would rely on public pensions. Everyone else would save individually in financial markets. The aggregate supply of financial assets would consist of claims against the capital stock. In equilibrium, retirement savings would be invested in risky capital assets and thus be subject to considerable rate of return uncertainty. Notably, savers would be full exposed to fluctuations in the profitability of capital, the risk of obsolescence, and they would be unprotected against uncertainty about their length of life. Annuities might be available, but likely subject to adverse selection. Moreover, the insurance companies issuing annuities would be owned by the same generation that needs insurance; hence there would be no insurance against aggregate longevity risk.

One should acknowledge that there may be some private risk sharing between narrowly defined cohorts (e.g., the age-60 cohort may hold less equity and more corporate bonds than the age-55 cohort.) On a broad time scale, however, neighboring cohorts are subject to essentially the same shocks over their lifetimes and therefore have much less scope for risk sharing than temporally more distant cohorts. For clarity, it is instructive therefore to abstract from the fine structure of age cohorts and treat prime-age workers who save for retirement as a single generation (as detailed below). To a first approximation, this generation of retirement savers must hold the capital stock. In addition, one may consider private risk sharing via altruistic bequests, but empirical evidence suggests that dynastic risk sharing is rather weak (see Altonji et al. 1992).[8]

International risk sharing would help to insure country-specific components of risk (see Shiller 1997). But international insurance is challenging, because it may be difficult to collect on large settlements due from foreigners—say, in response to a large negative domestic productivity shock—unless the claims are collateralized, which is technically

[8] Private risk sharing via altruistic bequests might play a greater role in countries where a substantial share of national wealth is held by small number of very wealthy families. Calibration results in Bohn (2006a) suggest that inherited wealth is important in some developing countries, but less relevant in developed economies with aging populations. Moreover, risk sharing between the very wealthy and the rest of the population is likely incomplete.

difficult. Shiller's macro markets still do not exist. Moreover, the main risks are likely correlated internationally. Longevity is driven in part by medical innovations that are accessible worldwide. Similarly, labor productivity and the obsolescence of capital are driven by innovations that are shared internationally, at least among the technologically leading economies and especially at the long time horizons relevant for pensions. Even non-technological shocks are propagated internationally, e.g., financial crises. Thus the major macroeconomic risks are best interpreted as global risks factors.

A second layer of public intervention arises through the general tax system. Interest and dividend incomes are commonly included in the tax base for income taxes, and capital gains are included in many countries. This tax treatment creates strong disincentives to save for retirement because returns to savings would be taxed repeatedly (Diamond 2009). When interest, dividends, and capital gains are taxed in nominal currency units, effective real marginal tax rates can easily approach or exceed 100 percent. This problem provides a basic motivation for setting up separate institutions for pensions savings. The segregation of saved labor income from other wealth allows a positive discrimination—encouragement—of "meritorious" retirement savings as compared to, say, inherited wealth.

Retirement contributions are commonly exempted from income taxes. The payouts are treated as taxable income. This tax treatment implies that total returns on retirement savings are shared in proportions of "tax rate" to "one minus tax rate" between the government and retirement savers. Because fluctuations in tax revenues are likely recovered over time from taxes on many cohorts of taxpayers, the effect is an intergenerational sharing of total return risk. Moreover, taxes on compensation are effectively deferred to the extent that they are diverted into retirement, which—ceteris paribus—raises the government debt and provides safe assets for retirement savers.[9]

The United States comes close to exemplifying a "nearly private" system of this kind. DC retirement plans are now prevalent in major corporations. They assign essentially no risk-

[9] Similar risk-spreading effects arise through consumption taxes and through corporate income taxes.

sharing role to companies and are best interpreted as pure tax shelters. Though U.S. social security provides wage-linked benefits, the linkage decreases with income and provides insufficient retirement income for the vast majority of wage earners.

A polar opposite is a system of proportional income replacement, e.g., as in Germany in the tradition of Bismarck. In such a system, pensions are wage-indexed and generous enough that most workers do not need supplemental savings. Wage indexing means that the incomes of workers and retirees are subject to the same disturbances—notably shocks to labor productivity. Assuming a relatively stable savings rate, which is empirically plausible, this system yields a high correlation of workers' and retirees' consumption opportunities. Such pooling of consumption risk is the hallmark of efficient risk sharing (Bohn 2006b, 2009). If there is a maximum contribution level, the system does not fully cover high-earners; the important difference to a Beveridge type system is that the middle classes are fully covered.

Left out of this description is a discussion of who bears capital risks. Implicitly, capital risks are either concentrated in a separate class of entrepreneurs, who are perhaps more risk tolerant than wage earners, or spread through the tax system in ways that are not entirely transparent. Another question is how taxes and benefits should respond to changes in longevity. This is now addressed in some systems, e.g., in Sweden after recent reforms, but often left unspecified, e.g., in Germany.

Tax-transfer systems can in principle share risk efficiently (Bohn 2006b, 2009). One must worry, however, that financial imbalances in a government-run system are resolved through political processes that are not transparent and not predictable ex ante, which may lead to new distortions and inefficiencies. It is worth examining therefore if the same risk sharing can be implemented in a less government-controlled manner.[10]

[10] A technical appendix shows more formally that a number of alternative risk sharing mechanisms are equivalent under suitable conditions. This suggests that an assessment of various frictions is central for comparisons, notably transactions cost, information problems, and commitment problems.

A promising third option is a pension system centered on pension plans with defined benefits sponsored by private employers.[11] The Dutch pension system is a leading example, and it motivates the focus on employer-sponsored systems and their potential in this study. Because the incomes of companies and their employees add up to national income, corporate pension plans have the potential to allocate national income efficiently, and in particular, to share both wage and capital incomes risks. Because firms are profit oriented, one might expect them to be more effective in managing pension and in discovering gains from trade between shareholders and workers than a government bureaucracy, and less subject to political pressures. Because a pension plan includes multiple generations of participants—including shareholders who are likely older than most active workers—efficient pension arrangements may include intergenerational risk sharing. In summary, private pensions have a *potential* for sophisticated reallocation of risk across multiple parties, but one must examine carefully under what conditions the potential can be realized.

Conceptually, a key challenge to risk sharing in pension funds is limited commitment. All insurance requires a settlement after an insured event has occurred, and this requires commitment. The problem has several dimensions. First, workers are typically supposed to make extra contributions when labor productivity is unexpected high, when capital held by retirees is unexpected devalued, and/or if retirees live unexpected long. But workers can always quit if they are paid less than their marginal product in alternative jobs. In the limit, if there was no attachment of workers to their jobs, the allocation of risk with pension funds would reduce to a laissez-faire allocation with no intergenerational sharing. Second, workers expect to contribute less if the opposite contingencies are realized. But in a competitive environment, firms can terminate workers who demand more than the current marginal product of labor. Third, firms have the option to declare insolvency. Thus whenever a pension

[11] To be specific, a defined benefit (DB) pension is an promise by a plan sponsor to pay benefits according to an explicit formula or indexation rule. (A "hybrid" plan would be DB in this sense.) This is in contrast to a defined contributions (DC) plan that gives retirees a claims on assets but not an enforceable claim against a sponsor. Not part of the definition is to what extend pension risk is retained by the sponsor or transferred to markets or to other (usually younger) plan members.

commitment to retirees is less than fully funded, firms have an incentive to avoid responsibility, e.g., by paying out the firm's value as dividends or through share repurchases, or by reorganizing their operations in other ways that reduce the ability of pensioners to enforce their claims. Even without intentional avoidance of responsibility, the limited liability of shareholders places an upper bound on pension commitments.

Regulations that mandate overfunding – a "buffer" above full funding – are a common solution to the insolvency threat. Overfunding is an attractive solution under idealized conditions—when there are no intermediation cost—but likely costly under realistic conditions. Moreover, a fund may have to be vastly overfunded to guarantee funding without recourse to the plan sponsor under all circumstances.

Thus it is not obvious to what extent pension funds can deliver on promises to share risk. As noted by Bulow (1982), these commitment problems cannot be dismissed by reference to contribution formulas that appear to make employers and employees jointly responsible for funding imbalances. Employment decisions are based on total compensation. In a competitive labor market, a company that, say, requires higher contributions from young workers to compensate for a pension shortfall must compensate for this "tax" by paying a higher salary. Cash salary plus pension accruals should add up to the marginal product of labor even if the stated contribution rate differs.

A systematic analysis of risk sharing in pension funds must disentangle the multi-faceted relationship between retirees, current workers, future workers—individually and acting collectively through unions—their employers—individually and collectively—and the government. In the literature, different assumptions are made about these relationships.

One the one side, Bulow (1982) assumes competitive labor markets, which reduce pension plans to a contract between each employer and his or her employer. Funding ensures that employers keep their commitments to intermediate risks on behalf of their workers. If a fund has no ability to tie workers to the firm, there is no intergenerational risk sharing. More

generally, Allen and Gale (1997) explain why market competition can constrain financial institutions in a way that makes risk sharing impossible.

On the other side, a substantial European literature examines institutional arrangements where participation in a pension fund is mandatory. Ponds (2003) and Teulings and de Vries (2006) lay out the general issues. Both emphasize that mandatory participation is essential to commit future generations to share risk in pension funds. Intergenerational risk sharing means that a generation receives net payments in some states of nature and must make net payments in other states of nature. Young individuals entering the workforce are naturally reluctant to participate in an underfunded plan that will require net payments to regain solvency. But if the underfunding arises in the context of an ex ante efficient funding plans, risk sharing is impossible unless participation can be enforced when net payments are due. A key difference to many other countries—notably the U.S. and U.K.—is that the regulatory environment in Netherlands favors mandatory industry and sectoral pension funds.

Several papers in the European literature have examined quantitatively how different rules for pension contributions and benefits influence the allocation of risk across generations and the division of the resulting gains in social welfare. Teulings and de Vries (2006), Cui et al (2009), Gollier (2008), and Bovenberg et al (2008) all examine overlapping generations models with each generation living for 55 annual periods. Hybrid plans mixing DB and DC elements are found to share risk flexibly. Teulings and de Vries (2006) show how risk sharing is improved by the inclusion of young cohorts prior to their entry in the workforce.

