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APPLYING THE SWEDISH PENSION BRAKE

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ABSTRACT: In non-financial defined contribution (NDC) pension systems the contribution rate is kept at a constant level. A key element is the balance mechanism which is automatically applied if the finances appear insufficient. The balance mechanism is based on the ratio of assets to liabilities. When the ratio is below unity, it will slow down the indexation of both notional pension accounts and pension benefits. Thus the burden of adjustment will fall on replacement rates, but when and how, depends on what the demographic and economic future will contain. We apply the balance mechanism to the Finnish private-sector earnings-related pension system and simulate the future with stochastic population projections and asset yields. The results show that depending on the contribution rate level, a direct application of the balance mechanism may turn out to be a slow way of running down the system, or end up with huge funds. The problems may appear very far in the future. Scaling the balance mechanism appropriately, however, results in financial stability.

Key words: non-financial defined contribution pensions, funds, intergenerational risk-sharing

JEL: H55, J11

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TIIVISTELMÄ: Nimellisesti maksuperusteisessa eläkejärjestelmässä eläke-etuudet määräytyvät maksuille kertyneiden kokonaan tai osittain laskennallisten tuottojen perusteella. Tarkastelemme tällaisen järjestelmän sovellusta yksityisalojen työeläkejärjestelmään Suomessa. Tulevaa väestökehitystä ja eläkerahastojen tuottoa kuvataan stokastisilla simuloinneilla. Tutkimme erityisesti eläkkeiden rahoituksen kestävyyttä olettaen, että eläkemaksuprosentti pidetään vakiona. Eläke-etuuksiin vaikuttaa uutena tekijänä ns. indeksijarru. Se perustuu tunnuslukuun, jota Ruotsin tapaan kutsutaan tasesuhteeksi. Jos tasesuhde alittaa tietyn kynnysarvon, sekä palkkakerrointa että eläkeindeksiä alennetaan. Jos tasesuhde myöhemmin taas ylittää kynnysarvon, palkkakertoimen ja eläkeindeksin kasvua nopeutetaan, kunnes indeksit päätyvät samalle tasolle kuin mille ne olisivat nousseet ilman jarrutusta. Jos tasesuhde pysyy huonona, sekä palkkakerroin että eläkeindeksi voivat jäädä pysyvästi alemmalle tasolle kuin ilman jarrutusta. Indeksijarrun suora sovellus voi johtaa eläkejärjestelmän konkurssiin, tai rahastojen kasvuun rajatta. Nämä kehityspiirteet saattavat tulla esille vasta useiden vuosikymmenien jälkeen. Tasapainoisempi kehitys voidaan saavuttaa skaalaamalla jarrumekanismi sopivasti.

Asiasanat: nimellisesti maksuperusteiset eläkkeet, eläkerahastot, sukupolvittainen riskien jako

JEL-koodit: H55, J11

Introduction

Ageing populations put pressures on public pension finances throughout the world. The non-financial (or notional) defined contribution (NDC) approach and especially the way it is exemplified in Sweden is an interesting construction: it aims to keep pension contributions at a constant level and still to provide reasonable pensions. One key element is the balance mechanism, to be automatically applied if the finances appear insufficient.

The Swedish balance mechanism is based on the concept of 'balance ratio' – a ratio of assets to liabilities. When the ratio is below unity, it will act like a brake: it will slow down the indexation of notional pension accounts as well as of pension benefits. The principle is simple, but to design and implement it around a mostly unfunded pension system has required both innovations and imagination, and the Swedes deserve credit for that. One important aspect of the Swedish system and balance mechanism is that it has made the system very transparent in its annual reporting of flows and stocks.

If the contribution rate is constrained, the burden will fall on replacement rates. This is clear from the outset. What is not at all clear is when and how the burden will fall. This depends on how the world will turn out to be – especially, what will the demographic and economic future contain. We demonstrate this by applying the balance mechanism to the Finnish private-sector earnings-related pension system and simulating the future with a large number of different economic and demographic paths.

In Lassila and Valkonen (2007) we showed that a direct application of the brake to the Finnish pension system shifts risks into the future and to future generations. Depending on the contribution rate level, the brake system could be interpreted to be a form of postponing new decisions for decades, or a slow way of running down the system, or a way to pile up huge reserves. Here we extend the analysis, especially its time-span, and find that fiscal sustainability is not always granted. We then amend the brake, following the work by Auerbach and Lee (2006), and show that fiscal sustainability can be achieved by scaling the brake appropriately. Finally the benefits, contributions and generational rates of return under the brake system are compared with those under the current defined-benefit rules.

The balance ratio and the balance mechanism

Two elements are needed to construct the brake[1]. First, a summary measure of the financial situation of the pension system – the balance ratio. And second, we need to define how and when the measure affects pension benefits.

The value of contributions in a pay-as-you-go pension system depends on the degree to which the contributions can finance the pension liability. This means that the flow of contributions is compared to a stock of pension liabilities. The essential question is, how many years of contributions are related to the current stock of liabilities. The Swedish solution is the concept of expected turnover duration, which is the expected average time between when a contribution is made to the system and when the benefit based on that contribution is paid out.

[1] The brake, and the Swedish pension system, is described in e.g. Könberg et al. (2005), Palmer (2002), Settergren (2001) and Settergren and Mikula (2005).

Contributions multiplied by expected turnover duration indicate how large a pension liability can be financed by contributions given the income and mortality patterns prevailing in the period measured. The contribution asset *CA* is the product of the annual contributions *C* and the turnover duration *T*.

(1) $CA(t) = C(t)T(t)$

The second asset of the system consists of possible pension funds. Sweden has buffer funds, and their value is added to the contribution asset, to get the total value of assets.

Pension liabilities are those pension rights that have been accrued up to the time of calculation. In a defined benefit system the evaluation of the rights involves several technical choices, but the heuristically the issue is clear.

Denoting the balance ratio by *B*, the pension liability by *D* and the pension funds by *F*, we can define the balance ratio the ratio of assets to liabilities, as follows.

