FIRSTRUN – Fiscal Rules and Strategies under Externalities and Uncertainties.
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Modelling the uncertainty in future demographics, productivity, asset yields and structural deficits for fiscal policy analysis with the FOG model

Abstract:
The paper describes the modelling choices for several variables that are used as stochastic inputs in an open economy general equilibrium model FOG. The economic model will be used in studying long-term fiscal sustainability and fiscal policy strategies as a part of the FIRSTRUN project. The uncertainties considered are related to future demographics, productivity, asset yields and structural deficits. We also describe how the uncertainties work in the economic model, in order to give insights on how to interpret the results of different policy rules.

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1 Introduction

The purpose of this paper is to describe the modelling choices for several variables that are used as stochastic inputs in an open economy general equilibrium model. The economic model will be used in studying fiscal policy strategies, as a part of the FIRSTRUN project. There is a secondary purpose also: we describe how the uncertainties work in the economic model, in order to give insights on how to interpret the results of this rather complex economic-demographic simulation device.

FIRSTRUN investigates the need for fiscal policy coordination in the EU, assesses the coherence of the recent reforms in the economic governance framework, and identifies reforms to fill possible gaps in the current EU governance framework.

One part of FIRSTRUN considers long-term fiscal sustainability by studying fiscal policy under uncertainty. We use an open economy general equilibrium model FOG (short of Finnish Overlapping-Generations model). We extend the model so that it can be used to study how a government could design a fiscal policy strategy that keeps it within the new EU debt and deficit limits, with given probabilities in an environment where several key factors are uncertain. The fiscal strategy should also be intergenerationally as fair as possible. The model accounts for many important features of the Finnish economy (for instance, a detailed description of the Finnish pension system), and it has been used in many published studies of population ageing and fiscal sustainability. In FIRSTRUN, we incorporate the new EU debt and deficit limits as well as new sources of fiscal uncertainty into the model.

The uncertainties considered in this paper are related to future demographics, labour productivity and asset yields. In addition, we consider perceptions of structural deficits which, although unobservable, are important in fiscal policy rules.

From Section 2 onwards we describe the different uncertainties, starting with demographics which gets the largest treatment because it interferes with economic model in many important respects. In each uncertainty section we first describe how that particular phenomenon appears in the economic model, before describing how the uncertainty is quantitatively dealt with. This is important because we include stochastic variation very selectively into the economic model. The FOG model is basically non-stochastic. It is a numerical overlapping-generations model of the type originated by Auerbach and Kotlikoff (1987). It is modified to describe a small open economy and calibrated to the Finnish economy. The model is usually run under the assumption of perfect foresight: households and firms know all the future prices, wages, taxes and values of other variables they need in their decision-making. In FIRSTRUN, however, we follow the assumption in Lassila, Valkonen and Alho (2011, 2014) that households believe in population forecasts with certainty. The forecasts are erroneous, and when a new forecast appears the households and firms re-optimize. They do not learn, however, that forecast errors occur, but continue to believe in the new forecast with certainty. In FIRSTRUN, the forecast approach is expanded to include also asset yields and productivity.

The FOG model consists of five sectors: households, enterprises, a government, pension funds and a foreign sector. Households 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 incomes and discounted received bequest and transfers equal discounted consumption expenditure and the given bequest.

Firms choose the optimal amount of investment and 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. The three markets, for labor, goods and capital, are all competitive and prices balance supply and demand period-by-period. There is no money or inflation in the model.

The stochastic analysis will be done around a dynamic baseline. The initial situation reflects the Finnish economy around 2015, to a limited degree a calibrated equilibrium model can produce. The future baseline consists of the current official population projection and base forecasts of other variables.

Section 2 considers demographics, Section 3 bond and equity yields, Section 4 productivity and Section 5 structural deficits. Section 6 discusses how uncertainty is taken into account in current ageing expenditure projections and fiscal sustainability assessments of the EU Commission and other organizations. Section 7 discusses future directions of fiscal analysis under uncertainty.

2 Demographics

2.1 Demographics in the FOG model

Public welfare systems are closely tied to demographics. A prime example is a mandatory defined-benefit pension system. It is hard to think of another economic institution with equally tight links to the number of people in different age groups or equal sensitivity to mortality, migration and fertility. Public expenditure on health and long-term care services also depends strongly on demographic factors. Thus when considering the situation and prospects of public finances we almost invariably include demographic issues, and often put them in the centre. This is reflected also in the FOG model.

Demographics enter the model through the household sector. There are overlapping generations of households, 16 adult generations living in each period (the unit period is five years). They all make lifetime decisions about consumption and leisure, according to the life-cycle hypothesis. People 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.

Labor input is determined partly by exogenous assumptions and partly due to endogenous adjustments in the model. Hours of work are decided by households. 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. Average retirement age follows life expectancy, and in the model this is achieved by changing in each age group the share of those retired.

The household variables, such as consumption, labour supply and wealth, are aggregated using population weights by age to obtain aggregate consumption, labour supply and household wealth. Similarly, aggregate wage bill, pensions, various taxes and transfers are obtained by analogous aggregation.

Demographics also affect the labour markets indirectly. Part of the labour input is used to provide health and long-term care services. This share depends on the number of elderly people, weighted by per capita need of these services in different age groups. Similarly, part of the labour input is used for education work, whose demand depends on the sizes of young cohorts. These parts of the labour input, which vary from one population path to another, reduce the labour available for private production and affect the wages that balance the demand and supply of labour.

The growing number of people in old age and near death increases the demand for health and old age care, as described earlier. We assume that these demography-driven additional services are produced in private sector, but production costs are paid totally by the public sector. These services are produced using labor and intermediate goods as inputs. There is no productivity growth in the production.

