

Demographic and Economic Uncertainties and the Evaluation of Sustainability and Adequacy of Pension Systems with numerical OLG models

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Abstract:

The relevant time horizon for pension policy is several decades. Therefore we know that the projected future demographic and economic trends that are used in forecasts are not likely to be realized. This leads to several interesting questions. How large is the uncertainty in pension variables, such as contribution rates and replacement rates? How the uncertainty affects the policy targets set and the policy instruments used? Is it possible to find and test policies or strategies, which affect both the expected value of the target variables and their distribution in a desired way? Answering to these questions necessitates the use of models, which describe the interaction of demographics, economic decisions and pension system rules. We show two examples of how numerical overlapping generations models can be used to simulate the effects of pension policy under uncertainty. The first studied policy is introduction of longevity adjustment, which cuts the pensions if life expectancy increases. The second policy is an amendment to prefunding rules, which allows more risky portfolios to pension funds.

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1. Introduction

The well-known fact that populations are ageing throughout the Europe has raised a need to reform the public pay-as-you-go pension systems. The pension schemes, which operated well in times of rapid growth of working-age population are now challenged by increasing number of retirees and diminishing number of workers. The sluggishness of the policy reactions can be traced back to unpopularity of retrenching pension politics and to the imprecise population projections. Previous experiences show that the demographic uncertainty is larger than people realize and there is no evidence that projections have become more accurate in time.

The most popular way currently to assess uncertainty is to calculate high and low alternatives in addition to the baseline forecasts. The best these can do is to give an idea of the sensitivity of the results to the alternative paths. There are several reasons, why this high-low approach is inadequate or even misleading method of dealing with uncertainty, see Lee and Edwards, 2002. Results of a recent questionnaire (see Ahn et al., 2006) reveal that alternative demographic scenarios have seldom affected policy.

Our approach combines economic analysis of population ageing with statistical analysis of demographic and economic uncertainty². We use a large number of sample paths from stochastic population and financial market yield models as inputs in a numerical overlapping generations model. This method gives us probabilistic description of the sustainability and adequacy indicators related to both current rules and to the reformed pension system. Third used criterion is intergenerational redistribution.

This paper presents two examples of the questions, which can be studied by the method. Both of them are actual policy changes that have recently been implemented in Finland. We concentrate on the earnings-related pension system and on a representative member of a household, leaving thereby aside the intragenerational redistribution aspects.

The first policy measure is introduction of longevity adjustment of pensions, which aims to improve financial sustainability by lowering pensions, if longevity increases. The economic effects of longevity adjustment has been analyzed before with stochastic simulations by Alho et al. 2005, Fehr and Habermann, 2006 and Lassila and Valkonen 2007b, 2007c. Its effects have also been simulated as a part of a Swedish type Non-financial defined contribution (NDC) pension system, see Auerbach and Lee, 2006, and Lassila and Valkonen, 2007a. Longevity adjustment was also a part of a proposed comprehensive reform of the US social security system, see Diamond and Orszag, 2003. The effects of this reform package was simulated by the Congressional Budget Office, see CBO, 2004.

The second analyzed policy measure includes actually two parts which change the prefunding rules of the Finnish earnings-related pension system. They smooth the forecasted hump in the pension contribution rate and allow the pension funds to aim at

² This method was extensively used EU-financed project DEMWEL to evaluate ageing costs under demographic uncertainty and to study how this uncertainty affects policy goals and policy instruments.

higher investment yields by investing more in stock markets. There are some previous studies, which also simulate pension policy under financial market uncertainty see e.g., Bosworth and Burtless, 2002.

This paper proceeds as follows. In Section 2 we present our methodology in more detail. In Section 3 we introduce the policy measures, show the simulated outcomes and provide interpretation for the results. Section 4 concludes.

2. Methodology

The starting point for our study is that uncertainty over future demographic and economic trends affect profoundly the way how we analyze the current pension systems and design future pension policy. Population ageing represents itself a realization of a demographic risk. If seen earlier, the pension policy would have undoubtedly been different. More importantly, we always face the same uncertainty, when we make predictions about the outcomes of the current pension rules or any policy reforms.