Several recent papers discuss systemic changes in Dutch pension plans since the 1990s; see Ponds and Van Riel (2007), Kortleve and Ponds (2009, 2010), and Van Ewijk (2009). Funding ratios have declined sharply in response to the stock market declines in 2001-02 and in 2008-09. These large declines apparently exceeded the pension funds' capacity to allocate risk according to pre-planned formulas. By agreement between unions and employers, benefit formulas have shifted since 2000 from DB to hybrid, and from final wage to average wage indexing—suggesting a burden-shifting onto the young. In addition, Dutch

regulators have imposed increasingly stringent funding rules, now requiring a significant overfunding of promised nominal benefits. This contrasts sharply with the U.S., where underfunding is common.

It appears the 2008-09 financial crisis had different effects across cohorts than the 2001-02 recession. Van Ewijk (2009) provides an insightful case study of how the Dutch pension system responded to the 2008-09 financial crisis. He finds that the burden of pension adjustments fell primarily on retirees (age 60+) and prime-age workers (about age 40-60), largely due to reductions in indexed benefits. The impact on younger adults (age 20-40), due to higher contributions, was also negative but smaller. These findings suggests that risk sharing was only partial and that the young did not bear a disproportionate burden. One may wonder why the 2008-09 shocks triggered such different responses. One possibility is that the 2008-09 shock is considered much more damaging to the labor productivity of the young—but this question remains unresolved.

Mandatory participation can be established either by law or regulation, by collusive agreements between employers, or by agreements between employers and unions. Either way, it gives private pension funds an ability to tax or subsidize entering cohorts that is conceptually equivalent to a government's ability to tax and subsidize future generations. Given the powers of taxation, ante efficient risk sharing is feasible—subject only to the same tax avoidance incentives that also complicate public risk sharing. Thus a reliance on mandates and similar governmental powers blurs the distinction between private and public pension plans and between private and public risk sharing.

The role of employers is secondary in the Dutch literature. Teulings and de Vries (2006) abstract entirely from employer involvement and focus on risk sharing between different cohorts of employees. According to Ponds (2003), employers and employees typically share contributions in fixed proportions, which gives employers a stake in the plan. The equity of a firm that contributes to a pension plan may be owned by others pension funds or even by the same funds to which the firm contributes. The result is a complex web of cross

holdings that makes net exposures difficult to ascertain. In addition, one must doubt that changes in pension contributions would have no impact on current compensation (wages net of pension contributions) would be unaffected by pension contributions. Thus the role of employers is unclear.

The next section sets up an economic model to examine the ability of private pension funds to share risk under different assumptions about the competitive and regulatory environment.

## 3. Optimal Risk Sharing with Industry Pension Plans

This section presents an overlapping generations model with industry-based pensions. The model describes an idealized setting in which such pensions are efficient in the sense that they yield optimal intergenerational risk sharing with a minimal degree of government involvement. Subsequent sections will examine limitations.

A typical life cycle can be divided into three phases – an education and training period, a work period, and a period of retirement. Education is usually subsidized by the government. Income from work is taxed to finance educations, retiree benefits, and general public services. Retirement is financed at least in part though a mandatory pay as you go public pension system. Thus private risk sharing occurs "on top of" the risk sharing implied by the public tax-transfer system.

### *3.1. Individuals*

To obtain economic insights, consider a stylized model that captures the essence of retirement. Individuals live for three periods. In the first period—youth, no economic activity takes place except education. The cost of education is inessential here; assume for simplicity that young cohort's cost of living are included in parental consumption and that education is provided by the government and/or parents at negligible cost.

In the second period of life—working age—everyone works. Assuming economy is "small" and open. The marginal product of a labor unit in period $t$ is exogenous and can be represented by a wage $w_t$.[12]

In the third period of life—retirement—individuals do not work and live off working-age savings, public transfers, and pensions. Individuals have increasing and concave preferences over second and third period consumption. Assume marginal utility is infinite at zero consumption, so retirement financing is an essential task. To capture changes in longevity, let $\lambda_t$ denote the (fractional) length of retirement, which may be uncertain and variable over time.

Every period, a new generation of children is born—an exogenous number, large enough that behavior is competitive. The country's population at time $t$ consists of the three generations that overlap in their life cycles.

A parsimonious way to think about financial markets is in terms of a pricing kernel and state-contingent claims. All real or financial assets and liabilities can be interpreted as portfolios of state-contingent claims (Arrow securities). The state of nature is defined by the history of the world up to time t, denoted $h_t$. The period-t price of a security with unit payoff in state $h_{t+n}$ can be written as product of the conditional expectation of the state and a pricing kernel $m(h_{t+n} \mid h_t)$. In a small open economy, the pricing kernel is exogenous and determined by international financial markets.[13] For now, assume financial markets are complete and frictionless. This means that claims against all states of nature can be traded without cost.

Individuals maximize expected utility subject to the given wage and the given pricing kernel. Working age consumption $c_w$ equals $w_t$ minus savings and taxes. Retirement income

[12] For clarity, assume everyone in a cohort earns the same wage. Though the arguments here apply applicable for wide a range of income levels (except perhaps at the extremes), cross-sectional heterogeneity would be a distracting complication.

[13] One can think of histories or states as generated by a sequence of shocks. History $h_{t+n}$ encompasses $h_t$ plus all new information in period- (t+n), notably about productivity, asset values, and longevity.

equals the return on savings plus government transfers; it must finance consumption $c_r$ for a period of length $\lambda_t$.[14]

A key issue is at what time individuals can first enter financial and insurance markets. Standard overlapping generation analysis assumes individual become economically active when they start to work. In the stylized three-period setting, this means workers can buy a portfolio of state-contingent claims to finance their retirement. The optimal portfolio aligns the marginal rate of substitution between work and retirement (MRS) with the pricing kernel:

$$MRS_{w,r} = \frac{MU_r(c_{rt+1}(h_{t+1}))}{MU_w(c_{wt}(h_t))} = m(h_{t+1} \mid h_t) \tag{1}$$

for all states of nature $h_{t+1}$, where $MU_r$ and $MU_w$ denotes marginal utilities over consumption in retirement and working age, respectively. A simple proof of (1) is by contradiction: If marginal utilities were misaligned, utility could be increased by consuming more conditional on a history with higher marginal utility and reducing consumption conditional on another history by an amount that, under the pricing kernel, has the same present value in the prior period.

Condition (1) disregards taxes on income from interest, dividends, and capital gains. Implicitly, retirement savings are assumed tax-sheltered, which is reasonable assumption in relevant applications. Condition (1) applies not only in a laissez-faire setting with untaxed individual savings, but also in setting with DC pensions—even including infra-marginal government pensions—and in optimal actuarially-fair DB plans where members enter during working age.

Pareto efficient risk sharing requires that the marginal utilities of *all* generations be aligned with the pricing kernel for *all* periods and *all* states of nature. Notably, the marginal utility of workers entering in period t should be proportional to $m(h_t \mid h_0)$, where time zero is an arbitrary stating period.[15] Because workers cannot insure themselves against disturbances

[14] To the extent that individual mortality is stochastic, this implicitly assumes access to fair annuities. Risk sharing implications of imperfect annuities and resulting accidental bequests are discussed in Bohn (2001).

[15] An implication is that marginal utilities of different cohorts must aligned with each other, a condition that applies even without an exogenous pricing kernel. Following Bohn (2009), efficiency refers to ex ante Pareto efficiency conditional on initial resources (see appendix for a formal exposition).

that are already known at the time they start working, Pareto efficiency is generally violated in the standard OG model. Put differently, there is no private risk sharing across generations.

This imperfection motivates are role for government. One can show that government can use state-contingent lump-sum taxes and transfers to shift resources across time and histories in a way that perfect aligns marginal utilities (Bohn 2009). That is, fiscal policy can achieve perfect risk sharing. The government's task is challenging in practice, however, because optimal state contingent taxes and transfers must compensate for all shocks to wages and to the return to savings, for all savings responses to shocks, and for all fluctuations in consumptions needs due to changes in longevity. This may be feasible in theory but difficult in practice.

*3.2. Firms and Pension Plans*

Assume production is organized in multiple firms or industries, each of which requires distinct occupational skills. Ideally, there is a perfect correspondence between industries—from a firm's perspective—and occupations—from the employee's perspective. Firms combine labor and capital to produce output. They hold capital between periods and they maximize profits.

Each young individual chooses an occupation (hence industry) and acquires the necessary skills. In working age, the individual either enters this industry, or the individual may switch industries. Switching industries and firms may incur a cost of reduced earnings and/or expenses for retraining.

Competition between firms and industries in this setting includes competition over compensation packages. If capital income outside of pension plans is taxable, every employer should offer at least a DC plan, which gives employees access to tax sheltered savings of their own choosing. DC plans have negligible cost to the employers and they are valued by employees, who will prefer employers that offer such pension plan.

Alternatively, a firm can offer a DB plan (or hybrid).[16] If multiple firms in each industry compete for employees and if there are no switching cost within an industry, a single-company DB plan cannot do better than a DC plan. No firm can pay entering young workers less than their marginal product. This precludes risk sharing between entering young and retiring older workers. But without intergenerational sharing, workers themselves can replicate any state-contingent income stream in retirement at a cost no higher than the firm would incur in funding the same income stream within a DB plan. One might quibble if higher management cost and realistic market incompleteness might DB an edge. Since a DB plan invariably involves credit risks and allows less individual choice than a DC plan, it is difficult to find a compelling argument for single-company DB plans in this setting.

If there are switching cost, firms and employers are facing an imperfectly competitive environment. However, employers still have an incentive to attract new employees by promising competitive career compensation. Workers may also be represented by labor unions, which would strive to protect employees from the (post-entry) monopoly power of employers. Importantly, switching costs serve as a commitment device and they imply that career employment is efficient. This commitment creates an opening for private intergenerational risk sharing that does not rely on governmental powers. By offering a DB pension plans with state-contingent contributions, a firm can offer insurance to entering workers against shocks realized during their work life. A pension plan is optimal if it aligns the marginal utility of workers in a period (t) with the pricing kernel from the previous period (t-1),

$$MU_w(c_{wt}(h_t)) = m(h_t \mid h_{t-1}) \cdot \mu(h_{t-1}) \tag{2}$$

where $\mu(h_{t-1})$ is a (t-1)-dated proportionality factor. The ability of individual firms to insure workers is limited by the cost moving to a new employer and the cost of terminating the worker. These costs are likely small for separations within an industry.