A fixed part of labour force goes administrative work in the public sector. This is an important assumption in connection to stochastic population simulations.

The share of publicly financed work to all work in the economy varies. Administratively, the shares of employees in private and public sector are kept constant. This is because of there are separate pension systems for public sector and private sector workers, and the assumption of fixed shares avoids unnecessary complications in fiscal analysis. As the need of publicly financed work varies, some of it may be bought from private-sector workers, and in some cases when e.g. health care need is small, public sector workers may actually be working in private firms.

Real wage adjusts to equalize the value of marginal product of labor and labor costs in the production of private goods and services. The rest of the workers, who provide tax-funded services produced in private and public sector, earn the same wage. The model includes thereby the Baumol effects.

We assume that immigrants in Finland work like natives. But they are of different ages when they arrive, and thus generally accrue lower earnings-related pension rights than natives. They may have accrued pension rights in the country of origin, and get pensions from there, but that is not the concern of the Finnish pension system. Therefore, with positive net immigration, assuming a full-career pension for all retired people in the country overestimates the pension expenditure. With net emigration the situation is reversed: many of those emigrating have accrued pension rights, and the pensions will be paid to them even though they are no longer part of the Finnish population. Thus assuming pensions are only paid to those retired who live in Finland underestimates the pension expenditure. So, assuming full-career pensions for all retired residents leads to a wider predictive distribution of pension expenditure, depending on the extent to which migration causes variation in the old-age population. To eliminate this, the FOG model has a correction mechanism to the aggregate pension expenditures.

Real wage growth varies between population paths, even though there is a common trend growth in total factor productivity in the production of the private good. Due to only partial indexation of pension accruals and benefits, this directly affects the replacement rates. Thus there would be considerable variation in all pension outcomes even without longevity adjustment of pensions.

Public expenditures have strong connection to the age of individuals in Finland. Provision of public services is allocated mainly either to the early part of the life cycle (day care and education) or to the last years (health care and old age care). Similarly, income transfers are distributed mainly either to young families or to retired individuals. We assume that all income transfers (except the earning-related pensions) are fully indexed to wages because any other assumption would have dramatic consequences to income distribution in the very long term analysis. Other than age-related public expenditure is assumed to grow at the same rate as the GDP.

A majority of the revenues of the public sector are accumulated by income taxes, consumption taxes and social security contributions. Another noteworthy revenue source in Finland is the yield of the public sector wealth. This is important especially for the pension funds, but also the central government has substantial amount of financial assets.

In the model the municipal sector, the public and the private sector pension fund and the national social security institute have their own budgets, which are balanced either by social security contributions or earned income taxes. The only exception is the state budget, which is balanced by borrowing until 2145, and after that by using a lump sum transfer to households. Earned income tax brackets are adjusted with the growth of the economy. The pension funds follow their current prefunding plans, and pension contributions are endogenous. Households are modeled to react to the income and substitution effects of taxation and social security contributions. Firms choose the optimal amount of intermediate goods, investment and use of labour to maximise the price of their shares.

2.2 Demographic uncertainty

To illustrate how long-term demographic forecasts can change substantially in a relatively short time, Figure 1 shows six forecasts, made between 2002 and 2015, for the future population in Finland. The total population was forecasted in 2002 to be about 5 million in 2050. The view has changed gradually, and the 2009 forecast is about 6.1 million in 2050. That means a 22 percent difference between forecasts made during seven years. The forecast made 2012 coincides almost perfectly with the 2009 forecast in Figure 1. The latest forecast, made in 2015, predicts the population be slightly below 6 million in 2060.

There were large and systematic changes also in the size of the working-age population (Figure 2) and the number of people aged 65 and over (Figure 3). These changes can be traced back to changing views on fertility, migration and longevity. They have affected empirical sustainability evaluations in various ways. There are more people working (good for tax revenues), more retirees (costly for public finances) and people live longer (good for individual welfare but costly for public finances).

Figure 1. Population in Finland, as forecast by Statistics Finland

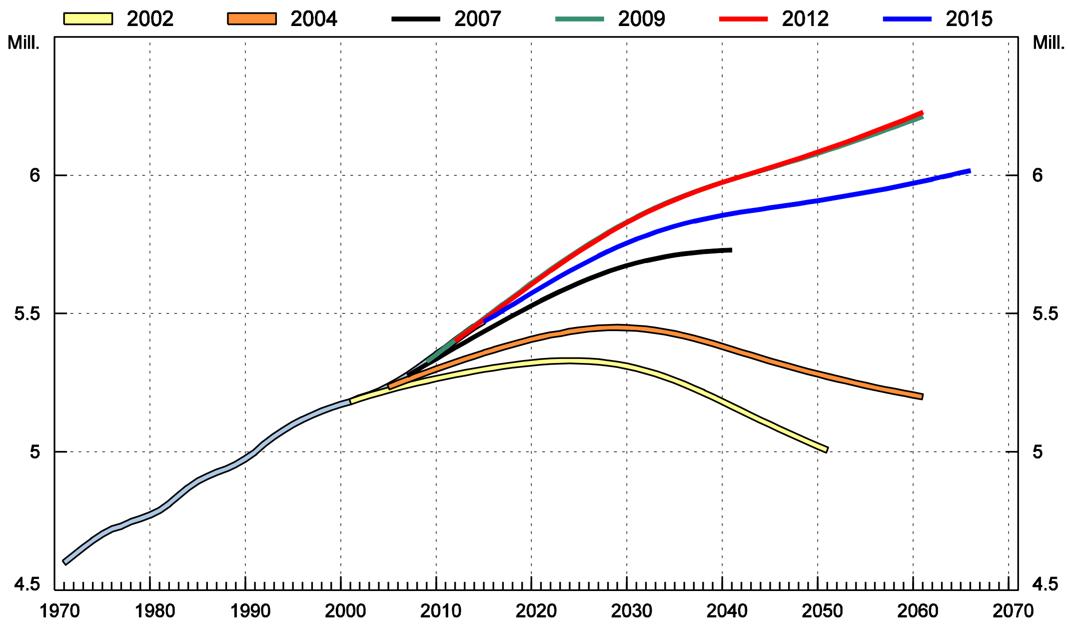


Figure 2. Population in ages 15 - 64 in Finland, as forecast by Statistics Finland