(2) $$B(t) = \frac{CA(t-1) + F(t-1)}{D(t-1)}$$

If the balance ratio is bigger than one, the total value of the contribution asset and the pension funds exceeds the liabilities, and the finances appear sound. If not, the balance mechanism is turned on.

An essential feature of the Swedish balance mechanism is that no forecasts are used. Only observed values of the variables are used. This choice is dictated partly by the aim of avoiding possible manipulation of the terms in the balance ratio. Forecasts are easier to manipulate than observed data. The downside of this choice is that no future changes can be taken into account ex ante. Even though the ageing of the population is foreseen, it does not affect the brake until it happens. This may postpone the adjustment of the pension system (when compared to a corresponding forward-looking automatic rule).

We have applied equations (1) and (2) directly to the Finnish system. In the Finnish private-sector earnings-related system (henceforth called by its Finnish abbreviation **TyEL**), both pension rights and benefits are index-linked, with 80 – 20 weights on wages and consumer prices, respectively, during working years and 20-80 weights after retirement, irrespective of retirement age. The index can be described by a function $I(t,\lambda)$ stating that the change in wages *w* from the base period 0 to period *t* is weighted by λ and the change in consumer prices *p* is weighted by 1-λ. Employee's contribution *e* is deducted from wages in this calculation.

(3) $$I(t,\lambda) = \left(\frac{w(t)\left(1-e(t)\right)}{w(0)\left(1-e(0)\right)} \right)^{\lambda} \left(\frac{p(t)}{p(0)} \right)^{1-\lambda}$$

The balance mechanism uses the numerical value of the balance ratio to diminish the changes in pension benefits and pension rights that come from indexation. With low balance ratios, the changes may become negative. When the balance mechanism is triggered for the first time the function $J(t,\lambda)$ is applied:

(4) $$J(t,\lambda) = B(t)I(t,\lambda)$$

When the balance mechanism continues to be on, the previous index value *J* is multiplied by the new balance ratio value and the change in the basic index *I*.

(5) $$J(t,\lambda) = J(t-1,\lambda)B(t)I(t,\lambda)/I(t-1,\lambda)$$

If the balance ratio again exceeds 1 and the balance mechanism goes off, equation (5) continues to be applied as long as long as $J(t,\lambda) \le I(t,\lambda)$. After that the index *I* will be applied. This means that if the balance is restored for a sufficiently long period, not only is balancing switched off but also the index effects that cumulated are cancelled.

How the balance mechanism performs

We turn to the effects of applying the balance mechanism in the TyEL system. The effects depend crucially on future demographics, especially the old-age dependency ratio, and on the evolution and yield on pension funds. The numerical results have been produced with an economic simulation model (described more closely in Appendix) using stochastic population simulations and stochastic asset yields as inputs[2]. Thus following results are conditional on the assumption that uncertainty about the demographic and financial market outcomes is similar that we have witnessed in the history.

For demographic uncertainty, we utilize the recent (2006) stochastic population forecast made for Finland by Juha Alho. The forecast is produced by estimating stochastic models for fertility, mortality and migration, as explained in Alho, Cruijsen and Keilman (2008), simulating these models 3000 times and compiling the results with a cohort component method. The resulting populations vary around a non-stochastic population projection which has a total fertility rate of 1.8, annual net immigration of 6000 – 7000 for the first 50 years and zero after that, and increasing life expectancies for the next 100 years.

The estimated stock market yield is based on Finnish Stock Exchange data (OMXHCAP) from years 1927-1999. The average real rate of return on stocks is set to 6 percent, with variance of 10.97. The real interest rate data is from the IMF Financial Statistics. We use German bond data from years 1955-2005, because of the too short time series of usable Finnish data. The average value for the real interest rate is set to be 2.5 percent, with variance of 0.87. Since the unit period in the model is 5 years, we use 5 year averages of the yield variables. Bond and stock yields are assumed non-correlated.

It is not obvious what the fixed contribution rate is that should be used when calculating the balance ratio. This is especially true in the TyEL scheme, where the baseline contribution rate projections show an increasing trend during the next 25 years.

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[2] The use of stochastic population simulations as inputs into a numerical OLG model is described more closely in Lassila and Valkonen (2007) and Alho et al. (2005).