It is not obvious how we should analyze pension policy under uncertainty. The first problem is to define which, from the point of view of sustainability and adequacy, are the most important sources of uncertainty. In pay-as-you-go pension systems, the obvious candidates are numbers of employed and retired people and the growth rate of labor productivity, which determines the growth rate of wages. In prefunded pension systems the rate of return on capital becomes also important. Considering a small open industrialized economy, where the interest rate as well as the rate of technological change is determined largely from abroad, it is easy to see that these economic risks are not easily controlled by the government. The same conclusion applies also to demographic risks, since population policy is not seen as very efficient in the long term.

After defining the relevant sources of risks, the second question is how to evaluate and measure the future uncertainty. Our approach is to estimate stochastic models using historical data and to simulate a large amount of future paths for the relevant variables. The resulting output can be used to describe future probabilities, assuming that uncertainty is similar in future as it has been in the past. This approach has become common in descriptions of demographic uncertainty (see, Alho and Spencer, 2005) and of short-term financial market risks.

The third step in stochastic pension policy analysis is to build an economic model, which will be used to simulate the effects of pension policies. In early versions of the analysis these models were very simple, see e.g., Lee and Tuljapurkar, 1998. The development of computational methods and computing capacity has improved dramatically the possibilities to model the demographic trends, economic behavior and the prevailing pension systems with a more policy relevant precision.

We use a numerical overlapping generations model (FOG), which is calibrated to the Finnish economy and which includes a detailed description of the rules of the Finnish

private sector pensions system. The households in the model have perfect foresight, e.g., they know in each of the simulated cases which of the sample paths of the stochastic population forecast and the pension fund yield is the relevant one³.

The final part of our analysis consists of producing two sets of simulations with the economic model: one for the current policy rules and one for the new rules. Comparing the outcomes gives information about the expected effects of the policy measure as well as probabilistic descriptions of the time paths of the target variables, such as pension contribution rates and replacement rates.

Description of risks

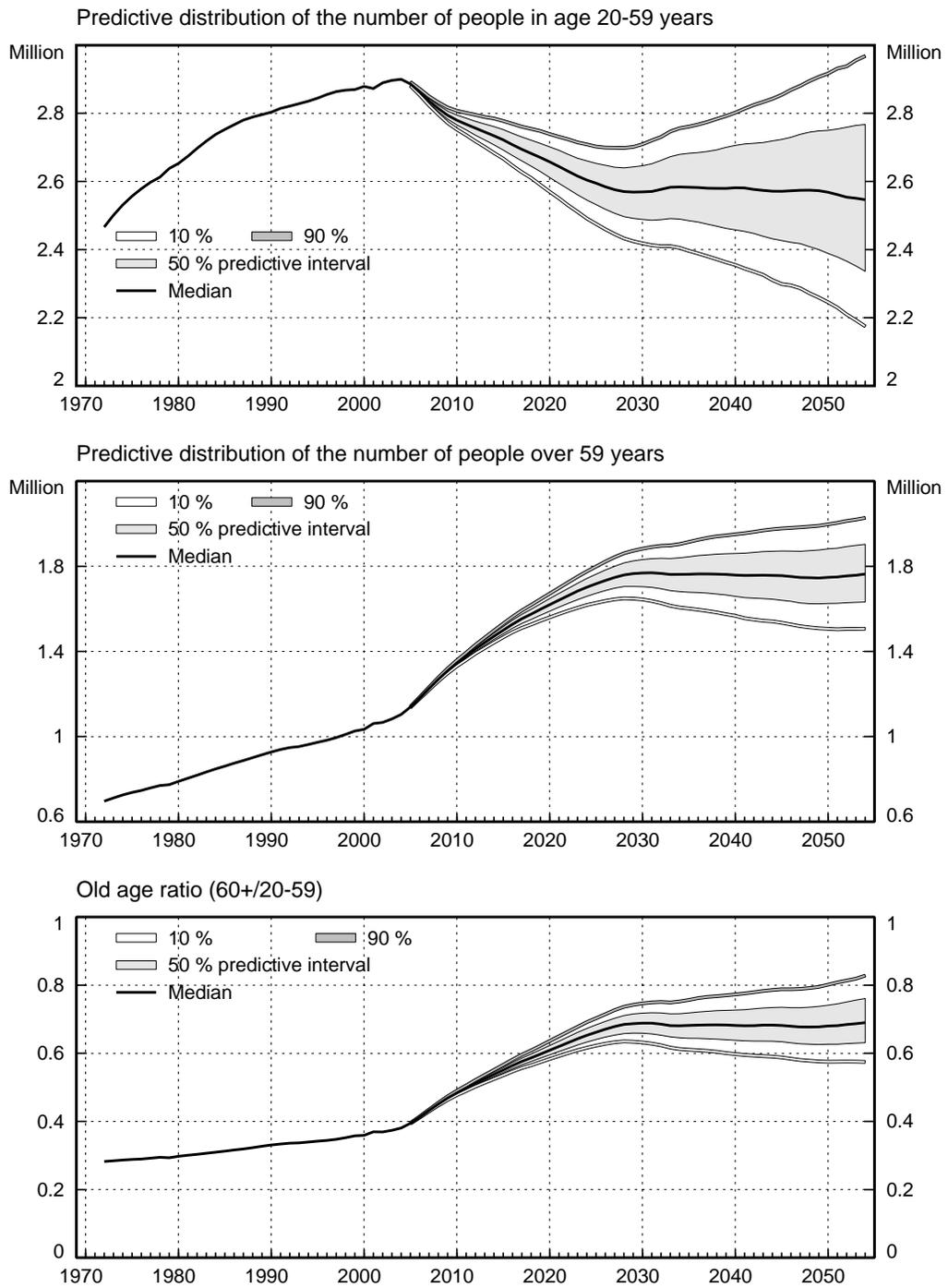
In case of demographic uncertainty, we utilize the recent stochastic population forecast made for Finland by Professor Juha Alho. The forecast is produced by estimating stochastic models for fertility, mortality and migration, simulating these models hundreds of times and compiling the results with a cohort component method. Figure 1 presents the outcome as predictive distributions of number of people in the given age groups.