[16] For brevity, the label DB is used for "pure" DB plans and for hybrid plans with DB elements. For purposes of this paper, it is not essential if pensions are a combination of a DB plan indexed to longevity and wages plus a separate DC plan invested in stocks and bonds, or a unified hybrid plan.

Industry pension plans promise a major improvement over single-employer corporate pensions because switching cost are—almost by construction—higher across industries than across firms that offer similar jobs. For a plan to satisfy condition (2), the required worker contributions must be less than the switching cost in all states of nature. This suggests that industry pension plans are most robust if they cover all jobs that are easily substitutable with each other. The main vulnerability is with respect to large negative shocks that would overtax workers' willingness to stay and contribute.

Optimal DB pension plans must also provide benefits to retirees that ensure condition (1) in all periods. If (1) and (2) hold, the marginal utilities of worker and retirees are perfectly aligned. Firms operate on goods and financial markets to maximize their present value under the pricing kernel. Thus all intertemporal trading opportunities between workers, retirees, the firm, and financial markets are fully exploited. If markets are complete, one may assume without loss of generality that pension plans are fully funded and hold assets that match their liabilities; there is no need for corporate plan sponsors to bear risk, and hence no default risk.

Industries must compete for new workers. Hence they cannot insure youth against shocks or events already know at the time of entry. Formally, marginal utilities of period-t worker do not respond proportionally in response to shocks realized in or before period t-1. This is key limitation of industry pension funds with voluntary entry. Risk sharing with industry pension funds is more efficient than risk sharing in the standard OG setting but not fully Pareto efficient.

Note that optimal DB pensions much simplify the government's problem of designing optimal policies. Because retirees share risk with workers, Pareto efficiency can be achieved without state-contingent retirement benefits and without state-contingent debt. Instead, one may assume without loss of generality that the government imposes state-contingent taxes only in working age and that government liabilities are simple securities such as default-free bonds. To smooth out fluctuations in marginal utilities across cohorts, it suffices to change the level of debt over time. (Formally, the optimal debt policy would align the factors $\mu(h_{t-1})$

with the pricing kernel.) Compared to a setting without private intergenerational risk sharing, the government's task of implementing efficient risk sharing is partially privatized. This avoids both the risk sharing inefficiencies of laissez-faire and the inefficiencies of a complicated "big" social welfare system that attempts to share all life risks through the government.

There is a monetary aspect to risk sharing with public debt. Nominal government debt can be viewed as a claim contingent on inflation. In a setting without private risk sharing, nominal debt held by retirement savers is a policy instrument that can be used to provide insurance to retirees.[17] The debt service required of succeeding generation would be similarly contingent on inflation and implement risk sharing across generations. In a monetary union or under strict inflation targeting, inflation is not available as policy tool. The returns on government debt are effectively exogenous (assuming no default). For members of the Euro zone, simplicity in debt policy is therefore a relevant practical advantage.

The improved efficiency of occupational pensions over ordinary corporate pension plans comes at a cost of raising questions about collusion and about corporate versus governmental powers. Firms in an industry collude by offering a common pension plan. Workers would have a credible threat to quit if new companies were to enter an industry without joining the pension plan. Maintaining a stable base of pension contributions likely requires governmental mandates or legal sanctions against uncooperative employers. An obligation to joint an existing occupational pension plan—even in a state of nature when prior insurance calls for payouts—may even discourage the creation of new firms. Moreover, the natural job market competitors of an innovative new firm may be unclear or subject to change, so clear lines of demarcation between occupations and industries are difficult to maintain.

An additional concern is that occupational plans might collude with each other in a way that eliminates competition for new employees. Regulations that encourage funds to

[17] Of course, nominal debt and inflation could also be misused and become another source of risk.

conform might have a similar effect. The occupational pension system as a whole would then be empowered to "tax" entrants just like a government. One the upside, such a system could implement ex ante efficient risk sharing without constraints. One the downside, one might suspect that if the young have no choices, the gains from improved risk sharing would be captured by the incumbents—firms and older cohorts. Though the political process does not protect entering generations either, it gives citizens ample (voting) opportunities to express their concerns about the welfare of their children and future generations. Firms and incumbent workers in an industry may be much less concerned about entrants into this particular industry, who are mostly not their children.

Put differently, delegating *all* risk sharing to pension funds may well yield an efficient allocation of risk, but an allocation that place little or no weight on the welfare of future generations—optimal intergenerational risk sharing with an undesirable intergenerational distribution. Competition at entry is therefore worth protecting. This reserves the task of redistribution to the government and ensures that the resulting allocation maximizes social welfare rather than the incumbents' welfare. (Competition between occupational pension plans at the time of entry—or more precisely, at the time of career choice—is assumed in the following sections.)

An alternative interpretation of Dutch pension regulations is that while entrants are indeed taxed, solvency regulations prevent an abuse of privately imposed taxes. The assumption that occupational pension plan can impose taxes is implicit in most of quantitative studies of Dutch pensions. Ideally, full funding means that the fair market value of assets matches the expected present value of benefits promised to current participants. Under- or overfunding at the start of the next period can then only result from unexpectedly low or high returns on assets or unexpectedly high or low realizations of variables that govern the

indexation of benefits. If the funding gap equals zero in expectation (adjusted for risk), there is no systematic redistribution at the expense of new entrants.[18]

Remarkably, Dutch regulations demand funding ratios greater than 100%. Taken literally, this would suggest redistribution in favor of entrants. (According to Kortleve and Ponds, regulators require 105% minimum, and 125-135% are required before benefits are fully indexed.) One problem with funding regulations is that they do not prevent a renegotiation of benefits when conditions are favorable to incumbents. For example, retirees could demand extra benefits in a stock market boom when solvency regulations are unlikely to bind. Van Bommel (2007) characterizes such scenario as a "raid." After a stock market crash, on the other hand, retirees can insist on their formula-fixed benefits and—perhaps citing unprecedented circumstances and severe underfunding—demand extra concessions by workers to return to full funding quickly. Regulators who worry about funding ratios are likely sympathetic to such arguments.

Asymmetric responses to shocks would have undesirable consequences. They are inconsistent with risk pooling, they provide incentives for incumbents to take excessive risks, and they create a potential for underfunding in expectation despite (seeming) overfunding under a baseline projection.[19] Thus a view of the Dutch system as intergenerational risk sharing with competitive entry is a sympathetic interpretation.

A more cynical view of pension funds as tool for incumbents to tax entrants would have implications for government reinsurance. Notably, it could explain a lack of demand for reinsurance against longevity risk. This is because uninsured longevity risk creates volatility

[18] Funding rules are commonly viewed as protecting retirees from the risk of a plan sponsor's default. In a system with intergenerational risk sharing, an important function of funding is to protect new entrants from incumbents who might attempt to tax them.

[19] Put differently, a formula-fixed benefit means retirees hold a put option on the market underwritten by the next generation. The required overfunding is acting as put premium. The value of the put is maximized by high-risk investments. A counterforce is that benefits are limited to full wage indexing, which means retirees are short a call option. Depending on funding rules and risks, one or the other option may be more valuable. A softening of the "kinks" in funding formulas would be worth considering. The fact that regulators impose overfunding suggest that they are concerned about redistribution and may have doubts about the effectiveness of their rules.

in funding ratios that can be exploited to grant extra benefits in good scenarios (say, no rise in longevity) and to tax entrants in unfavorable scenarios (rising longevity).

The assumption of complete markets is instructive but not realistic. Hence it is worth noting that incomplete markets are unproblematic for a pension plan associated with a well-capitalized corporate sponsor. A plan sponsor's promise to cover any mismatch between pension promises, plan assets, and employee contributions can be interpreted as an implicit pension asset that—from the perspective of the plan—completes financial markets. Moreover, if the corporate sponsor is a publicly traded company and the Modigliani-Miller theorem applies, the implicit pension asset is converted into a traded security. In a competitive environment with free entry, a well-fund corporate plan in a setting with incomplete markets is essentially equivalent to an independent and fully funded plan under complete markets. One caveat is that with corporate sponsors as residual claimants, a fund's ability to "tax" new entrants must be strictly supervised to prevent abuse.

Table 1 summarizes the interaction of private and public risk sharing under alternative pension systems. Row 1 considers plans with mandatory participation, which means entrants can be taxed. Row 2 considers plans where youth have a choice of competing plans—so entry is competitive—but members are subsequently locked into their plan. Row 3 considers plans without commitment.

Column A displays choices without organized private pensions: Mandatory public systems (A1); a hypothetical case of commitment to private risk sharing in youth (A2); and private savings in working age (A3). Column B displays allocations with employer-independent pension systems. The defining feature is that the sponsoring employers do not back the plan with shareholder funds. Hence any risk sharing must be between different generations of employees. Such systems can either replace government (B1), if mandatory; provide credibility to risk sharing commitments starting in youth (B2), in effect making (A2) feasible; or replicate individual savings (B3), which is no better than (A3). Column C displays

the analogous allocations with employer-backed pension systems, which are discussed in the next section.

My interpretation of Dutch pensions is that the system has elements of (B2), which has advantages over all the type-A systems, and it minimizes reliance on plans sponsors. Concerns are that the system may drift towards (B3) if there is lack of commitment; and the system may degenerate towards (B1) if new cohorts face systematically unfavorable entry conditions.

## 4. Limitations to Private Risk Sharing

This section examines problems that may limit risk sharing in pension plans. The section focuses on a mixed public-private system, where private pensions provide risk sharing to the maximum extent possible and government enters only when necessary to supplement private arrangement. As benchmark cases, assume youth enter competitively (setting B2).

An occupational pension plan then involves three parties: youth entering working age, workers transitioning into retirement (young and old workers, for short), and firms as plan sponsors. Because the old are always creditors of the plan, participation constraints involve young workers or the firm, and any default would be against the old. There are several relevant scenarios of how these parties interact. The emphasis of Dutch occupational pensions on intergenerational risk sharing differs notably from traditional pension analysis, which focuses more on old workers and firms.