Figure 1. Probabilities of braking, bankruptcy and excess funding

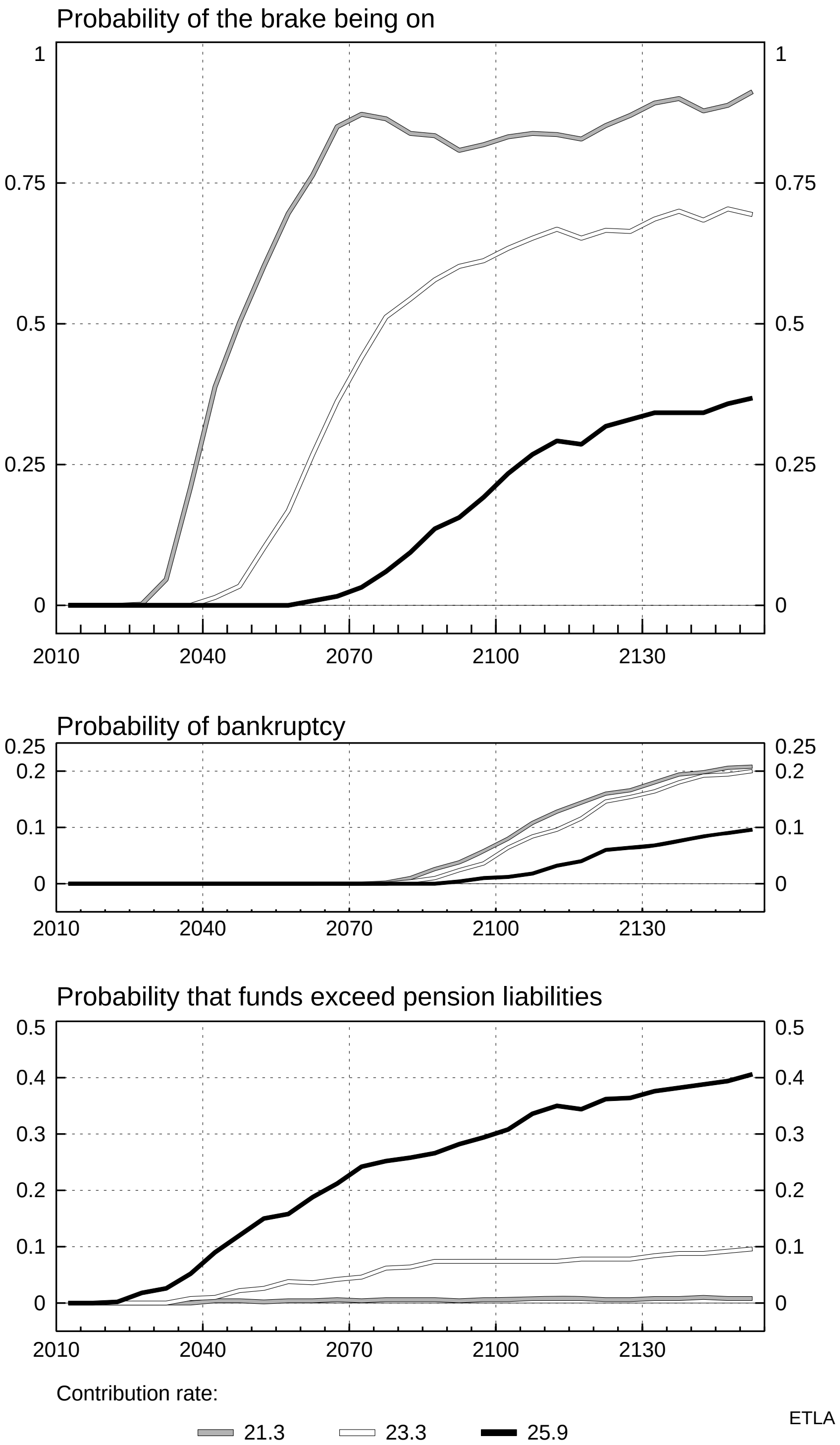


Figure 1 depicts three probabilities. The first is the probability that the brake takes effect. The second is the probability that the system would go bankrupt. This means here the possibility that the balance ratio becomes negative – instead of funds the system is in debt, and the debt is larger than the contribution asset. With our numerical choices, in these cases the contribution revenue is always smaller than the interest payment requirement, and debt grows even though the system does not pay benefits anymore. The third probability is that of the funds alone growing larger than the pension liabilities. The system could then be described as more than fully funded. This would be a huge change from the current situation of partial funding, where only a third of pension benefits are paid out from funds. With the brake, and especially with the higher contribution rates, the funds may in fact grow without limit, if nothing is changed[3].

All probabilities are calculated assuming either that current contribution rate (21.3) will be fixed, or that the contribution rate will be raised by two percentage points (23.3) or to a level which would balance the system in the expected case (25.9). The probabilities naturally vary between these choices.

The uppermost line in Figure 1 shows that keeping the contribution rate at the current level does not generate any brake-based adjustments in pensions during next 20 years. After that the probability of braking increases steadily to reach 75 % after 50 years. The two other lines show that raising the contribution rate immediately both postpones the time and lowers permanently the probability of the brake mechanism taking effect.

In our opinion, the middle part of Figure 1 is what matters most. The system can go bankrupt. With the two lowest contribution rate levels the probability eventually exceeds 20 %, and even with the highest contribution rate the probability reaches 10 %. But in all cases the system would survive at least the first 70 years. This shows that the balance mechanism is truly a long-run device – close to one hundred years is a minimum period to evaluate its effects in Finland.

Second attempt – scaling the brake

Direct application of the brake mechanism within the TyEL system yielded a significant probability of bankruptcy. Thus it must be considered a failure – it did not guarantee fiscal sustainability.

Auerbach and Lee (2006) studied the NDC concept within the U.S. social security type of system, and found it effective at preventing excessive debt accumulation. Instead of applying the brake directly, they scaled it (Auerbach and Lee 2006, p. 16). We follow that practice but in a different way – we divide the balance ratio by its median value in period 2005 – 2009. Denoting the median value by $\overline{B}$, we define a scaled balance ratio B^* as follows.