The grey area depicts the 50 per cent confidence intervals for the number of people in the presented categories. For example, there is a 50 percent probability that the number of prime age workers in Finland is between 2.4 million and nearly 2.8 million in year 2050. Even allowing demographic uncertainty of the given size, the main message of the simulations is that we will see a strong population ageing taking place during next decades. It is also very likely that the old age ratio will stay at high level very long time.

Since most of the public expenditures are aimed at old age and most of the taxes are paid during working years, a permanent shift in old age ratio means that the sustainability of public sector finances is under considerable strain in the expected population path, but also that sustainability is permanently vulnerable to further demographic shocks.

³ In an optimal simulation model, the household would be risk-averse and consider both the idiosyncratic and aggregate demographic and financial market uncertainty in their utility maximizing decisions. These type of models with detailed description of pension systems do not, however, exist yet due to computational problems.

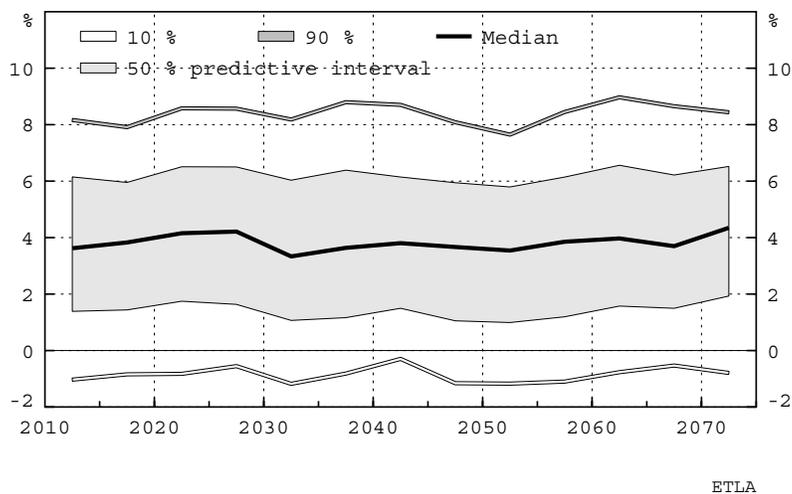
Figure 1. Demographic uncertainty in Finland



The other risk considered is the financial market yield available for pension funds. Data depicting various assets, geographical areas and time spans shows large differences for expected yield and the variation. Therefore we consider our results as indicative.