### *4.1. The Mobility Constraint with Complete Markets*

With complete markets, intergenerational risk sharing is essentially about the interaction of young and old employees. One may assume without loss of generality that firms contribute to the pension fund for each current worker an amount equal to the present value of the worker's pension. Because the fund can reinsure all risks on financial markets, there is no need for

firms to assume risks or other responsibilities. In effect the firm serves as platform for intergenerational contracts between employees and the fund.[20]

The most important limitation under complete markets is the mobility constraint, which is ability of the young to exit the pension plan whenever premiums are excessive. Suppose the opportunity cost of exiting is given and known. The constrained optimal risk DB pension plan satisfies condition (2) only for states of nature such that the wage minus pension contribution exceeds the marginal product of labor minus the cost of exit. In states of nature for which this condition is violated, pension contributions are bounded by the cost of exit.

Recall that the pricing kernel reflects all aggregate risks—uncertainty about return to capital, longevity risk, and labor productivity risk. The weights on labor productivity and on the return to capital are positive, whereas the weight on longevity is negative.[21] Because workers have labor income, the mobility constraint is most likely binding when the marginal product of labor his unexpectedly high, when the return on capital is unexpectedly low, and when retiree longevity is unexpectedly high.

A complication is that all three fundamental sources of risk may have global, national, and idiosyncratic components. For capital and longevity risk, which the young are buying, only the global components are relevant because only these components are priced and hence optimal for the pension fund to hold on behalf of the young. For productivity risk, the young are endowed with all three components. The idiosyncratic component is traditionally managed by the firm (which is arguably better equipped to deal with moral hazard and adverse selection) and not insured by the pension fund. The national component could be hedged either by the pension fund or by the employer; either way, the ultimate holders should be international investors. Global productivity risk is priced, and hence part of the optimal

[20] Cui et al (2009) also make this assumption. It applies only under complete markets.

[21] The negative weight on longevity risk factor is perhaps counterintuitive because life is valued. However, insurance is needed against the marginal cost of financing a longer life, which is a negative. Improving morbidity, if correlated with longevity, could be an offsetting factor. Note that labor productivity risk is priced in the market only to the extent that the young are integrated by entering a DB pension system in youth. That is, the pricing kernel pools all the risks faced by the economically cohort with access to financial and insurance markets.

portfolio of older workers. The pension fund's optimal strategy is to give the young a short position (up to the mobility bound), to give the old a long position, and to hedge the difference on financial markets.

The complete markets setting points to a fundamental commitment problem in private risk sharing: the inability of the young to pre-commit their labor effort. This is a fundamental constraint because it would be difficult to correct privately without permitting undesirable contracts—contracts resembling slavery. Public risk sharing through taxes can serve as substitute. Taxes on wage income are an obvious tool to reduce the young generation's exposure to labor productivity. High taxes on the young in response to a stock market crash and to abnormally high longevity would also improve risk sharing. Because of excess burden, tax responses to shocks are only a second-best substitute to private risk sharing. They are warranted only when shocks are so large that private responses would conflict with the mobility constraint. (However, as explained below, very large shocks encounter limitations to public risk sharing.)

A straightforward policy recommendation is that the revenues from unexpected fluctuations in the wage tax should be securitized as wage-contingent bonds and sold on financial markets. They would give retirees a more complete exposure to productivity risk. Similarly, there is a case for government insurance against market crashes and protection against high longevity. Ideally this insurance should be calibrated so that it provides protection to pension fund only against large shocks—large enough that pension plans cannot cover the resulting funding gaps by charging higher premiums to young employees.

From a practical perspective, there are many steps between an endorsement of contingent bonds and the issue of specific, well-designed securities. For indexing to longevity, much detailed work has been done; see Blake et al (2010). There is no comparable work on wage-indexed bonds, and aggregation issues are challenging. Given the long-run stability of the labor share in national income, GDP-indexed bonds should be close substitutes. They may be easier to develop (see Borensztein and Mauro, 2004) and they have

advantages over nominal bonds from a tax-smoothing perspective (Bohn 1990). Thus a practical proposal would be for governments to issue longevity bonds and GDP-indexed bonds.

Insurance contracts sold by the government directly to pension funds could provide similar reinsurance as bonds. Such contracts could even be customized to the needs of a particular funds, e.g., to account for differences in mobility or to provide protection against a combination of shocks. The pricing would lack transparency, however, which is troubling when the buyers include large funds that may have political power. Customized contracts might also encounter moral hazard or adverse selection problems if the funds have better information about their exposure to shocks than the government.

Finally, note that if there is uncertainty about the cost of exit, the mobility constraint creates a form of discontinuity risk. An unexpected reduction in exit cost would leave a plan unable to collect higher contributions in states of nature when the young were expected to cover underfunding. Again, taxes might serve as backup. Moreover, though the labor evidence is unclear, there is a perception that job mobility is rising and industrial restructuring is accelerating. This suggests that the ability of occupational pension funds to bind the young into risk sharing arrangements is declining as well and suggest a greater role for the government.

*4.2. The Solvency Constraint*

In general, a plan sponsor is needed whenever fund assets and employee contributions do not match pension promises. The need for a plan sponsor introduces a new constraint, the solvency constraint: Pensions must designed so that the plan sponsor remains solvent in all states of nature and committed to make the required contributions.

With complete markets, solvency is not a constraint on pension design. For any given state-contingent profile of pension promises and contributions, plan management can buy financial assets that match the gap between promises and contributions. A funded plan with optimal investment strategy will never become underfunded because of economic shocks.

With incomplete markets, funding gaps are generally unavoidable in response to economic shocks even in plans that are fully funded ex ante. The only exception would be a plan that uses retirees or workers as residual claimants, but this would severely restrict the allocation of risk. Otherwise, recourse to the plan sponsor can be avoided only by overfunding the plan so much that there is a surplus in all states of nature, even in the worst "worst case" scenario. The required degree of overfunding would depend on the riskiness of assets and on the state contingencies embedded in plan benefits.

Easily traded financial assets include corporate equity securities and bonds, and government bonds. Regular nominal government bonds are state-contingent in principle because they are indexed to inflation and inflation is controllable by monetary policy. Even in the Euro zone, inflation could co-vary with variables of interest, such as productivity. However, the ECB and other leading central banks claim to pursue price stability, i.e., they have disclaimed inflation as contingency. Hence government bonds are reasonably considered safe assets. Corporate securities are always risky. Moreover, because optimal pensions are linked to longevity and labor productivity, pension funds face a mismatch between assets and liabilities unless there are securities indexed to future labor productivity and to longevity. This mismatch provides an obvious argument for government issuance—but perhaps too obvious, because there might be alternatives.

One alternative is overfunding. If intermediation costs are (approximately) zero, the solvency constraint can always be satisfied by sufficient overfunding with government bonds. That is, firms can strengthen their pension fund by issuing equity and contributing the proceeds to the pension funds. If bonds have the same risk-adjusted returns as the firm's equity, shareholders would be indifferent. Optimal pension benefits and contributions would be the same as in a complete markets setting. In terms of Table 1, pension plans with corporate sponsors could replicate the risk sharing in independent plans. The mobility constraint would again determine if this risk sharing includes the young (setting C2) or only retiring workers (setting C3).

Zero intermediation cost are unrealistic, however, because issuing equity is costly relative to bonds, there is a cost of managing pension assets, and there may be agency costs if the firm's claims on surplus pension assets are imperfect. With intermediation costs, it would be efficient to use the assets of the plan sponsor—the value of corporate equity—as collateral even if markets were complete and a perfect matching of assets and liabilities were feasible.

The question to what extent plans can rely on corporate sponsors depends on the nature and valuation of equity capital. Firms are typically valued for their profit opportunities and for the physical and intangible capital assets they own. Pure profit opportunities require market power. Capital assets are reliable as collateral for pension only if they cannot be diverted easily. It is no surprise therefore that big industrial firms with monopoly power and a high ratio of fixed physical capital to labor were the first to embrace DB pension plans. In some cases, pensions were simply unfunded promises backed only by the firm's capital. Employees were major corporate creditors. In a setting with underdeveloped debt markets, this was arguably a mutually beneficial arrangement. Funding became more prevalent over time because of two problems: the exposure of employees to firm-specific risk and the vulnerability of employees' claims to financial restructuring.

In the United States, these problems have largely destroyed corporate DB pensions. Costly pension insurance was mandated after some well-publicized defaults and employee confidence in DB plans was undermined by pension terminations. The U.S. pension system has moves from a DB system with career employment that offered risk sharing (setting C2) to a DC system that has essentially no private risk sharing (setting A3).

To understand the solvency constraint, it is instructive to decompose corporations into their basic functions. In the context of pensions and career employment, corporations have fourth distinct functions. First, they combine labor and capital to produce output. Second, they accumulate capital. Third, they may promise a pension to current workers going into retirement next period. Fourth, they may offer a career employment and pension package to youth to attract them into the industry. These functions are typically combined in real world

firms, but they are important to distinguish because they use and provide collateral in different ways.

A pure production firm would rent capital on spot markets and hire workers on the labor market. Under perfect competition, it would earn no economic profits. Its accounting profits would just suffice to cover the cost of equity capital. Because it owns no assets, there is no collateral to backstop a defined benefit pension plan. Such a firm cannot commit to pay anything but the spot marginal product of labor to its workers. A production firm with monopoly power would earn pure profits that might serve as collateral. However, market power is often based on patents or other intellectual capital that can be stripped off.

A pure capital accumulation firm would hold capital and lease it to production firms at a leasing rate that covers depreciation plus the cost of financing. Because such a firm has essentially no employees (abstracting from managers), pension issues are moot.

Only if production and capital accumulation are combined one obtains a firm with capital assets that might serve as collateral for pension commitments. There is a question, however, to what extent a firm can commit to keeping capital unencumbered. In many countries, the standard for legally permissible asset sales is that the firm is solvent at the time and *expected* to remain solvent. This leaves contingent claims on *unexpected* events unprotected, notably, a promise to bear the residual long-run risks of a pension fund. The key lesson is that DB pensions are threatened by the possibility of reorganization events that could extract capital from a firm or establish competing claims on collateral. The spread of financial engineering in recent decades has been damaging to pensions.

If there is equity-financed physical capital, one may consider a production firm with pension for workers moving towards retirement. The pension fund must in each state of nature cover the gap between the promised pension and the firm's equity value. If firm's value reflects aggregate equity risk plus idiosyncratic risk, the pension fund should try to sell short the idiosyncratic risk and hold assets that fully support any wage- or longevity-indexed

pensions. (Some diversification of idiosyncratic risk is automatic in multi-employer plan where all employers are jointly liable.)