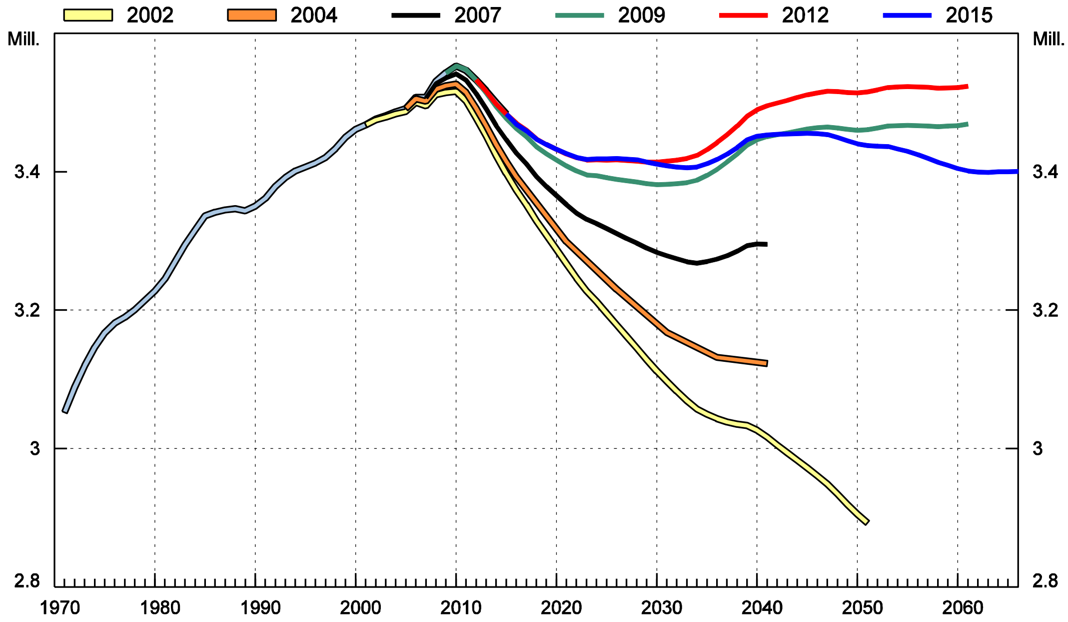
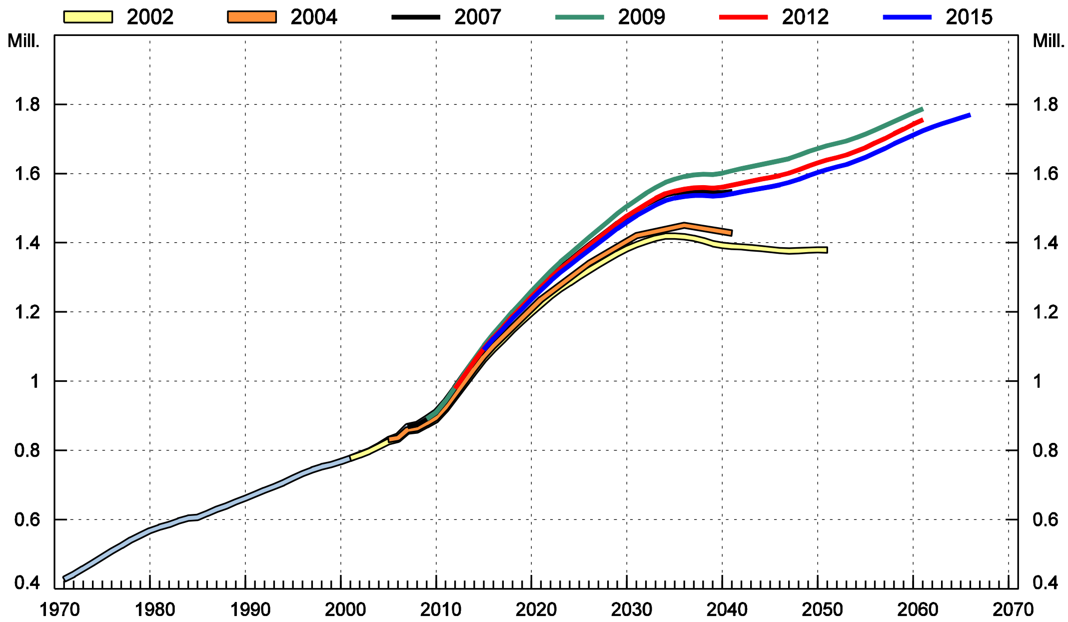


Figure 3. Population in ages 65+ in Finland, as forecast by Statistics Finland



Although the changes in forecasts have been significant, they all show the basic feature of an ageing society: the share of the elderly is growing. The issue is quantitative – the population is ageing but we don't know by how much.