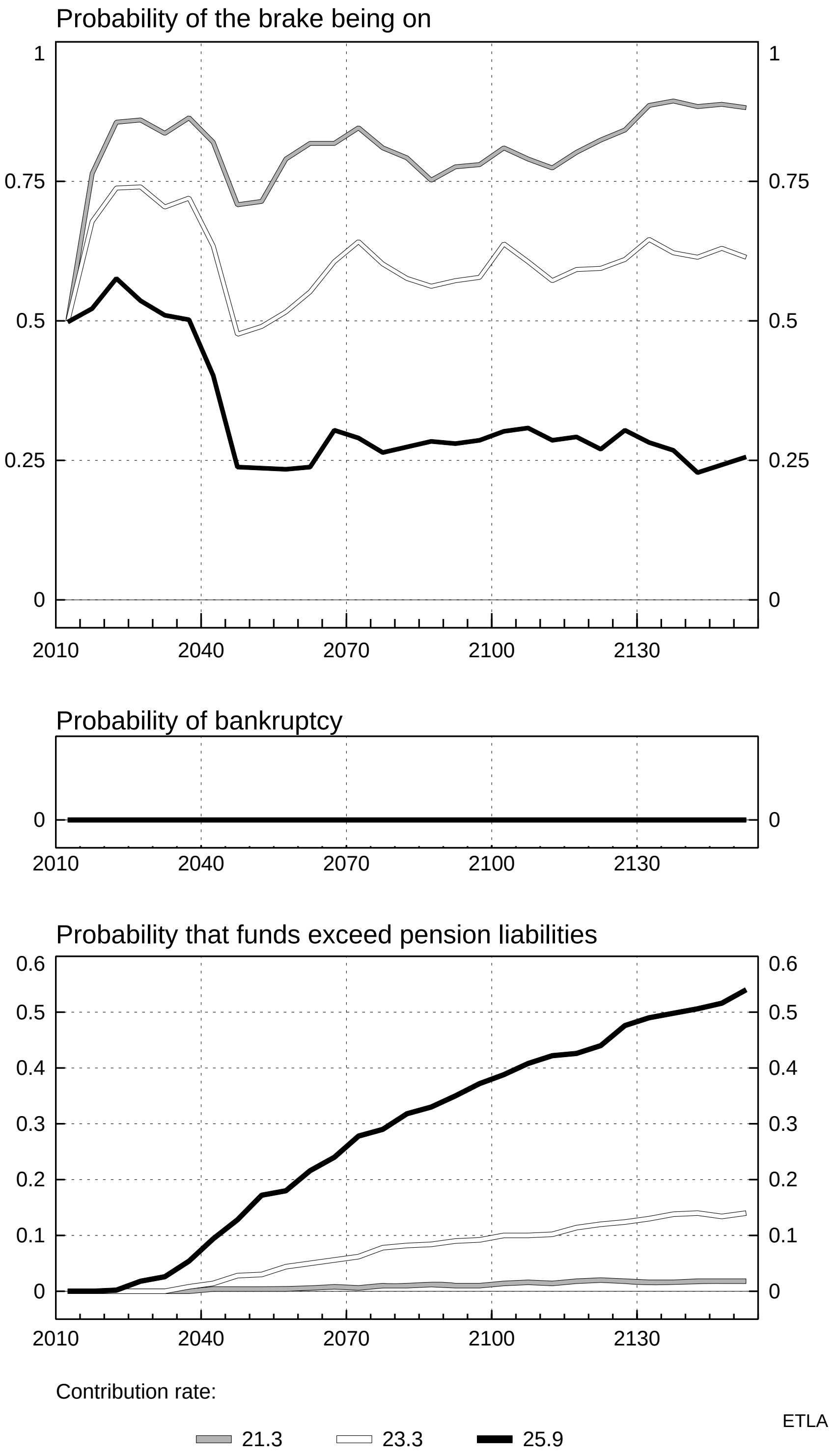
(6) $B^*(t) = B(t)/\overline{B}$

We then replace *B(t)* with $B^*(t)$ in equations (4) and (5). The median value is larger than one with all three contribution rate levels considered. After scaling the brake mechanism works as before - if the value of the scaled balance ratio falls below one, the brake will take effect.

There is a drawback in scaling: the rhetoric becomes less persuasive. With the original unscaled balance ratio one could say that benefits must be cut because assets are smaller than liabilities. With the scaled balance ratio, one can say that benefits must be cut because assets only exceed liabilities by less than some pre-specified value. That does not sound quite convincing.

3 Auerbach and Lee (2006) report a similar outcome in their application to the U.S. social security.

Figure 2. Probabilities of braking, bankruptcy and excess funding with the scaled brake



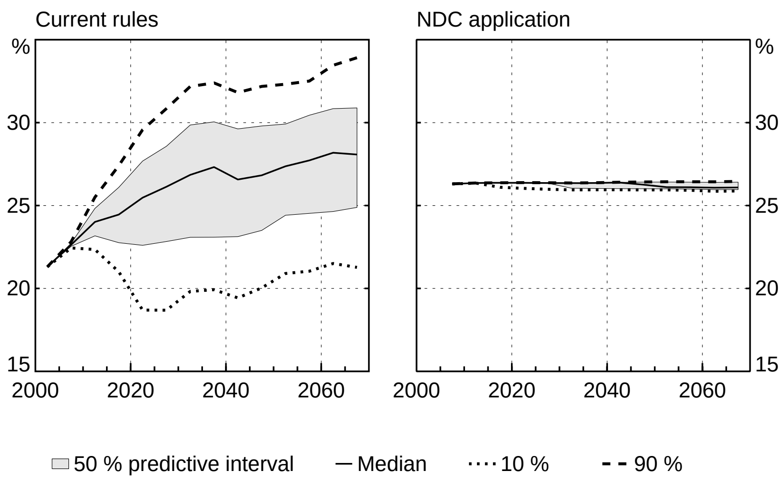
Scaling produces financial sustainability. As the middle part of Figure 2 tells, the probability of bankruptcy is zero – in all 500 simulated cases the balance ratio remained positive. Comparing the top parts of figures 2 and 1 we note the brake now becomes on earlier than with the unscaled brake. It prevents the system from running down the assets too much before braking, and that suffices. With the current contribution rate the brake would be on with a high probability. Increasing the contribution rate level decreases the need to brake, but even with contributions at the expected sustainability level the brake will be on in a quarter of cases.

The bottom parts of figures 2 and 1 show that the probability of excess funding becomes larger with scaling. In practice the rapid growth of funds would be stopped, probably by increasing benefits or lowering the contribution rate[4].

How a Finnish NDC would perform

Because the scaled brake seems to produce financial stability, we next develop an NDC application to the TyEL system. The current TyEL system follows the defined benefit principle, but will apply longevity adjustment to new pensions after 2010 (see Lassila and Valkonen 2008). The NDC application consists of only three changes to the current rules. First, contribution rate level is fixed. Second, the scaled brake, as described in the previous section, will be applied if needed. Third, in cases where the scaled balance ratio exceeds some prespecified level, which is greater than one, both the indexing of benefits and accruals will be increased and the employers will get some of their contribution payments back. The index increases follow the principles discussed in Sweden. The contribution reliefs mimic the current Finnish practice where competing private pension firms that run the statutory pension system can pay back contributions to client employers if the fund returns have been favourable.