Finally, suppose the same firm provides risk sharing for young workers. Because young workers desire exposure to equity, their claims are well collateralized by the firm's equity, especially if idiosyncratic components can be hedged. Moreover, young workers' willingness to take negative wage and longevity exposures reduces the pension fund's need to hold wage- and longevity-indexed assets. One may conclude that risk sharing on behalf of young workers does not trigger additional funding needs. Instead it simplifies the provision of benefits for older workers.

Put differently, the mobility constraint is again a problem. The wage- and longevity-indexed claims valued by retirees are scarce when a tight mobility constraint prevents young workers from taking material short positions in such claims.[22] Risk sharing would be improved if the government sells wage- and longevity-indexed claims.

*4.3. Equilibrium Considerations*

The equilibrium pricing kernel can only pool the consumption risks of individuals and generations represented in financial markets. It is affected by changes in mobility cost and changes in government policy.

In a benchmark case of a non-binding mobility constraint, young and old workers pool their risk. With optimal tax and debt policy, taxes ensure that risks are also pooled with future generations. Then the pricing kernel reflects current and lagged realizations of wage risk, asset return risk, and (negatively) longevity risk. In an international context, this would require optimal policy in the home country and abroad.

A polar alternative case is a pricing kernel that reflects zero intergenerational risk sharing. If the young cannot commit to firms and governments do not intervene, all financial assets must be held by workers moving towards retirement. This includes the equity of all the

[22] Another problem is the fund may be unable to insure against negative idiosyncratic shocks to the plan sponsors' equity. It seems plausible, however, that an occupational pension plan could hedge this risk either with OTC contracts or indirectly by tilting the fund's equity portfolio away from its own industry.

firms that operate pension funds. No matter what the pension plans promise, the total resources available to the retiring generation must add up to the value of corporate capital plus the their claims against government—debt and pensions. The pricing kernel is then proportional to retirees' marginal utility, which is declining in the return to capital and increasing in longevity. Unless public pensions or debt or are wage-contingent, wages have no weight in the pricing kernel.

Intermediate cases work analogously. With positive but not prohibitive mobility cost for the young, the weight of wages in the pricing kernel is an increasing function of mobility cost, and the weight of equity and longevity risk is reduced accordingly. If the government intervenes by supplying wage- and/or longevity-indexed bonds or taxing capital income, weights on the respective risk factors are shifted in the same direction.

Intergenerational risk sharing appears to be highly imperfect in many countries, not only in developing countries but also in large industrialized countries like the United States. This suggests that the worldwide pricing kernel excludes future generations and a large share of the worlds' young cohorts, and it implies that governments could sell longevity-indexed bonds at a substantial risk premium. Young and future generations would benefit.

By similar reasoning, retiring generations should be willing to buy wage-indexed bonds without demanding a significant risk premium. The premium is likely positive due to correlation between wages and the return to capital, but lower than the value of the insurance accruing to young workers.

If the government of a small open economy issues contingent bonds on behalf of future generation, the change in the asset pool has a negligible impact on the pricing kernel. Hence domestic policy choices do not alter the risk exposures of cohorts that are already participating in financial markets. Contingent debt increases welfare because it exploits differences between risk premiums in the market and the shadow value of the same risk for those currently excluded.

## 5. Limitations to Public Risk Sharing

Government solutions to market imperfections naturally raise questions about limitations to government intervention. If private risk sharing is limited, what limits public risk sharing? One obvious limitation is the need for taxes that are distortionary. This is well recognized in the public policy discussion. A second constraint has received less attention: Governments are also subject to mobility constraints.

International labor mobility is particularly relevant in the European union where legal restrictions against work in other member countries are being abolished. Though labor mobility in Europe has traditionally been low, it would be negligent for policy makers to disregard the likelihood of rising mobility. Moreover, individuals with the highest productivity and therefore highest ability to pay taxes have the greatest incentives to move.

The implications of rising cross-country labor mobility are analogous to the implication of rising job mobility for corporate pension funds. Insurance ex ante means taxation ex post. Even if young workers agree ex ante to be taxed in case of high wage realizations, or high longevity, or low returns to capital, they have an incentive to move away if a government attempts to collect. A government that cannot promise state contingent taxes also cannot issue wage- or longevity-indexed bonds or promise expensive wage- or longevity-indexed public pensions.

Furthermore, the relation between the European Union and member countries with regard to risk sharing can be seen as analogous to the relation between an occupational pension fund and member firms. Labor mobility is higher between members than between the group and the outside world. Hence cooperation between members or a centralized risk pool would enlarge the set of feasible insurance contracts. As cross-country mobility increases, it will be increasingly efficient for institutions of the European Union to play a role in coordinating consumption and labor income taxes.

International coordination in the European Union would be another step in a line of thinking that has gradually increased the scope of insurance schemes in an effort to prevent

members from exiting when payments would be due. Avoiding substitution is the basic force that makes occupational pension plans superior to single employer pensions. It should make national pension plans superior to occupational pensions as job mobility keeps increasing, and international plans superior to national ones.

Opposing forces are the declining ability to monitor and control tax avoidance in larger risk-sharing systems and an increasing operational and bureaucratic inefficiency. Employers are in a better position to judge their employees' work efforts than a government tax collector. This suggest that whenever efficient risk sharing calls for workers to be taxed, the excess burden is less if the tax is collected by the employer as pension contribution than if it is collected by the government. Instead of expanding the scope of insurance schemes beyond employers and nations as mobility increases, it is worth considering other ways to discourage opportunistic behavior.

A potentially promising area for rethinking is education. Boldrin and Montes (2005) have noted that public pensions and public education are offsetting intergenerational transfer schemes. Pensions require payments from younger to older generations. Education requires payments from older to younger generations. The highly productive workers most capable of moving internationally tend to be the ones that have received the most education in their countries of origin. In Europe, most education is publicly funded and essentially costless to recipients. If the mobility of educated workers makes pension systems fragile and intergenerational risk sharing difficult, it may makes sense to consider systems that link risk sharing more directly to education, or perhaps more narrowly, to professional training.

Because college fees are already increasing around the world, one should emphasize that improved risk sharing does not mean a net burden on students. To the contrary, claims of efficiency gains would be dubious unless young cohorts are also better off. Improved risk sharing would require a systemic change that matches notional charges for professional training with mechanisms for how the charges are written off over time. The charges are notional because they would normally be financed by the government or by an employer and

because optimal risk sharing would call for repayment linked to time, income, or other contingencies.

It is beyond the scope of this paper to suggest specific systems. It seems likely, however, that financing mechanisms for professional training would involve employers and unions in the relevant industry. An involvement of occupational pension plans would be natural and likely to strengthen such plans. In essence, limitations of public risk sharing increase the potential gains from finding innovative ways to improve private risk sharing.

## 6. Conclusions

The short answer to the question posed in the title is: Yes. Under reasonable conditions, governments should provide reinsurance both against aggregate longevity risk and against the risk of fluctuations in aggregate wages or GDP, especially against large shocks.

A more complete answer must be conditional on the structure of pension plans and on the mobility of labor across firms, occupations, and countries. The Netherlands are an instructive example—worth studying by economists elsewhere—because the Dutch system of occupational pension funds has, for many decades, facilitated a remarkable level of private intergenerational risk sharing.

Risk sharing in private pension funds faces two serious limitations. One is the ability of workers to exit firms when large negative shocks to their plan require excessively high future contributions. Industry funds mitigate this problem because exiting from an industry is more difficult than leaving a firm. Mobility of workers across industries is a problem for risk sharing in industry-based private pension funds. A second problem is the mismatch between pension assets and liabilities in a setting with incomplete financial markets. When there is a mismatch, corporate plan sponsors are needed to guarantee the pension fund's solvency. A commitment of equity capital to guarantee pension is difficult to maintain, however, if firms can restructure their operations and divert capital in the process. Thus financial engineering is a threat to private risk sharing.

Government reinsurance can mitigate both problems and hence stabilize pension funds. Governments can provide insurance that is not available on financial markets because they can enter commitments on behalf of taxpayers—current ones and future generations. Payments enforced through the tax system sidestep the problems of limited liability and of limited commitment in employment relationships. Insurance can be provided in form of explicit insurance contracts, perhaps issued directly to pension funds, or in form of contingent bonds; the latter are equivalent to insurance for aggregate risk sharing purposes but more liquid. Most relevant are contracts contingent on longevity and, because optimal pensions are linked to wages, contracts contingent on aggregate wages. Government provision of longevity- and wage-contingent claims would also help to complete financial markets, so pension plans would be able to hold assets that more closely match their liabilities. Moreover, government intervention may exploit imperfections in risk sharing in other countries. If risk premiums on world financial markets are set by the world's old generations, longevity insurance should command a high risk premium, whereas bonds linked to aggregate wages should have a low risk premium. Future taxpayers would benefit if the government issued debt contingent on longevity and wages instead of fixed debt.

Note that GDP-indexed bonds would be a close substitute for wage-indexed bonds, as the wage share of GDP is nearly constant; both provide insurance against productivity shocks. Though the theoretical analysis suggests wage indexing, GDP indexed bonds have been discussed in the literature (see Borensztein and Mauro, 2004; Bohn 1990) and may be more easily implementable in practice. Both wage- and GDP-indexed bonds would provide better risk sharing than fixed, non-contingent government debt. (Note that inflation-indexed debt is fixed in real terms and hence undesirable.)

Because government commitments must be backed by taxes, the government's ability to offer insurance is limited by its ability to tax future generations. International labor mobility is therefore a threat to the government's ability to offer insurance. The general principle here is that risk sharing and insurance are constrained by the ability of participants

to exit when payments would be due. This constraint limits public risk sharing when labor is mobile internationally just like it limits private risk sharing when labor is mobile across firms and industries. However, moving abroad is more costly than moving between industries. The cost of moving abroad includes cultural and language frictions that are likely to persist in the future. Hence governments can still offer reinsurance to private pension funds, though they must respect the bounds defined by the country's tax base.