We deal with demographic uncertainty by using stochastic population projections, which are used as inputs in the economic model. Statistical methods of expressing demographic uncertainty have been developed by many researchers (see e.g. Alho & Spencer, 2005, Lee & Tuljapurkar, 1998). These methods quantify uncertainty probabilistically, based on analyses of past demographic data and the views of experts. Fertility, mortality and migration are considered as stochastic processes. The parameters of these processes are fitted to match the errors of past forecasts (see Alho, Cruijsen and Keilman, 2008).

The uncertainty estimates related to fertility are based on a statistical analysis of the Finnish total fertility rate since 1776. The relative error of a naive forecast that assumes fertility to remain constant in the future was determined empirically. A naive forecast approximates closely the medium forecasts made in Finland. For mortality, the analysis of uncertainty was based on the relative error of the naive forecast with data for 5-year age-groups from 1900 onwards. The naive forecast assumed that the recent past decline in mortality continues indefinitely.

Alho (2002, p.9) explains how migration is dealt with in stochastic projections: "The forecasting of migration differs from that of fertility or mortality in at least three ways. First, migration can be influenced by government policies to a higher extent than fertility or mortality. Second, although out-migration can be reasonably analyzed via out-migration rates, it is typically difficult to define a meaningful risk population for in-migration. Third, data on migration are poor even in a country like Finland that has a well-functioning population register. Because of these problems, migration forecasts are typically judgmental, and given in terms of the net number of migrants one expects. On the other hand, a probabilistic approach is well suited to the handling of the uncertainty of judgment concerning future migration. The primary difficulty is in finding a robust way to elicit judgments."

After the processes for fertility, mortality and migration have been modeled, sample paths for future population by age-groups are simulated. As examples, some results of a stochastic projection for future population in Finland are presented in Figure 4 - 8. Half of the simulation outcomes in each period are in the shaded area around the median. 10 % of the outcomes are above the 90 % line and 10 % are below the 10 % line. The projections, made by Juha Alho, are presented around Statistics Finland's 2012 projection.

