A macromodel reveals the solvency of a pension system

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November 2025

Abstract

This paper presents a simple stochastic simulation model of the Finnish earnings-related pension system, TyEL. The model is based on the standard population projection of Statistics Finland and a timeseries of realized investment returns in 2002-2024. In a business-as-usual scenario, the pension funds will reach EUR 880 bn in 2063 after which they will decrease rapidly. The ruin probability of the system is very low until 2060. These results are subject to a number of assumptions regarding inflation, real GDP growth, and perhaps most importantly, demographics.

1 Introduction

In welfare states, pension systems are an important component of the national economy, both in stock and flow terms. In stock terms, the pension funds are an important concentration of (semi-)public wealth. In flow terms, the pension benefits represent a substantial flow of income. Equally importantly, statutory pension contributions can be an important part of the tax burden. For example in 2026, Finland will charge 24.4% of most salaries as a pension contribution (Valtioneuvosto, 2025). Finland has a nation-wide, statutory, earnings-related pension system known as Työeläke, abbreviated as 'TyEL', on top of a national pension and a guarantee pension which guarantee a modest income if the labor income of a person has been low. Finnish Centre for Pensions (Eläketurvakeskus, abbreviated as 'ETK') is a joint service producer of the earnings-related pension system and it calculates forecasts of the future development of the system.

In this paper, a macromodel is built for the Finnish earnings-related pension system. A macromodel introduced here means that the model is based on macroeconomic and demographic timeseries, as opposed to a cohort-based or individual-based simulation. In addition to obvious disadvantages, this approach has two advantages: Firstly, extreme simplicity makes the model lucid and approachable to non-experts, and secondly, the model offers an independent means to verify the calculations of ETK. The model is based on publicly available data (most importantly, investment statistics from TELA and demographic projections from Statstics Finland), but does not depend in any way on the forecasts of ETK. However, the model involves stochastic investment returns. This permits a Monte Carlo simulation of the ruin probability which can be seen as due diligence when studying the solvency of an insurance system (e.g. Daykin et al., 1993).

Data availability statement: The calculation code of the model is available at https://doi.org/10.5281/zenodo.17769959, together with all parameter values.

2 Material and Methods

The basic dynamics of the Finnish earnings-related pension system can be described by the equation

$$\Delta K = rK + B_1 + B_2 - X - C \tag{1}$$

where K is the value of assets, r is the nominal investment return, B_1 is the private contribution (i.e. the sum paid by the employers and employees), B_2 is the government contribution, X is the claims or benefits, and C is the operation cost. At the end of June, 2025, K had the numerical value of EUR 272 bn (TELA, 2025a). In 2024, the flow variables had the values $B_1 = 27.5$, $B_2 = 4.7$, $X = 36.2$, and $C = 0.4$, all of these in billions (ETK, 2025a). Additionally, there was a contribution of 0.7 billions from the Employment Fund, but we will assume below that this contribution is zero because of the recent headwinds faced by the Employment Fund. We will use this as the starting point of the study.

2.1 Investment returns

There is data available concerning the nominal returns of the Finnish pension system, see TELA (2025b). For this study, the nominal returns

of private-sector and public-sector pension providers in 2002-2024 were analysed. Three observations were made: 1. The two timeseries were almost perfectly correlated ($\rho = 0.97$) and could thus not be regarded as independent samples. The data from public-sector pension providers were removed from further analyses. 2. The annual returns of the private-sector pension providers were significantly non-normal ($W = 0.89$, $p = 0.02$, Shapiro-Wilk test). 3. However, there was no significant autocorrelation, and thus, the data from the private-sector pension providers was taken to represent the investment process.

In this study, the investment returns are modeled by using two complementary methods: a. They are assumed to be fixed at the mean value of the empirical data, i.e. $r \approx 0.057$. This yields the timeseries known as 'point estimates' in the Results. b. A value of r is sampled from the empirical data, independently for each year and stochastic realization. This yields the Monte Carlo sample in the Results.