Figure 2 depicts the predictive distribution of the real returns in 500 simulations. It describes a yield of a portfolio with 40 percent allocated in stocks and 60 percent in bonds⁴. The figure shows that there is about 50 percent probability that the real rate of return is between 2-6 percents in each 5-year period. It also indicates how well 500 simulations suffice to describe the underlying distribution, which in the figure would be expressed with straight lines. The expected yield is 3.9 percents.

Figure 2. Asset yield uncertainty



The investment risk is allocated to the pension contributions in the Finnish defined benefit pension system. A higher rate of return increases the amount of money that can be used to pay pensions, and lowers thereby contribution rates. It affects the pensions only inasmuch that the lower employers' pension contributions limit the increase in wage index and thereby the index that is used to raise pensions (in case of Finland, the weights of consumer prices and wages are 0.2/0.8 during retirement years in that index).

Baseline stochastic projection

The next step is to run the economic model using the sample paths of the stochastic models as inputs.

⁴ 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 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. s.

We simulate first the baseline projection set using a perfect foresight numerical overlapping generations model of the type originated by Auerbach and Kotlikoff (1987). The FOG model consists of five sectors and three markets. The sectors are 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 described in more detail e.g., in Lassila and Valkonen, 2007b.

The simulated Finnish private sector pension system resembles many older occupational pension schemes, with large funds and operating with defined benefit principle, but it is mandatory and is defined as belonging to the first pillar. The reform of year 2005 improved a lot the efficiency of the system in a sense that there is now close link between earnings and pensions.

Figure 3 Predictive distribution of the private sector pension expenditures/wage bill

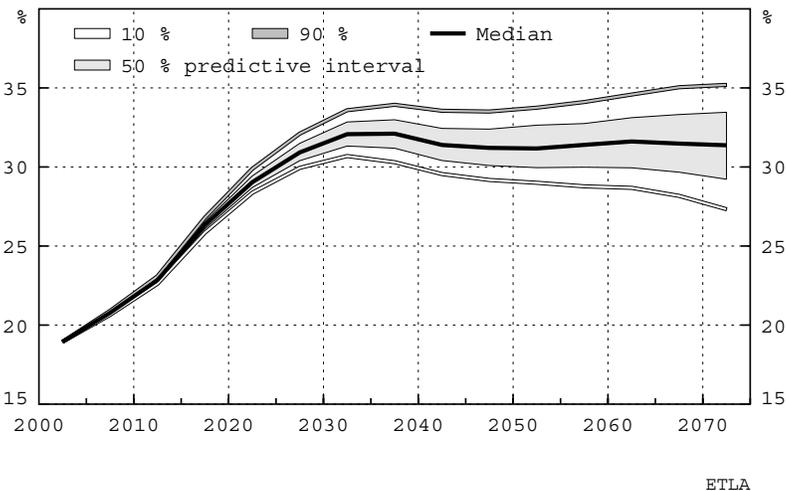


Figure 3 depicts the predictive distribution of the pension expenditures divided by the corresponding wage bill. It shows that the median of expenditures increases by 12-13 percentage points during the next few decades. The grey area describes the 50 % confidence interval. So it is quite certain that the expenditures will be much higher in future. It is useful to compare the outcome to the old age ratio described in the lowest section of the Figure 1. The similarity of the trends is very obvious and tells about the central role of demographic uncertainty in pension expenditure projections. Expenditure uncertainty would emerge earlier and be larger without longevity adjustment of pensions. The adjustment mechanism and its effects are explained in more detail in the next chapter.

3. Policy simulations

3.1 Longevity adjustment of pensions

In anticipation of future gains in life expectancy, several countries have passed laws that automatically adjust pensions, if life expectancy changes. The aim is to preserve the expected present value of future pensions. If benefits are received for more years, then pensions per year will be lower. Another reaction to longevity trends has been to raise set retirement ages.

In countries that have applied longevity adjustment or consider doing so, its expected effects have been investigated to some degree. However, the fact that future mortality developments are uncertain has not received much attention. For pension contribution rates this is not a serious deficiency; the adjustment itself takes care most of this uncertainty. But for monthly pension benefits and replacement rates this uncertainty exists. We study the economic effects of longevity adjustment under demographic uncertainty, using as an example the recently reformed Finnish earnings related pension system, where, from 2010 onwards, new old-age pensions will be affected by the rule.⁵

The exact details of the longevity adjustment are important for the intergenerational risk-sharing properties. Adjustment of currently paid pensions with continuously updated life expectancy estimates would be problematic for the retirees. Another policy option is to adjust pensions to the expected longevity of the cohort at the time of retirement. This option is in use in Finland and in Sweden. It allows reacting to surprises by adjusting the labor supply.