Figure 4. Predictive distribution of total population in Finland

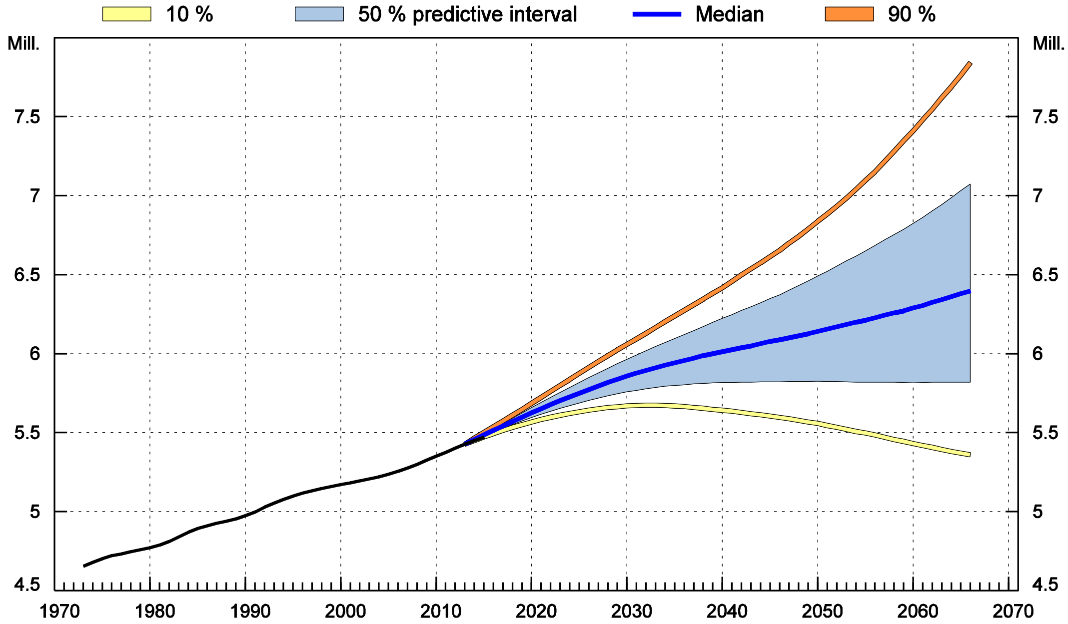


Figure 5. Predictive distribution of population aged 15 – 64 in Finland

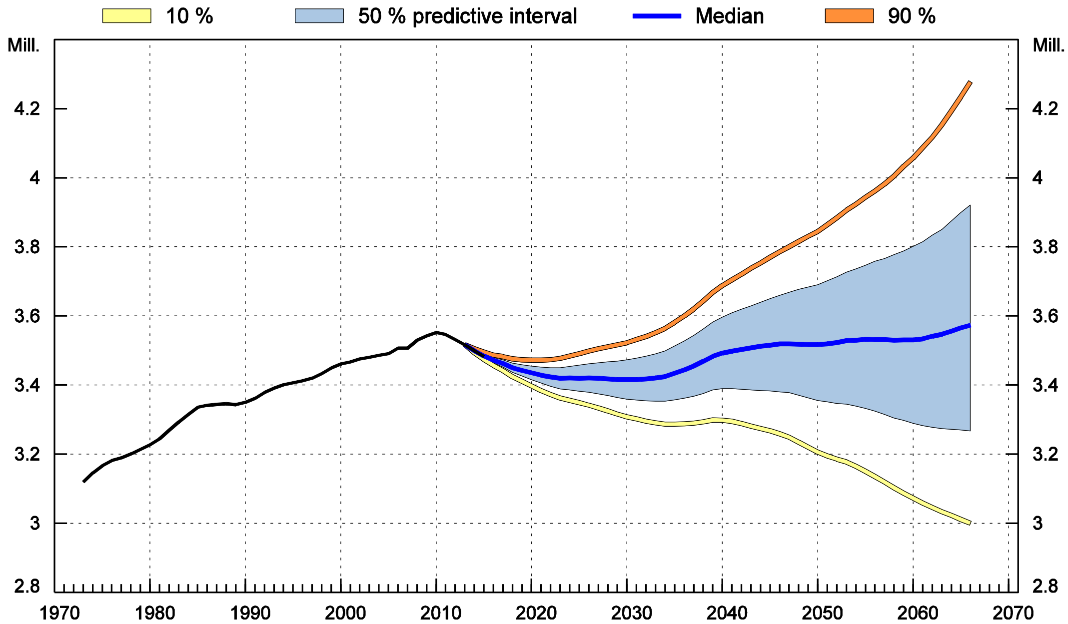


Figure 6. Predictive distribution of population in ages 65+ in Finland

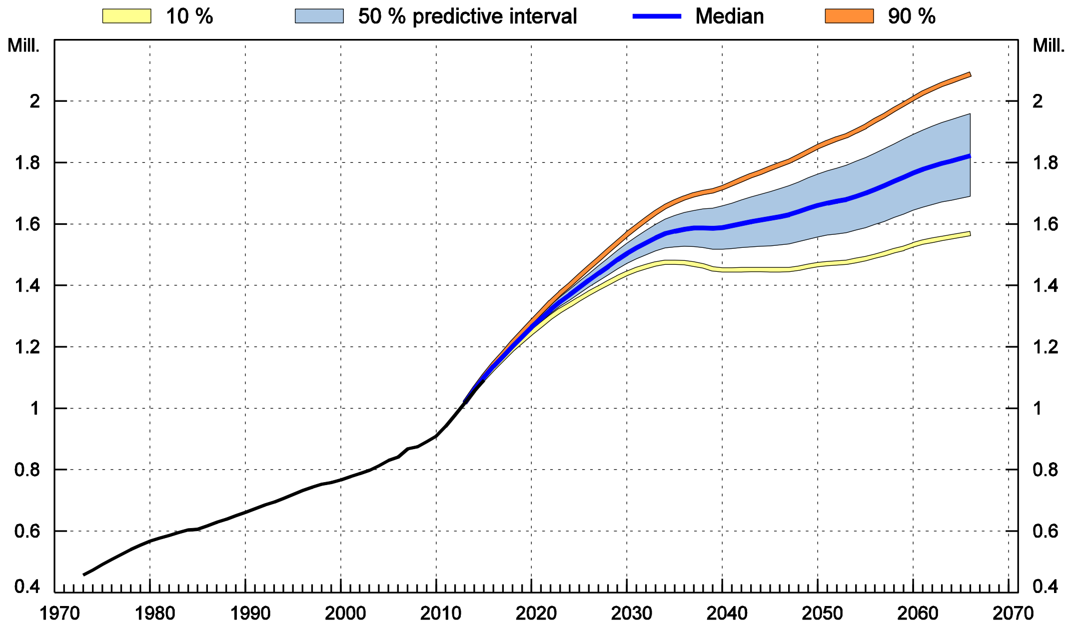


Figure 7. Predictive distribution of age ratio (65+ / 15 – 64)

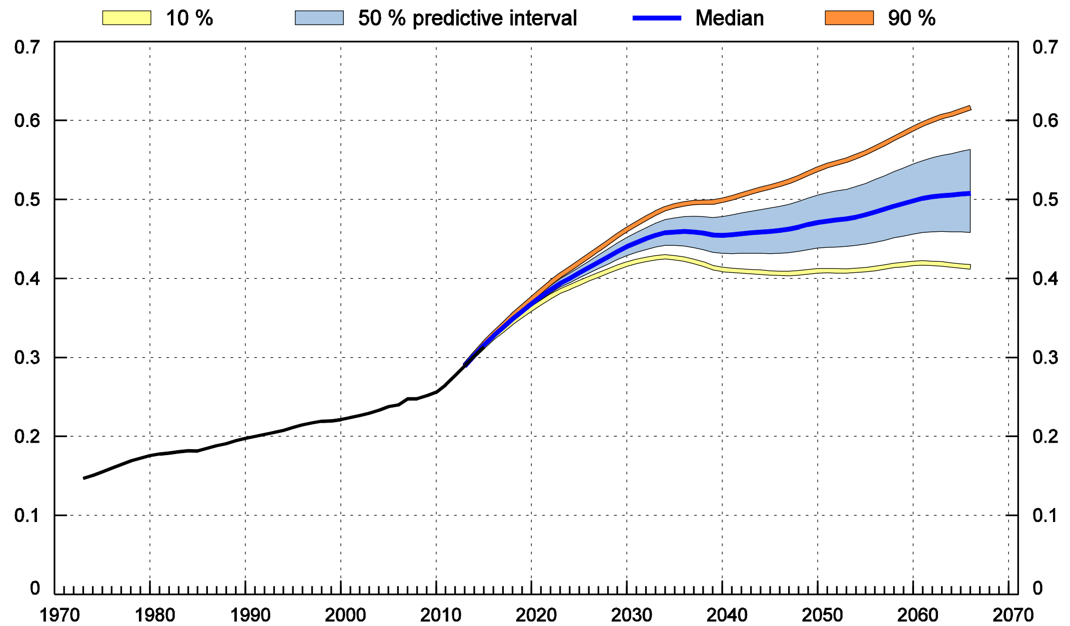
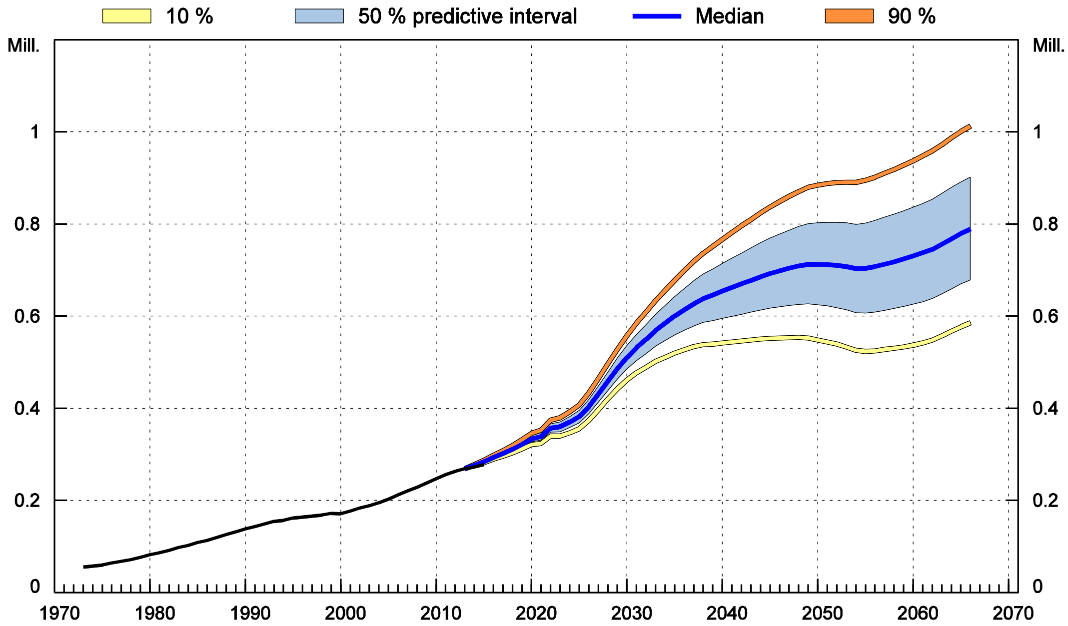