Figure 3. Contribution rates under current rules and the NDC application



We only describe the NDC outcomes for the contribution rate that would balance the current system under expected case. Figure 3 shows the contribution rates under the two systems. The variation in the NDC case is due to the payment reliefs that have been subtracted from the constant rate level of 25,9 %. The predictability of future contribution rates is low in the current Finnish defined-benefit system, whereas even with payment reliefs the contributions are almost perfectly predictable in the NDC application. Qualitatively this is what one would expect, but quantitatively the difference may be surprising.

[4] "The Swedish discussion so far has lent toward increasing the indexation if there is a surplus. A government committee has investigated the issue and suggested that if the balance ratio exceeds 1.1000 the normal indexation should be speeded by the balance ratio / 1.1000. However, no legislation on this has been put to parliament" (Comment by Settergren).

In the NDC system the risks are shifted from the contributions to the benefits. This can be seen in Table 1.

Table 1: Pensions in ages 65 – 69 relative to wages in the Finnish TyEL system, %

	d1	Q1	Md	Q3	d9
	Current rules				
2030	45.2	46.4	47.9	49.5	51.3
2050	40.1	41.8	44.1	47.0	49.7
2070	38.0	39.6	41.9	44.6	46.7
2090	36.1	37.7	39.6	41.9	43.8
2110	35.0	36.5	38.1	40.1	41.6
	NDC with contribution rate 25,9 %				
2030	40.5	42.8	45.7	47.8	49.7
2050	37.8	41.6	44.9	49.3	54.8
2070	36.4	40.0	44.5	50.0	58.5
2090	31.1	37.0	42.2	49.1	60.1
2110	27.6	33.8	40.1	49.1	61.5

The ratios are those of the average pension of retired persons, with medium-level education, in age group 65 – 69, to the average wage income of workers with the same education level. Md denotes the median, Q1 and Q3 the first and third quartiles and d1 and d9 the first and ninth deciles. The distributions are based on 500 simulations.

The fall in the median value of the relative pension rate is due to the lower future old age mortality rates, which affects the longevity adjustment. Uncertainty in future longevity explains most of the variation under current rules in Table 1. The variation is definitively larger under NDC than under current system.

Figure 4 takes a closer look at the whole old-age periods of two cohorts. The older cohort, born in 1955, is likely to be worse off in the NDC application. As shown in Figure 2, the brake would often affect their benefits. There is, however, some chance of higher benefits also. The younger cohort will face a much larger uncertainty in their benefits under NDC than under current system. On average (looking at the median) they will be better off. There is some chance that they could be much better off. But they could also see their pensions fall very low compared to average wages.

The NDC system would redistribute resources between generations. The outcome depends on the future trends in the economy and demographics. We describe the results by calculating internal rate of return (IRR) for paid contributions for each 5-year birth cohort.

There are some assumptions that should be mentioned. The annual trend in labour productivity growth is 1.75 percents and the expected yield of pension funds is 3.9 per cent. Since we have a partially prefunded pension system, a steady state IRR for pension contributions is well over 2 percent, when current rules are followed.

Raising the contribution rate to 25,9 per cent immediately would reduce the median IRRs for current working-age cohorts and increase the IRRs of future generations. The uncertainty becomes larger for future generations, but this also means good chances for higher IRRs than under the current system.

Figure 4. Pensions relative to wages for two cohorts, %

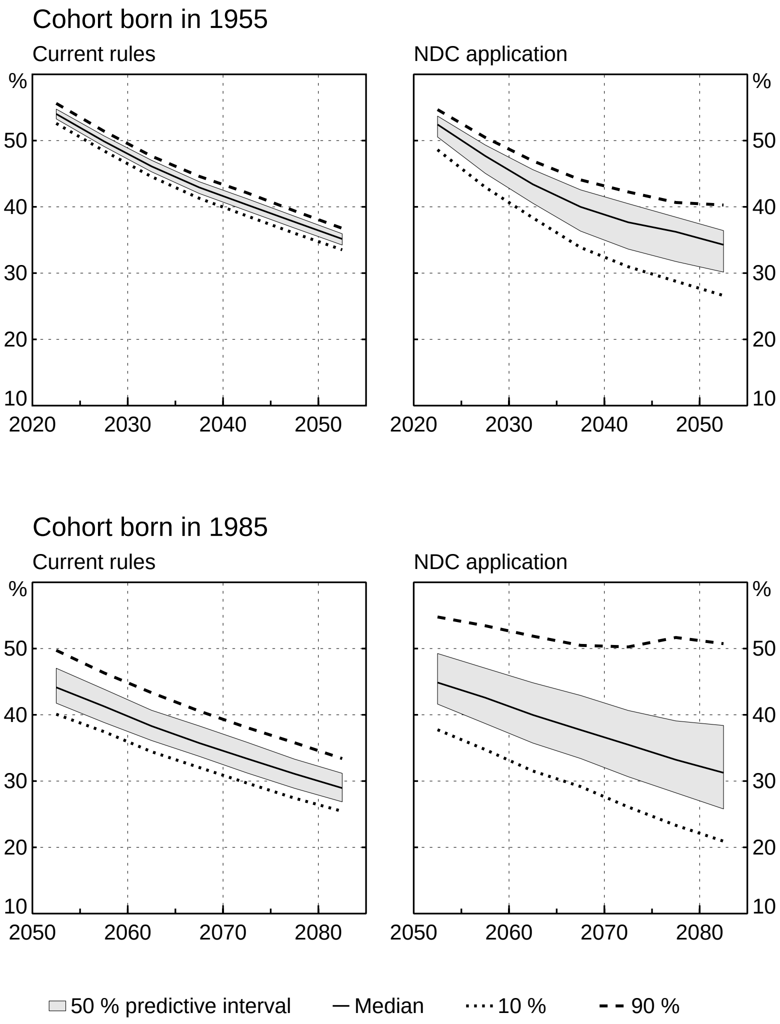
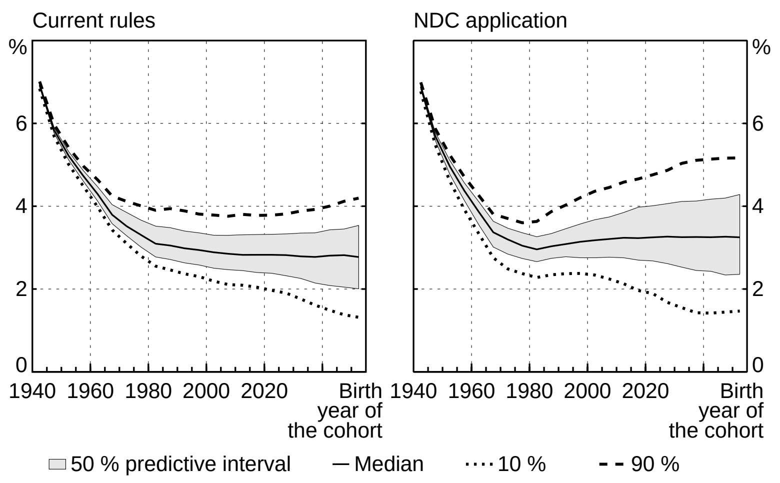