There are also two alternatives for the indicator of future longevity. The first is to use official cohort projections and the second is to use known ex-post cross-sectional survival data. Use of observed data provides stronger protection from political intervention and is therefore preferred in Finland and in Sweden. The obvious problem is the lagging realization of adjustments if longevity continues to increase. However, in the case of defined benefit systems, this approach may still be preferable since it generates larger expected cuts in future pensions than the adjustments based on forecast longevity. The reason is that the increase in longevity has already taken place in the base period's forecasts but not in the observed mortality rates.

Table 1 shows that longevity adjustment usually decreases the contribution rates, and the reduction is bigger the higher the rate would have been without the reform. Thus the longevity adjustment works very nicely as a cost saver. On the other hand, contribution rates are higher in demographic worlds where labor is scarce, wages higher and

⁵ The size of longevity adjustment is determined by a life expectancy coefficient. The coefficient is calculated comparing 5-year average of life expectancy data of a 62 year old birth cohorts from period 2003-2007 to the life expectancy of the birth cohort in question when it reaches age 62. If life expectancy increases, the coefficient will be smaller than 1 and the pensions will be cut by an amount directly indicated by the value of the coefficient. A more detailed description of the analysis and the results can be found in Lassila and Valkonen (2007c).

replacement rates lower. Thus longevity adjustment increases the uncertainty in replacement rates. It thereby significantly weakens the defined-benefit nature of the Finnish pension system and brings in a strong defined-contribution flavor. But it is important to note that demographic uncertainty itself reduces the defined-benefit feature, so adopting longevity adjustment is a change in degree, not a change in kind.

Table 1. Contribution and replacement rates and longevity adjustment

	d ₁	Q ₁	Md	Q ₃	d ₉
Contribution rate					
2050 - 2054					
without longevity adjustment	26.72	28.64	30.74	32.30	34.10
with longevity adjustment	25.80	26.82	27.84	28.90	29.86
Replacement rate					
2050 - 2054					
without longevity adjustment	47.17	47.80	48.44	49.04	49.53
with longevity adjustment	38.90	40.56	42.68	45.01	47.73
Effect of longevity adjustment					
on contribution rates					
2050 - 2054	-4.52	-3.71	-2.76	-1.70	-0.69
on replacement rates					
2050 - 2054	-8.82	-7.42	-5.77	-3.74	-1.55

We define a *sustainability gap* as an immediate and permanent increase in the contribution rate, which equals the discounted incomes and expenditures of the pension system. The median of the sustainability gap falls from 7.7 to 5.7 percents after introduction of the longevity adjustment, see Table 2. Also the variation in sustainability gap reduces.

For adequacy, we calculate a measure that uses the replacement rates in the base case scenario. Fixing the replacement rates from that scenario, we calculate the present value of pension expenditure in all population paths and compare it with the actual present value for that path. We call the difference between the actual and hypothetical present values the *adequacy gap*, and express it as percentage of the present value of the contribution base. Thus the gap gives the immediate and permanent change in contributions that is needed to finance replacement rates equal to those in the base case. With this definition, the adequacy gap is directly comparable to the sustainability gap.

Longevity adjustment lowers the pensions, raising the median of the adequacy gap by 2.6 percentage points and increases markedly the probability of large adequacy gaps.

Table 2. Sustainability and adequacy gaps and longevity adjustment

	d ₁	Q ₁	Md	Q ₃	d ₉
Sustainability gap					
without longevity adjustment	5.42	6.63	7.74	8.76	9.90
with longevity adjustment	4.57	5.15	5.73	6.30	6.78
Adequacy gap					
without longevity adjustment	-1.73	-1.68	-1.62	-1.55	-1.49
with longevity adjustment	-0.93	0.05	0.92	1.81	2.61
Effect of longevity adjustment					
on sustainability gap	-3.32	-2.72	-2.00	-1.30	-0.48
on adequacy gap	0.60	1.66	2.56	3.48	4.26

The gaps are calculated using a time span of 145 years.