Figure 8. Predictive distribution of population in ages 80+ in Finland



2.3 Forecasting demographic forecasts

Even more information can be pried out of stochastic population projections. In essence, we add a demographic forecast to each time-point in each simulated population path. Thus the view concerning future demographics is periodically updated when we move along any simulated population path. Given the uncertainty of population forecasting, it might seem that trying to forecast what future population forecasts are like would be nearly hopeless. As argued more thoroughly in Alho (2014), however, such forecasts are, for both theoretical and practical reasons, more regular than actual developments. As a practical reason, the development of the recent past often has a heavy influence on projections of the remote future.

Stochastic population projections are produced by a computer program *PEP* (Program for Error Propagation). Another computer program *FPATH* extends the application of results from *PEP* to the FOG model, where agents are allowed to revise their lifetime economic plans as they realize that the population has not evolved according to the expected path. For this purpose *FPATH* calculates a numerical approximation to the conditional expectation of future population at future years for a (typically random) *subset of paths.* The details of computation are spelled out in Alho

(2014). Briefly, the whole computation is based on stochastic simulation in which samples are taken from the predictive distribution of future population as disaggregated by age and sex. A set of, say, 900 such samples play the role of target paths, for which the economic OLG calculations are made. A much larger set of, say, 20,000 supplementary paths is used in the calculation of updated forecasts. This is done by selecting of subset of supplementary paths after the first time period that are the closest to a given target path at that time. A weighted average of the future values of these supplementary paths forms the estimated conditional expectation (= updated forecast) at that time. The next period the weights are revised to reflect the distances of the chosen supplementary paths from the target path, at that time. The weighted averages are recalculated for the remaining future years of interest, etc. In statistical terms, this is equivalent to repeated nearest neighbor kernel regressions. We can think of the conditional expectation as being *a forecast of what would be a forecast* in a future year.

Figure 9. Population in ages 65+ in Finland in one simulated path with embedded forecasts

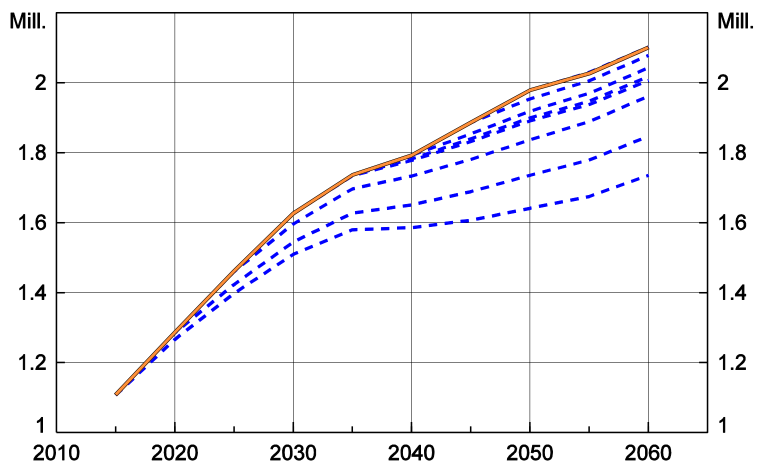


Figure 9 describes population in ages 65+ in one path of the simulated population projections for Finland, produced by the program *PEP*. The solid line is the actual simulated path, and the dotted lines represent the forecasted forecasts for the path. The forecasts lie nicely below the actual path, but this is not generally true in other simulated paths, where the forecasts can and do both overestimate and underestimate the 'actuals'.