Figure 5. Internal rates of return by cohort



It appears that moving to an NDC system includes a trade off between more predictable contributions and more risky benefits. It may be, however, that the previous results exaggerate the effects. The real question may be whether the NDC system is more credible than the current defined-benefit system. There is a chance that instead of increasing the contribution rates to the required level, depicted in Figure 3, the benefits will be cut. If that is the case, then the figures above give too narrow an impression of the benefit risks under current rules (and too large impression of the contribution risks). If NDC is more credible, then trade-off is actually between more predictable contributions and more reliable benefit rules.

Conclusions

The Swedish balance system has been praised as a politically stable way of tying down the pension contributions. But the jury is still out. Final evaluation depends on the likelihood of socially and politically unsustainable outcomes, measured here by the pension replacement rate and the internal rates of return for different cohorts.

The Swedish balance mechanism is by no means a general panacea, to be used wherever pension finances are under threat. We tested the brake within the Finnish private-sector earnings-related pension system, with different levels of contribution rates. If the balance mechanism is applied directly, the price of keeping the contribution rate constant is the additional risk that is put to pension benefits. That risk turned out to be substantial, especially for future generations. The system may well go bankrupt. The risk may materialize far in the future, if the funds are significant as they are in Finland, but already concerns cohorts that are being born now. The downward risk can be mitigated by starting with a higher contribution rate, but then the chances of pension funds growing very large increase. This would probably lead to higher pensions in the future, and thus be generationally unfair to the opposite direction. In our application, a direct application of the brake mechanism shifts both positive and negative risks towards the future. The balance ratio is an artificial concept; although the funds and the liabilities are natural and well-defined concepts, the contribution asset is not. Thus pretending that it is crucial whether “assets” exceed liabilities or not restricts the brake too much.

A simple scaling of the balance mechanism will, however, produce financial stability of the system. Pension benefits, contributions, and internal rates of return by different cohorts under a full NDC application can then be compared to the current DB system. The comparison shows that NDC provides an alternative with some lucrative features, and some features that raise doubts. Credibility of the rules, whether they are NDC or DB, seems an inevitable issue.

Some preliminary remarks on two issues can be made. First, the brake could perform differently if the indexation of accruals and benefits would be different. The obvious alternative would be indexation to the contribution base. The number of contributors would then affect pension expenditure directly. That might leave a smaller role for the brake. Indexation to the contribution base was part of the original design in Sweden, but that was changed during the political process.

Second, it seems that the contribution asset could, and perhaps should, be defined so that it indicates future changes in population. This would not require using any forecasts, and thus would not be any more prone to manipulation than the current definition. The number of children, e.g., does predict the future size of the labour force, so observed variables could be used but the resulting contribution asset would reflect the future of the contribution base.

The balance mechanism, and the whole NDC approach, is an interesting and innovative solution concept. The idea of fully freezing the contribution rate is probably being considered in several countries. There are several choices to be made, however, leading to widely different outcomes. Before applying a balance mechanism, we recommend testing and simulating it to a much larger extent than carried out anywhere thus far. Our results show that the horizon must be very long, well over 100 years. That in itself creates difficulties in assessing the uncertainties quantitatively.

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Appendix 1 The economic model

We simulate the economic impacts of introducing the Swedish balance mechanism by using a perfect foresight numerical overlapping generations model of the type originated by Auerbach and Kotlikoff (1987). There are five sectors: households, enterprises, a government, a pension fund and a foreign sector. The labour, goods and capital markets are competitive and prices balance supply and demand period-by-period. There is no money or inflation in the model. Households and firms are forward-looking decision-makers. The unit period is five years, and the model has 16 adult generations living in each period.

The model is adjusted to imitate the Finnish economy by a process of calibration. First, parameters for household behaviour (e.g. preference for leisure) and production technology (e.g. substitutability of capital and labour) are extracted from the economic literature and used to generate numerical versions of those model equations describing the dynamics of the economy. The current and future household cohorts are then aggregated using population statistics and forecasts. Finally, the model is scaled so that the outcomes resemble the key macroeconomic, public sector and household statistics for recent years. The earnings-related pension system is gradually brought into the model starting from the 1960s.

Household behaviour

Individuals make economic decisions according to the life-cycle hypothesis. They maximise the utility from consumption and leisure in different periods and the bequest that they give. The lifetime budget constraint says that discounted lifetime wage and pension income and discounted received bequest and transfers equal discounted consumption expenditure and the given bequest. Households consider the possibility of early death by discounting future consumption and incomes by a factor that includes both the interest rate and the age-specific survival probability.