As an intergenerational measure of the connection between benefits and contributions we define the following. The *actuarial ratio* is the ratio of a cohort's discounted benefits from the pension system to its discounted sum of payments to the pension system. Table 3 shows that actuarial rate medians for successive generations decline. The reasons for that are population ageing and the maturing of the pension system financed with a pay-as-you-go principle.

Table 3. Actuarial rates and generational equality

	d ₁	Q ₁	Md	Q ₃	d ₉
Actuarial rate					
Born 1970-74					
without longevity adjustment	0.84	0.89	0.93	0.98	1.02
with longevity adjustment	0.83	0.86	0.89	0.92	0.94
Born 1990-94					
without longevity adjustment	0.74	0.76	0.79	0.81	0.84
with longevity adjustment	0.72	0.73	0.75	0.76	0.77
Born 2010-14					
without longevity adjustment	0.69	0.70	0.72	0.74	0.75
with longevity adjustment	0.67	0.69	0.71	0.72	0.74

Longevity adjustment lowers the actuarial rate of the current young workers because they experience quite a considerable cut in their pensions, but only a small reduction in contributions. The benefit cuts are largest for the future generations, but their aggregate outcome will be positive due to the even bigger reductions in contributions. The overall changes in actuarial rates are small due to high correlation between paid lifetime contributions and pension benefits in the Finnish earning-related pension system.

3.2 New investment rules

Many of the current occupational pension systems are at least partially funded but follow defined benefit rules. This creates an obvious need to try to forecast the cash flows involved and to evaluate the financial soundness of the system by comparing the liabilities and assets. A more risky investment policy would necessitate larger buffers. Another option is to allow the pension institutions to take more risks by applying more liberal solvency rules.

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. Partial prefunding of the accrued old age pension rights takes place in the age range of 18 – 54. 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 pre-funded. The rest comes from the PAYG part, the so-called pooled component in the contribution rate.

We simulate the outcomes of the recent Finnish pension reform, which included two changes in the prefunding rules. Our aim is to give a probabilistic evaluation of the reform in terms of variation in the contribution rate.

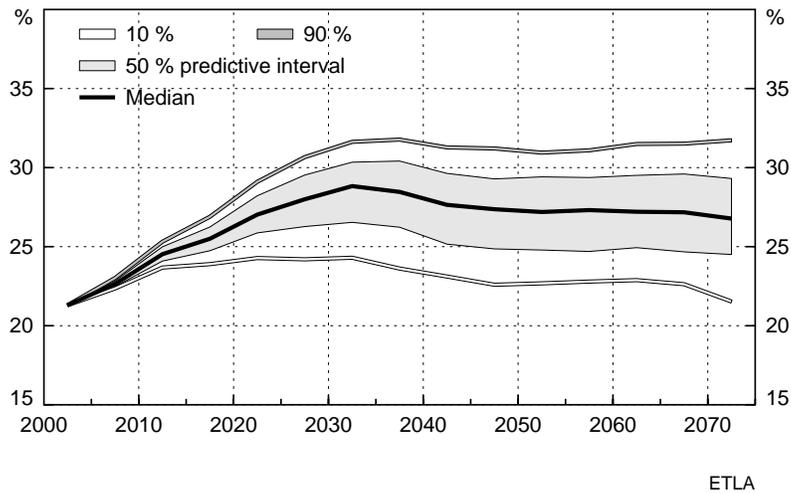
The first change allocates part of the yield of the pension funds to older people's individual accounts. When the accounts for the younger people are rewarded with a lower yield, the average balance in all the accounts will be lower and so will be the actual prefunding rate of the pension rights. It also means that the individual accounts are run down faster than previously. The policy measure is aimed to smooth the projected baby boom hump in the pension contribution rate that would otherwise appear in 2030's.

The second part of the reform changes in a complicated way the solvency rules of the private pension institutions, which run the pension system. It introduced an equity linked buffer to the technical reserves. The idea is to weaken the link between return of equity investments and the actual solvency capital. The weaker link allows the solvency capital to be utilized to increase risky equity investments. Simulations with the new buffer show that it should enable the pension companies to increase the share of stock market investments by 10 per cents (Ranne, 2007).