Looking forward, as mobility is arguably growing and efficient risk sharing is worth preserving, it would be desirable to strengthen individuals' attachment to private and public risk sharing arrangements. One promising area is the financing of education. Most education is traditionally provided free under the implicit assumption that students will grow up to be the country's taxpayers. International labor mobility invalidates this assumption. With mobile labor, risk sharing could be improved if education were provided in exchange for a contractual claim against the person's human capital. Such a claim would provide collateral for insurance arrangements—public or private. Occupational pension plans would be natural financiers for education, because they have funds to invest and because many students would become plan members anyway once they start working in the occupation for which they studied. Though a full analysis of education funding is beyond the scope of this paper, it is a promising area for future research.

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**Table 1: Pension Systems and the Role of Government**

| Membership Commitment (#) | Private Pension System | | |
|---|---|---|---|
| | No system, or pure DC (A) | Employer-independent plans (B) | With employer as residual claimant (C) |
| Mandatory participation (all generations) (1) | Comprehensive Bismarckian social insurance<br>Germany, Sweden<br>Problems: Cost, Political risk | Risk sharing and redistribution delegated to pension plans<br>Problem: Incumbents taxing future gen. | Hypothetical<br>Fatal flaw: Corporate control over citizens. |
| Choice of plans in youth (at career entry) (2)<br>Commitment in working age | Individual risk sharing contracts. Gov. redistribution<br>Problem: No collateral. Not credible | Private risk sharing in pension plan. Gov. redistribution<br>The Netherlands<br>Problems:<br>• Incomplete markets<br>• Labor mobility<br>Solution: Reinsurance | Private risk sharing in corporate plan. Gov. redistribution<br>US (old-style)<br>Problems:<br>• Default risk<br>• Labor mobility<br>Solution: Reinsurance |
| No commitment in youth (3)<br>Choice of plans in working age | Individual savings or DC plan Gov. risk sharing<br>US (current)<br>Problems:<br>• Incomplete markets<br>• No risk sharing except by government | Private savings in pension plan. Gov. risk sharing<br>Problem: No advantage over individual savings | Private savings in corporate plan. Gov. risk sharing<br>Problems:<br>• Default risk<br>• No risk sharing except by government |

Note: The table characterizes pension systems by sponsor and effective entry age. "Gov. redistribution" means that government intervention can be limited to reallocating initial (working-age) endowments. "Gov. risk sharing" means that efficiency requires optimal state contingent taxes and government debt. Country labels are illustrative.

## Technical Appendix: A Model of Optimal Risk Sharing

This appendix provides a more formal treatment of the optimal risk sharing problems discussed in the paper and of the conditions for optimal reinsurance.

*A.1. The Economic Environment*

Time is indexed by discrete periods t. Each period, a vector of shocks $s_t$ is realized. A history $h_t$ encodes the sequence of shocks up to period t and is defined recursively by $h_t=(s_t,h_{t-1})$.

Individuals live for three periods, youth, working age, and retirement. Retirement is a fractional period of length $\lambda_t=\lambda(h_t)$. Assume generation t reaches working age in period t, and without loss of generality, assume a single representative domestic agent is born each period. Generation t maximizes the expectation of

$$U_t = u_w(c_{wt}) + \lambda_{t+1} u_r(c_{rt+1}) \tag{A1}$$

where $u_w$ and $u_r$ are increasing and concave utilities over working-age consumption $c_{wt}$ and retirement consumption $c_{rt+1}$. Individuals have no income or consumption in youth, but they may enter financial markets. Individuals in working age (workers) supply a unit of labor, which has an exogenous marginal product $w_t=w(h_t)$, they pay lump-sum taxes $T(h_t)$, and they may save, either individually and/or by contributing to a pension fund. Individuals in retirement age (retirees) receive exogenous government transfers $B_{t+1}(h_{t+1})$, while living, and returns from working-age savings and/or a pension. Let pensions for generation t be defined generally by a state-contingent benefit profile $X(h_{t+1}) \geq 0$ and contributions $x(h_t) \geq 0$.

Because savings can be viewed as purchases of state contingent claims, individuals maximize utility subject to

$$\lambda_{t+1} c_{rt+1}(h_{t+1}) = a_r(h_{t+1}) + X(h_{t+1}) + \lambda_{t+1} B_{t+1}(h_{t+1}) \tag{A2}$$

$$c_{wt}(h_t) + \sum_{h_{t+1}} \xi(h_{t+1} \mid h_t) a_r(h_{t+1}) = w_t(h_t) - T(h_t) - x(h_t) \tag{A3}$$

by choice of state-contingent retirement savings $a_r(h_{t+1})$ for given prices $\xi(h_t \mid h_0)$. For reference below, let state prices be written as product of conditional probabilities, denoted $\pi(h_t \mid h_0)$, and the pricing kernel $\xi(h_t \mid h_0) = \pi(h_t \mid h_0) m(h_t \mid h_0)$. Then the present value of

assets, $\sum_{h_{t+1}} \xi(h_{t+1} \mid h_t) a_r(h_{t+1}) = E\left[m(h_{t+1} \mid h_t) a_r(h_{t+1}) \mid h_t\right]$, can be interpreted as conditional expectation weighted by the pricing kernel.

The government maximizes a welfare function $\overline{U}_0$ that weights the ex ante utility of generation t by $\omega_t>0$,

$$\overline{U}_0 = E\left[u_r(c_{r0}) + \sum_{t\geq 0} \omega_t U_t \mid h_0\right]$$

subject to the intertemporal budget constraint

$$NW_0 + \sum_{t\geq 0} \sum_{h_t} \xi(h_t \mid h_0) w(h_t) = \sum_{t\geq 0} \sum_{h_t} \xi(h_t \mid h_0)\left(c_{wt}(h_t) + \lambda(h_t) c_{rt}(h_t)\right) \tag{A4}$$

where $NW_0$ is the country's initial net worth. Cohort size is normalized to one. Assume utility is strictly concave, the l.h.s. of (A4) is finite, and the world economy is dynamically efficient. Let $\Lambda$ denotes the Lagrange multiplier on (A4). Then Pareto optimality requires

$$\pi(h_t \mid h_0) \omega_t u_w'(c_{wt}(h_t)) = \xi(h_t \mid h_0) \cdot \Lambda \tag{A5}$$

$$\omega_{t-1} \pi(h_t \mid h_0) \lambda(h_t) u_r'(c_{rt}(h_t)) = \xi(h_t \mid h_0) \lambda(h_t) \cdot \Lambda \tag{A6}$$

By concavity, (A4-A6) define a unique allocation. In the following, optimal values are highlighted by superscript star (*). Implied are consumption values

$$c_{wt}^*(h_t) = (u_w')^{-1}\left(m(h_t \mid h_0) \cdot \tfrac{\Lambda}{\omega_t}\right) \text{ and } c_{rt}^*(h_t) = (u_r')^{-1}\left(m(h_t \mid h_0) \cdot \tfrac{\Lambda}{\omega_{t-1}}\right), \tag{A7}$$

where and a path for national net worth

$$NW_t^*(h_t) = \sum_{i\geq 0} \sum_{h_{t+i}} \xi(h_{t+i} \mid h_t)\left(c_{wt+i}^*(h_{t+i}) + \lambda(h_{t+i}) c_{rt+i}^*(h_{t+i}) - w(h_{t+i})\right).$$

I will call an allocation efficient if it is optimal for some set of welfare weights $\{\omega_t\}$.

Define the generational accounts of generation t in working-age and youth by

$$GA_t(h_t) = T(h_t) - \sum_{h_{t+1}} \xi(h_{t+1} \mid h_t) B(h_{t+1})$$

and $$\overline{GA}_t(h_{t-1}) = \sum_{h_{t-1}} \xi(h_t \mid h_{t-1}) GA_t(h_t).$$

Then unique optimal account balances

$$GA_t^*(h_t) \equiv w(h_t) - c_{wt}^*(h_t) - \sum_{h_{t+1}} \xi(h_{t+1} \mid h_t) \lambda(h_{t+1}) c_{rt+1}^*(h_{t+1})$$

and $$\overline{GA}_t^*(h_{t-1}) = \sum_{h_{t-1}} \xi(h_t \mid h_{t-1}) GA_t^*(h_t)$$

are implied by the optimal allocation.

*A.2. Implementing Efficient Allocations*

An optimal allocation for given $\{\omega_t\}$ can be decentralized in several equivalent ways. The numbering below matches the cells in Table 1. In each case, conditions for efficiency are noted, even if unrealistic. The sequence is driven by analytical convenience:

Setting #1A: Optimal public pensions: Set $B(h_t) = \lambda(h_t)c^*_{rt}(h_t)$ for all $h_t \neq h_0$, $T(h_t) = w(h_t) - c^*_{wt}(h_t)$ for a all $h_t$, and assume $B(h_0) = \lambda(h_0)c^*_{r0}(h_0) - a_{r0}$ at t=0, where $a_{r0}$ are assets held by the old.[23] Assume the government invests or borrows funds abroad in a portfolio that returns $NW^*_t(h_t)$ in state $h_t$. Then the allocation is optimal with zero savings and no need for pensions.

Setting #1B: Optimal mandatory private pensions. Suppose taxes and government benefits are arbitrary sequences $T(h_t) < w(h_t) - c^*_{wt}(h_t)$ and $B(h_t) \leq \lambda(h_t)c^*_{rt}(h_t)$ that satisfy the intertemporal budget constraint:

$$\sum_{i\geq 0}\sum_{h_{t+i}} \xi(h_{t+i} \mid h_t)\big(T(h_{t+i}) - \lambda(h_{t+i})B(h_{t+i})\big) = D(h_t). \tag{A8}$$

where $D(h_t)$ is government debt (potentially negative).