2.2 Contributions and costs

The contributions (B_1 and B_2) and the operation costs (C) are assumed to grow at the growth rate of the nominal economy. Notably, for the contributions, this is likely to be a good first approximation: If the labor intensity of production does not change, the ratio of total wages to GDP is not likely to change very much, and in the Finnish pension system, the contributions are proportional to the total wages. In the numerical examples of this paper, a growth rate of $r_B = 0.035$ is assumed, based on an assumed inflation of 2% and a real growth of 1.5%.

2.3 Benefits

Here, it is assumed that the ratio of average pension to average wage stays constant. This is the aim of the various indices in the earnings-related pensions system (e.g. ETK, 2025b). This is modeled as follows.

Firstly, the average wage in year t is given by

$$\overline{w}(t) = \frac{cB_1(t)}{l(t)} \tag{2}$$

where c is the unspecified ratio of total wages and private contributions and $l(t)$ is the labor force at time t. In this paper, the population projection of Statistics Finland (2024) is used so that the sum of the age classes 25-64 in this projection is used as a proxy of $l(t)$. The ratio c is a policy

variable with a value of some $c = 0.24$ and is assumed constant in time in this study.

Secondly, the average pension in year t is given by

$$\overline{x}(t) = \frac{X(t)}{n(t)} \tag{3}$$

where $n(t)$ is the number of pensioners. In line with the labor force, the projected sum of the age classes 65+ is taken as a proxy of $n(t)$.

Then, it is noted that the ratio $\overline{x}(t)/\overline{w}(t)$ is a constant, and hence, we have

$$\frac{\overline{x}(t)}{\overline{w}(t)} = \frac{\overline{x}(2024)}{\overline{w}(2024)} \tag{4}$$

for all time. Substituting the definitions and canceling c,

$$\frac{X(t)/n(t)}{B_1(t)/l(t)} = \frac{X(2024)/n(2024)}{B_1(2024)/l(2024)}. \tag{5}$$

Solving $X(t)$ yields

$$X(t) = \frac{B_1(t)}{B_1(2024)} X(2024) \Big(\frac{n(t) l(2024)}{n(2024) l(t)} \Big). \tag{6}$$

As noted above, B_1 is assumed to grow at a deterministic rate, so that $B_1(t) = \delta^{(t-2024)} B_1(2024)$, with the assumed numerical value of $\delta = 1.035$, whereas $X(2024)$ is known from the data. The fraction in parentheses is calculated from the population projection of Statistics Finland (2024) and can be called as a 'demographic inflator'. Intuitively, Eq. 6 means that $X(t)$ grows at a rate which depends both on the nominal growth rate of the economy (*via* the first fraction) and on the demographic inflator. Thus, in an aging population, $X(t)$ grows somewhat faster than B_1 and B_2.

3 Results

Figure 1 presents the point estimate of K as a function of time and the mean estimate calculated from the Monte Carlo sample. Additionally, the dashed line represents the nominal value of the most recent known endowment (EUR 272 bn from summer 2025). The fact that the estimates are above the dashed line for most of the simulation period indicates that pension funds will grow, both in real and nominal terms, subject to these assumptions. However, the funds will start to decline rapidly after 2063, again subject to assumptions.

Figure 1

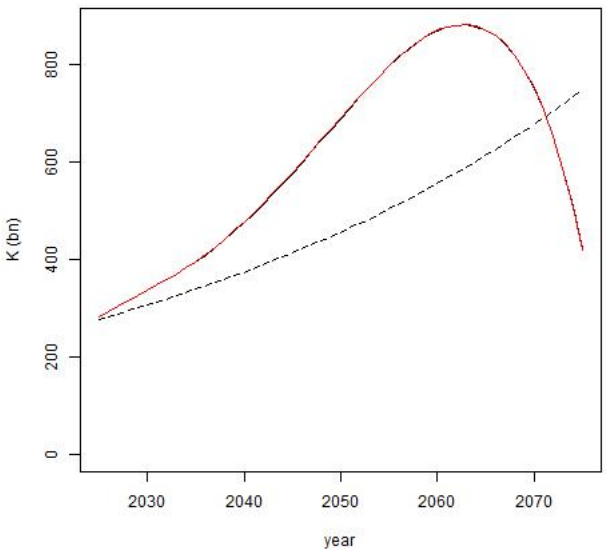
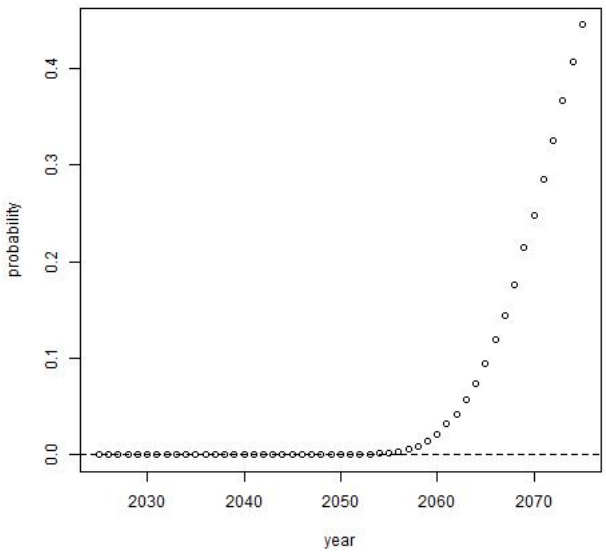