We assume that the initial pension fund portfolios were allocated to bonds (71.4 percents) and stocks (28.6 per cents), which gives expected annual real rate of return of 3.5 per cent. After the reform the share of the bonds in the investment portfolio is reduced to 60 percent and the share of the stocks is increased to 40 percent. This shift raises the average yield of the funds to 3.9 per cent, but also scales up the variance.

Figure 4 shows the predictive distribution of the contribution rate with the old prefunding rules. It describes the contribution rates before the reform in 500 simulations, each with one arbitrary sample path from the stochastic model for population, stock market yields and interest rate. Comparison to the Figure 3 shows that the future investment income is expected to lower markedly the pressure to raise the contribution rates, even with the earlier stricter investment rules.

Figure 4. Predictive distribution of the contribution rate before the investment rule reform



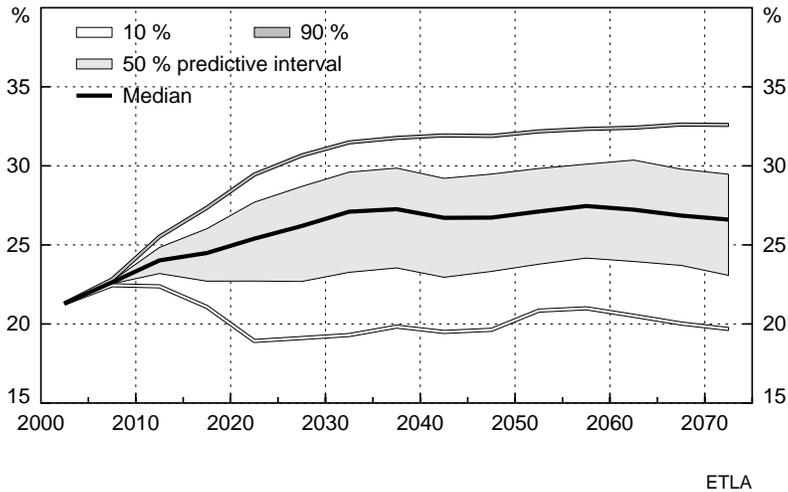
The predictive distribution of the contribution rate with the new rules is illustrated in Figure 5. The reform limits the expected increase in the contribution rate in a way that was planned. The effects are most evident during the years when the contribution rate would have been the highest.

The first part of the reform lowers the contribution rate median during the next two decades, but raises the longer term rate. The second part lowers permanently the median of the contribution rate, since the expected real rate of return is higher. The overall effect is that the median of the contribution rate grows much slower, but end up to almost the same level than before the reform.

Allowing more risky portfolios also increases the variation in the contribution rate. The increase in risks is asymmetric. In sample paths where the yield is low on average, the pension fund will become gradually smaller and the pension contribution rate becomes

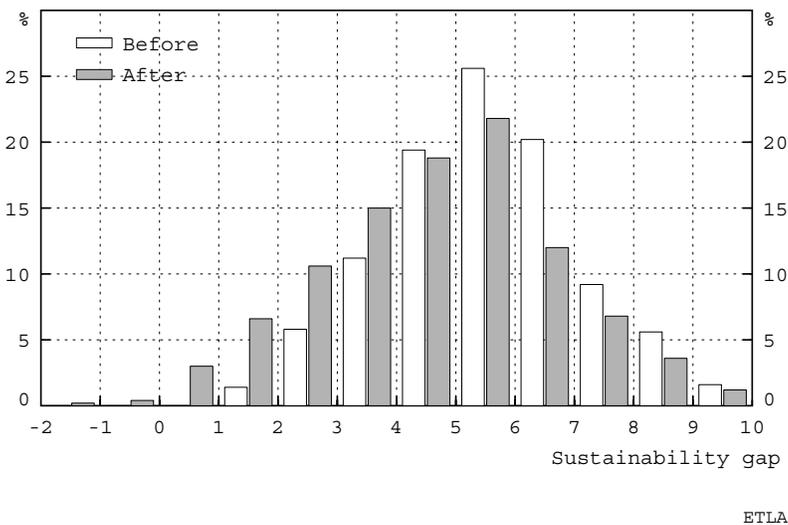
less sensitive to yield shocks. In case of favorable market conditions the fund will be larger and the role of asset yields more pronounced.

Figure 4. Predictive distribution of the contribution rate after the investment rule reform



How this reform performs if we use financial sustainability, adequacy of pensions and actuary rate as criteria? A simple answer to sustainability question is that it is very likely to have improved, but not much.