Suppose there is a member-owned (employer-independent) pension fund with asset $F_t = F(h_t)$ in period t. It faces the intertemporal budget constraint

$$\begin{aligned} F(h_t) &= \sum_{i\geq 0}\sum_{h_{t+i}} \xi(h_{t+i} \mid h_t)\big(X(h_{t+i}) - x(h_{t+i})\big) = \\ &= X(h_t) + \sum_{i\geq 0}\sum_{h_{t+i}} \xi(h_{t+i} \mid h_t)\big(\xi(h_{t+i+1} \mid h_{t+i})X(h_{t+i+1}) - x(h_{t+i})\big) \\ &= X(h_t) - \hat{x}(h_t) - \sum_{i\geq 1}\sum_{h_{t+i}} \xi(h_{t+i} \mid h_t)\hat{x}(h_{t+i}) \end{aligned} \tag{A9}$$

where $\hat{x}(h_t) = x(h_t) - \sum_{h_{t+1}} \xi(h_{t+1} \mid h_t)X(h_{t+1})$ is the gap between pension contributions and the present value of benefits (interpretable as payment for insurance against shocks realized before working age). If assets in period t are $F(h_t) = NW^*(h_t) + D(h_t)$ and plan managers maximize welfare $\overline{U}_0$, the plan will pay $X(h_t) = \lambda(h_t)c^*_{rt}(h_t) - B(h_t)$ and collect $x(h_t) = w(h_t) - T(h_t) - c^*_{wt}(h_t)$; the resulting allocation is optimal.///

[23] In all settings, retiree benefits in period zero require special treatment if initial conditions differ from "normal" conditions in the respective setting; to avoid distractions, assume a suitable initial tax or transfer.

Remark: The inequality restrictions on taxes and benefits ensure that pension payments and receipts are non-negative; that is, government must not be "too big." This is plausibly satisfied in the Netherlands, where 1st pillar benefits are low.

Setting #3A: Optimal individual savings for retirement. Suppose there is no pension system, so each generation must save for retirement. Assume the government sets taxes and transfers so that generational accounts $GA_t(h_t) = GA_t^*(h_t)$ are optimal, and assume markets are complete. Then it is straightforward to verify that $c_{wt}^*(h_t)$ and $c_{rt+1}^*(h_{t+1})$ maximize utility, so the allocation is efficient (analogous to Bohn 2009).///

Remark: Without loss of generality, one may assume that the government sets benefits arbitrarily (say, in a simple way) and sets taxes

$$T(h_t) = GA_t^*(h_t) + \sum_{h_{t+1}} \xi(h_{t+1} \mid h_t) B(h_{t+1}).$$

Note that returns to retirement savings are not taxed in this setting. Hence savings are best interpreted as tax sheltered, e.g. in a DC plan. Also note that optimality generally requires access to state contingent claims markets; otherwise government benefits would have to be optimally designed (as in Setting #1A) and not arbitrary. Let $a_r^*(h_{t+1})$ denote optimal private savings in this setting.

Setting #2A: Optimal individual savings and optimal insurance in youth. Suppose there is no pension system, so each generation must save. However, assume now that youths can commit, so generation-t workers can enter financial market in period t-1 and buy/sell state contingent claims $a_w(h_t)$. Government policy sets taxes and transfers so that generational accounts $\overline{GA}_t(h_{t-1}) = \overline{GA}_t^*(h_{t-1})$ are optimal for all generations. Because youths have no income, their utility maximization is subject to (A2),

$$\sum_{h_t} \xi(h_t \mid h_{t-1}) a_w(h_t) = 0, \tag{A10}$$

and

$$c_{wt}(h_t) + \sum_{h_{t+1}} \xi(h_{t+1} \mid h_t) a_r(h_{t+1}) = w_t(h_t) + a_w(h_t) - T(h_t) - x(h_t), \tag{A3'}$$

which replaces (A3). It is straightforward to verify that if $\overline{GA}_t(h_{t-1}) = \overline{GA}_t^*(h_{t-1})$, then $c_{wt}^*(h_t)$ and $c_{rt+1}^*(h_{t+1})$ maximize utility. Hence the allocation is efficient. Moreover, $a_r(h_{t+1}) = a_r^*(h_{t+1})$ and $a_w(h_t) = GA_t(h_t) - GA_t^*(h_t)$. ///

Remark: Without loss of generality, one may assume that $GA_t(h_t)$ is designed to simplify other policy choices. Of particular interest here is debt management: Government may issue debt with arbitrary return distribution $R(h_t \mid h_{t-1})$. To see this, define end of period t-1 debt by

$$\tilde{D}(h_{t-1}) = D(h_{t-1}) - T(h_{t-1}) + \lambda(h_{t-1})B(h_{t-1}) \tag{A11}$$

and assume the government issues debt with returns $R(h_t \mid h_{t-1})$, which are subject only to the arbitrage condition $\sum_{h_t} \xi(h_t \mid h_{t-1})R(h_t \mid h_{t-1}) = 1$. Then debt at the start of period t is $D(h_t) = R(h_t \mid h_{t-1})\tilde{D}(h_{t-1})$. From (A9) and the definition of generational accounts, debt must also satisfy

$$D(h_t) = -\lambda(h_t)B(h_t) + GA_t(h_t) + \sum_{i\geq 1}\sum_{h_{t+i-1}} \xi(h_{t+i} \mid h_t)GA^*_{t+i}(h_{t+i-1}).$$

Optimal consumption for other generations requires that generation t's account must be

$$\begin{aligned} GA_t(h_t) &= R(h_t \mid h_{t-1})\tilde{D}(h_{t-1}) + \lambda(h_t)B(h_t) \\ &\quad -\sum_{i\geq 1}\sum_{h_{t+i-1}} \xi(h_{t+i} \mid h_t)GA^*_{t+i}(h_{t+i-1}) \end{aligned}. \tag{A12}$$

Thus taxes on generation t absorb all variations in the return on government debt. One may assume that government debt is safe. ///

<u>Setting #3B: Optimal savings with a voluntary DB pensions</u> offered in working age. Assume again that $GA_t(h_t) = GA^*_t(h_t)$ and that markets are complete, but now assume there are competing pension plans. With competition, a plan that promises benefits $X(h_{t+1})$ must charge actuarially fair contributions $x(h_t) = \sum_{h_{t+1}} \xi(h_{t+1} \mid h_t)X(h_{t+1})$. Then individual can obtain $c^*_{wt}(h_t)$ and $c^*_{rt+1}(h_{t+1})$ for arbitrary benefits $X(h_{t+1})$ by saving $a_r(h_{t+1}) = a^*_r(h_{t+1}) - X(h_{t+1})$ on their own. Thus pension plans are unnecessary. Alternatively, one might assume that the pension plan sets $X(h_{t+1}) = a^*_r(h_{t+1})$, so individual savings become unnecessary. ///

<u>Setting #2B: Optimal savings with voluntary DB pension offered in youth</u>. Consider the same setting as in #3B. Suppose employers offer pensions with arbitrary benefits $X(h_{t+1})$ and assume contributions satisfy

$$\sum_{h_t} \xi(h_t \mid h_{t-1})x(h_t) = \sum_{h_{t+1}} \xi(h_{t+1} \mid h_{t-1})X(h_{t+1}).$$

Then $c^*_{wt}(h_t)$, $c^*_{rt+1}(h_{t+1})$ again maximize generation t's utility, now with

$$a_w(h_t) = \left[GA(h_t) - GA^*(h_t)\right] + \left[x(h_t) - \sum_{h_{t+1}} \xi(h_{t+1} \mid h_t) X(h_{t+1})\right]$$

and $a_r(h_{t+1}) = a^*_r(h_{t+1}) - X(h_{t+1})$. Again, individual savings are unnecessary if the pension plan is designed appropriately, namely if $X(h_{t+1}) = a^*_r(h_{t+1})$ and

$$x(h_t) = x^*(h_t) \equiv \sum_{h_{t+1}} \xi(h_{t+1} \mid h_t) a^*_r(h_{t+1}) - \left[GA(h_t) - GA^*(h_t)\right].$$

As emphasized in the text, the link of insurance and employment is promising because the employment relationship serves as collateral for insurance. Hence setting #2B is more credible than #2A. ///

In summary, allocations in all six settings are equivalent in principle. For each allocation without pension plans (settings 1A, 2A, 3A) there is a corresponding allocation with private pension plan (1B, 2B, 3B), and each can be designed to make separate private savings unnecessary. If individuals lack access to complete markets on their own, only the settings with optimal pensions are efficient.

Comparing pairs #1A-B, #2A-B, and #3A-B, one finds that private pension plans simplify government policy. The virtue of simplicity is not modeled explicitly because the implied complications would be distracting. Given the equivalence of allocations in principle, differences in cost and commitment are potentially decisive for a choice of systems.

Note that the pension plans above do not require a plan sponsor, provided they have access to complete markets. Implicitly, pension contributions are invested in state contingent claims that perfectly match the plan's obligations. That is, they are neither underfunded, which avoids default problems, nor overfunded, so there is no residual claimant.

For the following settings assume individuals and pension plans may have limited access to financial markets. Assume corporations are valued under the pricing kernel *m* and the Modigliani-Miller theorem applies. Consider:

<u>Setting #2C: Optimal savings with employer-sponsored pensions</u> offered in young age.

Assume $\overline{GA}_t(h_{t-1}) = \overline{GA}^*_t(h_{t-1})$ and assume that corporations offer a pension plan to workers and entering young workers. Sponsoring a pension means the corporation contributes

$z(h_t)$ in period t and is entitled to a return $Z(h_{t+1})$ in period t+1.[24] The representative corporation earns a return $R^k(h_{t+1})$ on equity capital $K_t$. Fund investments have a return distribution $R^F(h_{t+1})$, which is imperfectly controllable—say, exogenous for simplicity. The investments $z(h_t)+x(h_t)$ are worth $F(h_{t+1})=R^F(h_{t+1})[z(h_t)+x(h_t)]$ in the next period.