2.4 Previous FOG analysis with demographic uncertainty

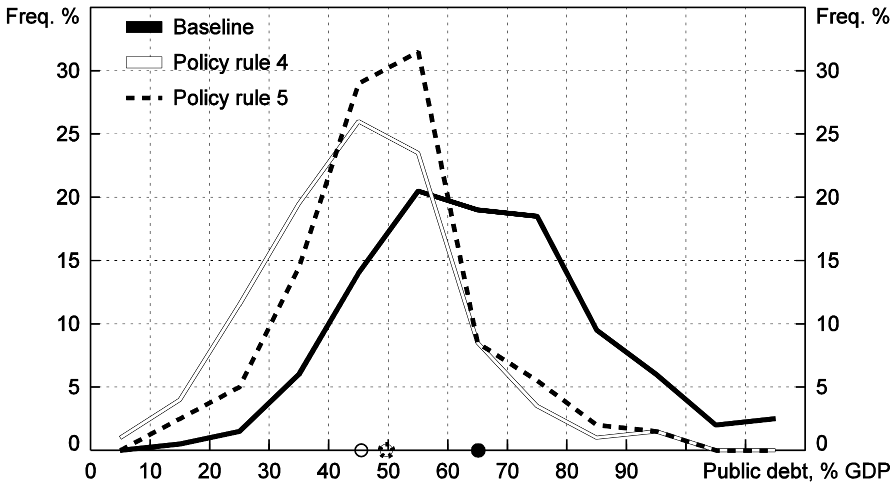
Stochastic population projections have been used as inputs in FOG in numerous studies. Alho et al. (2002) and Alho, Jensen, Lassila and Valkonen (2005) analyzed ageing in the Lithuanian economy using a large set of OLG model simulations. Lassila and Valkonen (2004) study prefunding in connection to publicly financed health and long-term care expenditure. Pension policies have been analyzed in Alho, Lassila and Valkonen (2005) and Lassila and Valkonen (2007a, 2007b and 2008b).

Lassila, Valkonen and Alho (2011, 2014) introduced the use of regular demographic forecast revisions, embedded in stochastic population projections, in fiscal policy analysis. This method allows the separation of the expected and the realized effects of population ageing on public finances, in each demographic outcome and under different policy rules. In the Finnish application, (Lassila, Valkonen and Alho, 2014) demographic uncertainty produces considerable sustainability risk. The authors consider policies that reduce the likelihood of getting highly indebted and demonstrate that although demographic forecasts are uncertain, they contain enough information to be useful in forward-looking policy rules.

Since this method will be used in FIRSTRUN, Figure 10 gives an example of results in Lassila, Valkonen and Alho (2014). It is based on model runs with 200 simulated population paths, each with embedded forecasts. The model runs differ only with respect to demographics.

In the baseline policy, welfare transfers and services are provided according to current Finnish rules and practices. Mandatory pension contributions adapt to pension expenditure, which vary from one demographic path to another. Aggregate health and long-term care costs depend on the population age structure and proximity to death. They are financed by municipal taxes, which thus also depend on demographic variables. Municipalities are nevertheless compensated for a share of the health and LTC expenditure via block grant from the state. State tax rates are held constant, so variation in expenditure and tax bases causes variation in public debt. We describe the outcomes of this base policy on gross public debt per GDP in Figure 10 (for results concerning a total tax measure, which includes the pension contribution rate, municipal taxes and all state taxes, see the original article).

Figure 10: Frequency distribution of public debt, as % of GDP, in the 2060s



Policy rule 4: VAT conditional on 20 year forecast of public debt /GDP ratio
Policy rule 5: VAT conditional on two successive forecasts of public debt /GDP ratio

The authors consider two alternative strategies. They are based on the model's forecast of gross public debt/GDP. In the first strategy, if in some period the debt/GDP ratio is forecast to exceed 60 % within the next 20 years, then the VAT rate is increased permanently by two percentage points. Using this strategy, the improvement in the debt outlook in 2060s is huge, as Figure 10 shows. The expected debt/GDP ratio, marked with a circle on the x-axis, falls from the baseline's 65 % to about 45 % (Policy rule 4). The likelihood of debt ratios over 60 % has decreased dramatically.

One may, however, consider as a drawback the fact that policy rule 4 often leads to lower debt levels also in cases where the debt would have stayed below the Maastricht level without tax increases. As a possible remedy, the second alternative is a rule where the policy reacts to forecast debt levels but only after two successive forecasts have been over the threshold (Policy rule 5). The likelihood of high indebtedness is not much higher, whereas unnecessary interventions in low-debt cases are much less frequent.

In FIRSTRUN, the length of the period during which forecasts are updated must be reconsidered. In above, the last period a new forecast appeared was 50 years from the first period. This may not be sufficient for generational analysis. This is discussed in Section 7.

3 Asset yields

3.1 Assets and asset yields in the FOG model

Whereas population dynamics are slow and it takes decades for the age structures to change significantly, asset prices and yields can vary significantly within a day. From our modeling point of view, however, the issues are similar. Decisions are based on expected returns, and when expectations turn out to be more or less faulty agents re-optimize, based on new expectations. To be precise, we do not let the yield uncertainty to affect the saving and investment decisions of the private sector. But the yield variation causes unexpected variation in prices, wages and taxes, and these variations cause the need for re-optimization.

Unlike most eurozone countries, the Finnish public sector has significant amounts of financial wealth, in addition to debt, as Table 1 shows. The table also describes the financial structure in the FOG model, where financial wealth consists of bonds and equities and debt is in bonds.