Figure 5. Histogram of the sustainability gap before and after the investment rule reform



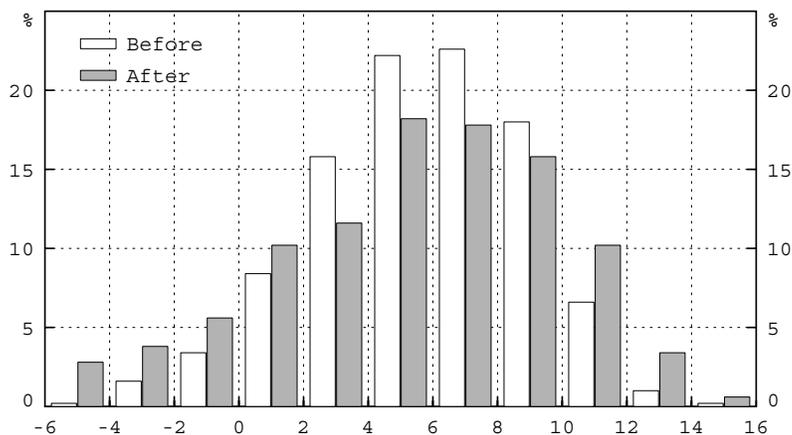
One way of illustrating the results is to calculate predictive distributions of the sustainability gap before and after the reform, just as in the case of the longevity

adjustment. Figure 5 shows the results as a histogram. The whole distribution has shifted to left. The change is not, however very large, and the probability that the current contribution rate would permanently suffice to finance future expenditures is still extremely small.

Sustainability gap distribution shows the required increase in the contribution rate in each stochastic sample path when its period-by-period variation is totally abolished. Actually, the contribution rate varies a lot. High variation is problematic both to the payers of the contributions and to the policy planner. Periods of high yield create political pressures to lower the contribution rate, even though the long-term prospects of the financial sustainability have not improved much.

Figure 6 demonstrates that it is not very unlikely to end up to a situation, where erroneous decision is possible. It shows with a histogram how much the contribution rate in period 2050-2054 is expected to deviate from the current rate. The shift to riskier pension fund portfolio increases the probability of both very high and low outcomes, when the studied period is relatively short. This result would be even more outstanding, if we had chosen to use yearly data instead of a five-year average. It is evident that one should be cautious to change the long-term conception of financial sustainability of the pension system, even when the financial market yields have been low or high several consecutive years.

Figure 6. Histogram of deviation of the pension contribution rate from the current level in period 2050-2054 before and after the investment rule reform



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The links between the new investment rules and the size of pensions are rather weak, so we do not expect that the reform has any marked effects on adequacy. The third evaluation criterion is generational equity. The first part of the reform improves most the position of the generations born between years 1970-2010, because those benefit from the lower expected contribution rate. The asymmetric change in the contribution rate risk provides an interesting result. The higher probability of low contributions means that the

current young and future generations may be expected more often positive than negative surprises in the intergenerational redistribution after the investment rule reform.

4. Conclusions

Demographic and economic uncertainties are large and increasing with the time horizon considered. This should be kept in mind especially in case of pension policy, since the average representative of the age cohort that start her/his working career this year, is likely to get last pensions in 2070's.

An optimal pension system is designed so that it performs well in the expected future path and tells exactly how the risks are shared between pension contributions and benefits, when something unexpected happens. We show that in case of the Finnish pension system, the risk sharing properties have been changed a lot with the recent reforms. Longevity adjustment allocates most of the life expectancy risks to pensions, but in a way that the size of the adjustment is quite well seen already during working years. Fertility and migration risks as well as the now higher pension fund investment risks are still born almost totally by contributors. It is likely that this risk sharing is not politically stable, especially when there is a large probability of markedly higher contribution rates.

Our method provides a new approach for the evaluation of uncertainty in pension policy outcomes. It allows crash-testing of the current pension systems and any alternatives that are discussed in public. It also helps to find and test policies or policy combinations that are not seen otherwise. Introducing uncertainties in a systematic way in numerical pension policy analysis is a new and rapidly developing field of research. A natural next step here would be a model in which both idiosyncratic and aggregate uncertainty influence behavior and welfare.

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