The corporation is worth $V_{t+1}(h_{t+1})=R^k(h_{t+1})K_t+Z(h_{t+1})$ in period t+1. From the Modigliani-Miller theorem, $\sum_{h_{t+1}}\xi(h_{t+1}\mid h_t)V_{t+1}(h_{t+1})=K_t+z(h_t)$, which means the corporation can afford actuarially fair contributions. With incomplete markets, individuals cannot generally attain $c^*_{wt}(h_t)$ and $c^*_{rt+1}(h_{t+1})$ on their own and would participate even in plans that are actuarially unfair. But competing employers must offer optimal pensions $X(h_{t+1})=a^*_r(h_{t+1})$ and charge optimal contributions $x(h_t)=x^*(h_t)$. The pension surplus in period t+1, $Z(h_{t+1})=F(h_{t+1})-X(h_{t+1})+\hat{x}(h_{t+1})$ is accrues to the corporation. This is feasible provided the value of the corporation is non-negative in all state of nature, $Z(h_{t+1})\geq -R^k(h_{t+1})K_t$, or equivalently,

$$R^F(h_{t+1})(z(h_t)+x(h_t))=F(h_{t+1})\geq X(h_{t+1})-\hat{x}(h_{t+1})-R^k(h_{t+1})K_t\forall h_{t+1}. \qquad \text{(A13)}$$

Provided $R^F(h_{t+1})>0$ (e.g. with some safe assets), this can be satisfied by setting $z(h_t)$ high enough, i.e., by sufficient contributions in period t. Thus efficient risk sharing can be attained even with incomplete markets. However, solvency in all states of nature will generally require a (large) funding buffer in (most or all) other states of nature.///

<u>Setting #3C: Optimal savings with employer-sponsored pensions</u> offered in working age. Consider a corporate plan as in #2C but only for workers. Assume that $GA_t(h_t)=GA^*_t(h_t)$. Then competing employers must offer optimal pensions $X(h_{t+1})=a^*_r(h_{t+1})$ and charge actuarially fair contributions $x(h_t)=\sum_{h_{t+1}}\xi(h_{t+1}\mid h_t)X(h_{t+1})$. The pension surplus or deficit in period t+1, $Z(h_{t+1})=F(h_{t+1})-X(h_{t+1})$, is assigned to the corporation. The corporation is solvent provided (A13) holds with $\hat{x}(h_{t+1})$. As in setting #3A, the resulting allocation attains $c^*_{wt}(h_t)$

[24] Note that corporate contribution may be in cash or by paying employees a wage that differs from the marginal product of labor and having the employee contribute a corresponding amount. The return might be a reduced contribution. Thus measurement is not trivial.

and $c^*_{rt+1}(h_{t+1})$. Thus efficiency is feasible even with incomplete markets. But as in #3A-B, there is no intergenerational risk sharing except through the government.///

Setting #1C. For completeness, note the possibility of mandatory employer-sponsored pensions. Such a pension plan would operate under the intertemporal budget constraint

$$F(h_t) = X(h_t) - \hat{x}(h_t) - \sum_{i\geq 1}\sum_{h_{t+i}} \xi(h_{t+i} \mid h_t)\hat{x}(h_{t+i})$$
$$+\sum_{i\geq 0}\sum_{h_{t+i}} \xi(h_{t+i} \mid h_t)\big(Z(h_{t+i}) - z(h_{t+i})\big)$$

The mechanics would be a straightforward combination of #2C and #1B. However, without competitive entry, corporations would have no incentive to offer actuarially fair plans. Workers would be taxed for private profit. (Higher $\hat{x}(h_{t+i})$ reduces z(h) in the budget constraint.) As this seems socially unacceptable, setting #1C is disregarded in the text.///

*A.3. Macroeconomic Shocks*

Consider Setting #2B, where pensions have a key role in risk sharing. The pricing kernel reflects aggregate risks. To be specific, assume world investors have power utility with risk aversion γ, and assume their consumption depends positively on stochastic labor productivity (measured by the wage $\overline{w}(h_t)$), positively on a stochastic return to world capital $\overline{R}^k(h_t)$ and negatively on longevity $\overline{\lambda}(h_t)$. Then the pricing kernel can be written (approximately) as

$$m(h_t \mid h_0) = \Big(m_0 + m_R\overline{R}^k(h_t) + m_w\overline{w}(h_t) - m_\lambda\overline{\lambda}(h_t)\Big)^{-\gamma} \tag{A14}$$

where $(m_0, m_R, m_w, m_\lambda)$ are positive parameters. Recall that government benefits and debt management do not have to provide insurance against current shocks: assume both are safe (non-contingent). Finally, assume domestic individual also have power utility. Then optimality consumption in (A7) can be written as

$$c^*_{wt}(h_t) = \big(\Lambda/\omega_t\big)^{-1/\gamma}\Big(m_0 + m_R\overline{R}^k(h_t) + m_w\overline{w}(h_t) - m_\lambda\overline{\lambda}(h_t)\Big)$$
$$c^*_{rt+1}(h_{t+1}) = \big(\Lambda\beta/\omega_t\big)^{-1/\gamma}\Big(m_0 + m_R\overline{R}^k(h_{t+1}) + m_w\overline{w}(h_{t+1}) - m_\lambda\overline{\lambda}(h_{t+1})\Big)$$

where $\beta$ denotes preference between working age and retirement. From (A2), optimal retirement benefits have the form

$$X(h_{t+1}) = \lambda_{t+1}\left[c^*_{rt+1}(h_{t+1}) - B_{t+1}\right]$$
$$= \lambda(h_{t+1})\left[\left(\frac{\Lambda\beta}{\omega_t}\right)^{-1/\gamma}\left(m_0 + m_R\overline{R}^k(h_{t+1}) + m_w\overline{w}(h_{t+1}) - m_\lambda\overline{\lambda}(h_{t+1})\right) - B_{t+1}\right] \quad \text{(A15)}$$

Thus pensions should be linked to the return to world capital and to world wages, fully indexed to domestic longevity, but less than fully indexed to world longevity. From (A2-3), optimal pension contributions have the form

$$x(h_t) = w_t(h_t) - T_t(h_t) - c^*_{wt}(h_t)$$
$$= w_t(h_t) - T_t(h_t) - \left(\frac{\Lambda}{\omega_t}\right)^{-1/\gamma}\left(m_0 + m_R\overline{R}^k(h_t) + m_w\overline{w}(h_t) - m_\lambda\overline{\lambda}(h_t)\right) \quad \text{(A16)}$$

Ceteris paribus, pension contributions should be fully indexed to own wages; negatively linked to the return to world wages; negatively linked to the return to world capital; and positively linked to world longevity. Intuitively, full indexing to own wages and a negative link to world wages means that idiosyncratic wage shocks are fully hedged whereas shocks that impact both own wages and world wages are generally not fully hedged.

*A.4. Frictions*

Several frictions destroy efficiency unless policy responds appropriately.

(a) <u>Mobility</u>: Consider an optimal pension offered in youth (setting #2B), but now assume workers can exit the pension plan at a cost $\chi_w>0$ and then save on their own (as in #3A) or join an employer offering a retirement plan to workers (as in #3B). To avoid exit, the original pension plan must operate under the mobility constraint

$$x(h_t) - \sum_{h_t}\xi(h_{t+1}\,|\,h_t)X(h_{t+1}) \le \chi_w \quad \text{for all } h_t. \quad \text{(A17)}$$

If $x(h_t) = x^*(h_t)$ in (A17) violates this constraint, private pensions cannot provide efficient risk sharing. One remedy is straightforward from the construction of $x^*(h_t)$: The government can ensure that

$$x^*(h_t) - \sum_{h_t}\xi(h_{t+1}\,|\,h_t)X(h_{t+1}) = -\left[GA(h_t) - GA^*(h_t)\right] \le \chi_w,$$

by setting $GA(h_t) \ge GA^*(h_t) - \chi_W$. That is, taxes on generation t must be high enough in states of nature where (A17) would otherwise be violated. From (A16), the mobility

constraint is most likely binding in states of nature with high wages, low returns on capital and high longevity. From (A12), $GA(h_t)$ is raised if the government issues bonds that promise a high return. Thus wage and longevity indexed government bonds relax (A17), which is an argument for issuing such securities.

(b) Incomplete markets with funding costs: Suppose securities are priced according to (A14), but the only generally available investment options for pension funds are government bonds and claims on the value of corporate assets.

One way to maintain efficiency is to use a corporation as residual claimant (plan sponsor), as noted above. However, to satisfy (A13) in all states of nature, $z(h_t)$ would have to be very high if $R^F$ is near zero in some states of nature. In most other states of nature, there would be large surpluses, and potentially a return of funds to the corporation (Z<0). To make such "churning" of funds matter formally, one may assume that fund management is costly.[25] A government supply of wage and longevity indexed bonds would reduce these imbalances and enhance efficiency, which is another argument for issuing such bonds.

(c) Incumbent selfishness: Consider the setting with mandatory pensions (setting #1B). Suppose pensions in period t are increased marginally to $X^+(h_t) = \lambda(h_t)c^*_{rt}(h_t) - B(h_t) + \Delta X$ and contributions are reduced to $x^-(h_t) = w(h_t) - T(h_t) - c^*_{wt}(h_t) - \Delta x$. In the next period, contributions are increased to

$$x^+(h_{t+1}) = w(h_{t+1}) - T(h_{t+1}) - c^*_{wt}(h_{t+1}) + R^F(h_{t+1})(\Delta x + \Delta X).$$

This change increases the utility of generations t and t-1 at the expense of generation t+1. Hence a mandatory pension plan managed by incumbents who value own utility more than the social planner—or even place zero weight on future generations—would not implement the socially optimum.

[25] For example, suppose that pension returns are reduced by a management cost, so $\sum_{h_t} \xi(h_{t+1} \mid h_t) R^F(h_{t+1}) = 1 - \chi_F$, where $0 < \chi_F < 1$. To avoid bias against private plans, one should then also recognize that taxes are distortionary. A formal treatment would be complicated and hence is not presented here.

Note that voluntary entry provides an effective constraint on such redistribution. First, if members enter in working age (as in setting #3B), competition between employers and plans ensures $\hat{x}(h_t) \leq 0$ for all t, so (A9) reduces to $X(h_t) \leq F(h_t)$. This means plan management can be delegated to plan members. To maximize own utility, each generation will provide optimally for their own retirement; the resulting allocation is the optimal allocation. Second, if members enter in youth (as in setting #2B), competition ensures

$$\sum_{h_{t+1}} \xi(h_{t+1} \mid h_t)\hat{x}(h_{t+1}) \leq 0 \text{ for all t} \tag{A18}$$

so (A9) reduces to $X(h_t) \leq F(h_t) + \hat{x}(h_t)$. Moreover, $\hat{x}(h_t)$ is constrained because the plan must credibly commit to honor (A18) in t-1. Hence plan management can again be delegated to the retiring generation. Mandatory funding rules may also constrain redistribution, but they create distortions except with complete markets and under a rule that requires an exact matching of assets and obligations. Matching is needed not only to avoid underfunding but also to avoid excess funds that could be diverted by those who control the fund.