Retirement occurs at the age of 65 at the latest. At ages below 60 an exogenous share, increasing with age, of persons retire due to disability. There is also an endogenous retirement decision in the 60 – 64 age group. In that group the price of leisure, besides lost wage income and discounted effects on future pensions, also includes the amount of pension one can have if retiring then. Part of the leisure so decided is interpreted as a decline in the share of people working, and the share of those retiring at the age of 65 is reduced correspondingly. The elasticity of retirement to early pensions (and resulting changes in future pensions) is calibrated to observed behaviour in Finland between 1970 and 2004, taking into account the developments in the unemployment rate at ages 60 – 64 and changes in the eligibility and other rules of unemployment pensions and early old-age pensions.

Decision problem for firms

Firms choose the optimal amount of investment and use of labour to maximise the price of their shares. The market value of the firm is determined as a discounted sum of future dividends. The problem can be presented as maximising at the beginning of the period the dividends distributed during the period plus the value of the firm at the end of the period, subject to the amount of initial capital stock, the cash-flow equation of the firm, the CES production function, the accumulation condition of the capital stock, the determination of the firm's debt and the investment adjustment costs.

Markets

The model includes four markets, which clear every period. In the labour market, firms demand labour according to the marginal productivity of labour rule. Households' aggregate labour supply is divided between public and private employment. The wage rate is determined by equating supply and demand in the labour market.

Firms are the sole suppliers of the domestic good in the market. The product is used by other firms as part of the composite intermediate and investment goods, by households as part of the composite consumption good and by foreign agents. The domestic agents demand and the prices of the composite goods are determined by a cost minimising procedure. Domestic demand for fixed-price imported goods is also determined by minimising the costs of the composite goods. The perfectly elastic supply adjusts to demand in this market. The fourth market is the capital market, in which saving and investment are balanced by the domestic interest rate. In the simulations we use a model version in which the interest rate is set equal to the rate in international capital markets. In this case total saving is the sum of domestic saving and foreign portfolio investments.

The presentation above only describes the most relevant parts of the model. The actual model includes a local and a central government, both with intertemporal budget constraints, and trade and capital flows with the rest of the world.

The TyEL system

The earnings-related pension system aims to provide sufficient retirement income to cover consumption comparable to levels enjoyed during working years and to current workers' consumption. It covers risks related to old age, disability and death of family earners. In cases where the earnings-related pension is absent or insufficient, the national pension guarantees a minimum income. Both of these first-pillar systems are mandatory. Voluntary pensions are still of minor importance in Finland but are becoming more common. Below we describe the private sector earnings-related system.

Benefits

The pensions can be thought of as consisting of both disability pensions and old-age pensions. Every year's earnings and accrual rates directly affect the future pension. The accrual rate is 1.5 % per year between the ages of 18 and 53 and 1.9 % between the ages 53 and 62. Between the ages 63 and 68 the accrual is 4.5 % per year, aiming to reward later retirement in a cost-neutral way.

Both pension rights and benefits are index linked, with 80-20 weights on wages and consumer prices respectively during working years and 20-80 weights after retirement, irrespective of retirement age. In the model, function $I(t,u,\lambda)$ states that the change in wages w from period t to period u is weighted by λ and the change in consumer prices p is weighted by 1-λ. Employee's contributions e are deducted from wages in this calculation.

$$(7) \qquad I(t,u,\lambda) = \left(\frac{w(u)\left(1-e(u)\right)}{w(t)\left(1-e(t)\right)} \right)^{\lambda} \left(\frac{p(u)}{p(t)} \right)^{1-\lambda}$$

We denote the accruals with *k(x)* where *x* refers to age. If retirement occurs due to disability, the pensioner is compensated for lost future accruals. The compensation depends on the age at the time of the disability event; we denote it by $f(\tilde{x})$ where $\tilde{x}$ refers to the age during the last working period. After receiving the disability pension for five years there is a one-time level increase in the pension. This increase is 21 % for a person aged 26 or less, and smaller for older persons, so that those aged 56 or more get no increase. This feature is denoted by $a(x,\tilde{x})$. Thus the pension benefit *b*, without longevity adjustment, for an individual *i* in age group *x* who retired at age $\tilde{x}+1$ and had earned wage incomes denoted by *y* is as follows.

$$(8)\quad \begin{aligned} b_i(t,x,\tilde{x}) &= a(x,\tilde{x})\sum_{s=1}^{z} k(s)y_i(t-s)\big(1-e(t-s)\big)I(t-s,t-x+\tilde{x},0.8)I(t-x+\tilde{x},t,0.2) \\ &+a(x,\tilde{x})f(\tilde{x})y_i(t-x+\tilde{x})\big(1-e(t-x+\tilde{x})\big)I(t-x+\tilde{x},t,0.2) \end{aligned}$$

where $x > \tilde{x}$.

Longevity adjustment

The pensions are adjusted for increasing life expectancy simply by taking the increasing longevity into account in the value of the annuity. The adjustment coefficient is a ratio of two present values of a unit pension, calculated at two different periods. The present value of a unit pension, which begins in period *t* and is calculated forward from age 62, is as follows.

$$(9)\qquad A(t,62) = \sum_{s=63}^{100} S(t-1,62,s)/(1.02)^{s-62}$$

The present value of a unit pension is a discounted sum of terms generated during various retirement years. The terms have two parts. The first term, *S*, expresses the survival probability from age 62 to age *s*, and the first subscript of the term demonstrates that the probability is evaluated using information available in period *t*, when the latest the observed mortalities are from period *t-1*. The survival probabilities are actually five-year moving averages. The second term is the discount factor where the discount rate is 2 % per year. In the model individuals die at the age of 100 at the latest.

The pension of a person born in period *t* – 62 is multiplied by the longevity adjustment coefficient *E(t,*62*)* after age 62. The coefficient is a ratio of two *A*-terms as follows.

$$(10)\qquad E(t,62) = A(2009,62)/A(t,62)$$

The median *Md*, the first and third quartiles *Q*, and the first and ninth deciles *d* for the predictive distribution of the adjustment factors in 2030 and 2050, calculated from the 500 population paths in this study, are as follows.

year	d_1	Q_1	Md	Q_3	d_9
2030	0.86	0.89	0.91	0.95	0.98
2050	0.79	0.82	0.87	0.91	0.97

We expect the adjustment coefficient to decline to about 0.87 in 2050, with an 80% prediction interval [0.79, 0.97]. These intervals are valid providing the volatility of the trends of mortality during the next 50 years does not exceed the volatility of mortality during 1900-1994.