Figure 2 presents the ruin probability, i.e. the probability of the event $K < 0$, as a function of time, as calculated from the Monte Carlo sample. Notably, the stochastic simulation has been run with 10,000 independent iterations which permits an accurate estimation of probabilities in the range 0.01-0.99. Consequently, the data in Figure 2 can be regarded as fairly accurate. In this sample, the first ruin event occurs in 2049 and the ruin probability exceeds 2% in 2060. However, after that point the probability grows rapidly.

Figure 2



4 Discussion

We have built a stochastic simulation model of the Finnish earnings-related pension system TyEL. The model is based on macroeconomic and demographic variables and independent of the projections provided by the Finnish Centre for Pensions. The main result is that the pension funds will grow until 2063 after which they decline rapidly. Another result is that the ruin probability is non-substantial until 2050 and increases rapidly after 2060.

Should the substantial ruin probabilities after 2070 raise alarm? Not necessarily so because either the government contributions, private contributions or both would be raised, should the funds go uncomfortably low in the real world. In a certain sense, a statutory pension scheme can never go bankrupt. Equally well, one could discuss the upper tail of the funds distribution. For example, in 2050, the 99th quantile of the funds distribution is 1,572 bn which would be 958 bn in 2025's money. This is equally unrealistic and the contributions would be cut before this level would be reached.

One may ask how realistic the forecasts after, say, 2065 are. Half of the workforce in 2065 is yet unborn. We do not know the size of these age cohorts, albeit we can calculate predictions. This study relies on the

standard population projection of Statistics Finland (2024). It should be noted that in a small aging population like Finland, immigration makes an enormous difference, and thus, the solvency of the pension system may be better than calculated here if the predictions of Statistics Finland (2024) are exceeded. However, this of course requires that the immigrants are integrated in the labor force.

In this study, solvency has been measured simply by checking that the pension system's total assets are positive. In insurance business, solvency typically means the difference of a company's assets and liabilities, discounted in some appropriate manner, and is roughly comparable to equity in a usual company. The study run here could perhaps more accurately be called 'sustainability' of a pension system. However, the usual solvency concept has some interesting percussions here. The code used here can easily be modified to calculate the net present value of the future pensions. Discounted to the start of 2025 at a 6% rate, this yields 1,055 bn. In this sense, the Finnish pension system is by far insolvent at present. This is of course because the future pensions are expected to be (partially) covered by future contributions. One could argue that there is little point and little realism in trying to increase the assets to match the liabilities.

Finally, a word can be made regarding the usefulness of macromodels in the pension domain. For one thing, one might argue that the future predictions should be made making use of all known details, e.g. calculation bases in the case of pension systems. While this argument has its merits, it may be said that the macromodels can offer an indpendent, lucid verification of the official forecasts.

Figure legends

Figure 1. Estimates of the pension funds. The black line represents the point estimate, whereas the red line represents the mean of the Monte Carlo sample. The dashed line presents the nominal value of the most recent endowment (272 bn), calculated with an inflation assumption of 2%.

Figure 2. Ruin probability as a function of time. This figure presents the fraction of iterations with negative funds for each simulation year.

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