Prefunding at the individual level

The Finnish earnings-related system has collected substantial funds to smoothen the contribution increases due to population ageing in the future. Funding is collective but based on individual pension rights. Individual pension benefits do not depend on the existence or yield of funds. Funds only affect contributions. When a person receives a pension after the age of 65, his/her funds are used to pay that part of the pension benefit that was prefunded. The rest comes from the PAYG part, the so-called pooled component in the contribution rate.

Equations (11) and (12) describes new funding for an individual *i*. A share α of the present value of the pension right accruing in period *t* to workers in the age range 18 - 54 is put in the funds. The present value includes all old-age pension years, from 65 to a maximum age assumed to be 100. The labour income *y* creates a pension right for each year in old age. For prefunding purposes, the magnitude of the pension right is evaluated ignoring all future changes due to wage or price developments. Thus the value of the right is simply *k* times the labour income, without the employee contribution part, for each retirement year. Discounting includes both the survival probabilities *S* and the so-called fund rate of interest *q*, which is administratively set. For individual *i* aged *x*, the amount funded in time *t* for the period *t*+ *z* in retirement is $g_i(t,x,z)$ and the total amount funded for her is $h_i(t,x)$.

(11) $$g_i(t,x,z) = \alpha k(x) y_i(t)(1-e(t))S(t-1,x,z)/(1+q)^z$$

where *x* = 18,…, 54.

(12) $$h_i(t,x) = \sum_{j=65}^{100} g_i(t,x,j-x)$$

Equation (13) states that for a retired person the amounts prefunded earlier (when the current pensioner was between the ages of 18 and 54) for period *t*'s pension, with the interest accrued to them with rate *r* and leading to a total amount *v*, is used to pay a part of the pension expenditure in period *t*. The interest accrued is assumed to be the market yield of a portfolio with fixed shares of bonds and stocks.

(13) $$v_i(t,x) = \sum_{j=18}^{54} g(t-x+j, j, x-j) \prod_{s=j}^{x} (1+r(t-x+s))$$

where *x* = 65,…, 100.

Contribution and replacement rates

The equations (11) and (13) are important for the aggregate dynamics of the pension system, especially for the level and time path of the contribution rates.

Let *n(t,x)* be the number of workers and $\overline{h}(t,x)$ the average amount of new funding per worker in age *x* in period *t*. The total amount of new funding in period *t* is obtained by multiplying the average individual funding in age group *x* by the number of workers in the age group, and summing over all age groups where funding takes place. Analogously, *m(t,x)* is the number of retired persons and $\overline{v}(t,x)$ is the average amount withdrawn from the funds per retiree in each age group, and the total amount withdrawn from the funds is obtained by multiplying the average withdrawals by the number of retirees and summing over relevant age groups. Three other aggregates are defined in a similar fashion: the total wage bill from which the pension contributions are collected, denoting the average wage income at age *x* by $\bar{y}(t,x)$, the total amount of earnings-related pension expenditure, denoting the average pension of retired persons by $\bar{b}(t,x)$ and the total amount of other transfers from the pension sector, denoting the average transfer per person by $\bar{s}(t,x)$.

The time path of the contribution rates is given by the equation (14). Besides employees, employers must also pay contributions, which we denote by *c(t)*, based on the wage bill. The left-hand side of the equation is the total amount of contributions. That must be sufficient to cover that part of the pension expenditure (first term on the right-hand side) that does not come from withdrawals from the funds (second term), plus new funding (third term), plus transfers (the final term).

$$\begin{aligned}\left[c(t)+e(t)\right]\sum_{x=18}^{64} n(t,x)\bar{y}(t,x) &= \sum_{x=18}^{100} m(t,x)\bar{b}(t,x)-\sum_{x=65}^{100} m(t,x)\bar{v}(t,x)\\ &\quad+\sum_{x=18}^{54} n(t,x)\bar{h}(t,x)+\sum_{x=18}^{100}\left[n(t,x)+m(t,x)\right]\bar{s}(t,x)\end{aligned} \tag{14}$$

Employer contributions were on average 16.8 % and employee contributions 4.6 % of wages in 2004. Future changes have been agreed to be shared 50-50 between employers and employees. Since 2005, employees aged 53 and over pay contributions that are about 1.27 times that of younger employees, reflecting their higher accrual.

When we speak about *the* contribution rate we mean the sum of employer and employee contribution rates, where the latter is weighted from the age-dependent rates with corresponding revenue shares. By the replacement rate in age group *x* we mean the ratio of the average pension of retired persons $\bar{b}(t,x)$ to the average wage income $\bar{y}(t)$ of all workers.

Internal rate of return

As an intergenerational measure of the connection between benefits and contributions, we calculate the internal rate of return for each cohort. When discounted with the internal rate, a cohort's discounted sum of benefits from the pension system equal its discounted sum of payments to the pension system. The benefits include all pensions and transfers from the earnings-related pension system. The internal rate of return $\rho(t)$ for the cohort born in period *t* is such that equation (15) holds.

$$\begin{aligned}&\sum_{x=18}^{100} m(t+x,x)\bar{b}(t+x,x)(1+\rho(t))^{-x}+\sum_{x=18}^{100}\left[n(t+x,x)+m(t+x,x)\right]\bar{s}(t+x,x)(1+\rho(t))^{-x}\\ &=\left[c(t+x)+e(t+x)\right]\sum_{x=18}^{64} n(t+x,x)\bar{y}(t+x,x)(1+\rho(t))^{-x}\end{aligned} \tag{15}$$

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