Table 1. Assets and liabilities of the public sector in 2014, % of GDP

Statutory pension system - private sector - public sector	 53,6 31,0
Central government - financial wealth - gross debt	 29,5 58,2
Gross public debt (EMU)	59,3
Net financial wealth of municipalities	-1,2

3.2 Asset yield uncertainty

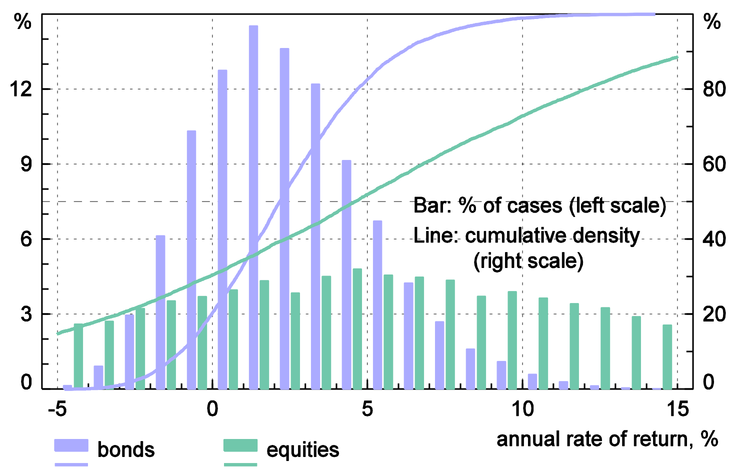
Uncertainty in asset yields is an important ingredient in fiscal sustainability analysis, because it allows considerations concerning risk-taking in public asset management. Public sector financial assets have grown rapidly and portfolios have been shifted towards more equity holdings. This is most clearly seen in pension funds of the statutory earnings-related pension system, where the explicit aim is to alleviate or prevent the projected increase in pension contributions by acquiring better asset yields. Similar developments, although not explicitly stated and much less discussed in public, can be observed in other parts of public sector. In these choices Finland is not alone, the tendencies are clear in countries where the public sector holds significant amount of financial assets or the pension systems are partly or fully funded.

Studies concerning asset yields variations are truly abundant. Ronkainen (2012) builds stochastic models for equity and bond returns, in a way that is promising for FIRSTRUN topics. For equities, the S&P 500 yearly total return, in log-differences, is modeled by an uncorrelated and Normally-distributed process to which exogenous Gamma-distributed negative shocks arrive at Geometrically distributed times. This regime-switching jump model takes into account the empirical observations of infrequent exceptionally large losses.

For bonds, Ronkainen (2012) models the 5-year US government bond yearly total return as an ARMA(1,1) process after suitably log-transforming the returns. This model is able to generate long term interest rate cycles and allows rapid year-to-year corrections in the returns.

Simulating the model for equities that Ronkainen prefers (Model 5, see p. 31 in Ronkainen, 2012) and the model for bonds that he reports on p. 52, and aggregating over 5-year periods, yields the distributions of 5-year rates of return (in per year rates) depicted in Figure 11.

Figure 11. Asset yield uncertainty (Ronkainen 2012, Model 5)



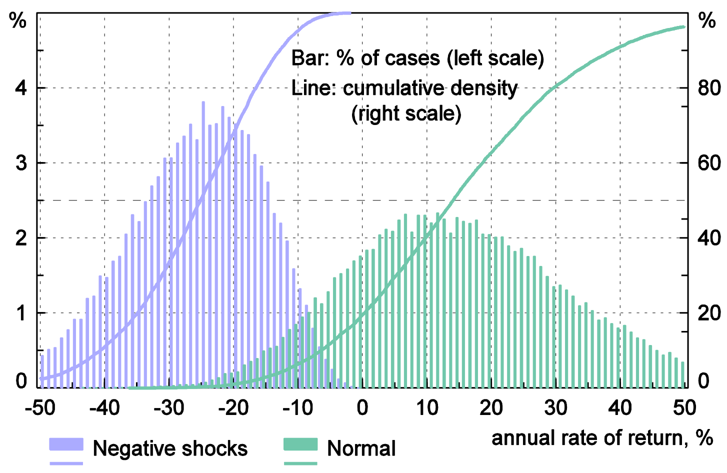
The above models are for nominal rates of return, so we must model some inflation process to obtain real rates. Then we can use the models in a way that Lassila and Valkonen (2008c) used similar but differently parameterized models (see the subsection on previous FOG analysis with asset yield uncertainty). But the jump model provides additional possibilities worth considering.

The negative shock model describes equity market crashes. Such events have often counterparts in the real economy, in the form of depressions and slumps. They are events that really test actual fiscal strategies. One could say that crises are the real reason we are studying fiscal strategies, although normal non-crisis periods are those during which good strategies should be followed.

The jump model provides a way to incorporate ***depression elements*** into the fiscal analysis with the FOG model. One depression element could be modeled as an exogenous increase in public debt. For instance, the Finnish state debt was 32 per cent of GDP in 2008, and has risen to 58 per cent in 2014. The second element relates to expected future productivity growth. The expectation can be unduly pessimistic during a depression. This will be discussed more in Section 4. The third element concerns perceptions of structural deficits, which can also be very pessimistic even when the depression is a business cycle event. This is discussed in Section 5.

How often would depressions occur in the model? The (truncated) distributions of the two parts of the jump model are shown in Figure 12. They are now yearly returns instead of 5-year returns, and based on 45000 simulated values of Model 5 (Ronkainen, p. 34). In the combined model the negative shocks appear with probability 0,071. In an average 5-year period the probability of no shocks is 0,691, of one shock 0,264, and of two or more shocks 0,045. If a shock of 25 % or more in absolute value would be interpreted as a depression, its probability is around 17 % - on average, once in six 5-year periods.

Figure 12. Equity returns jump model decomposed

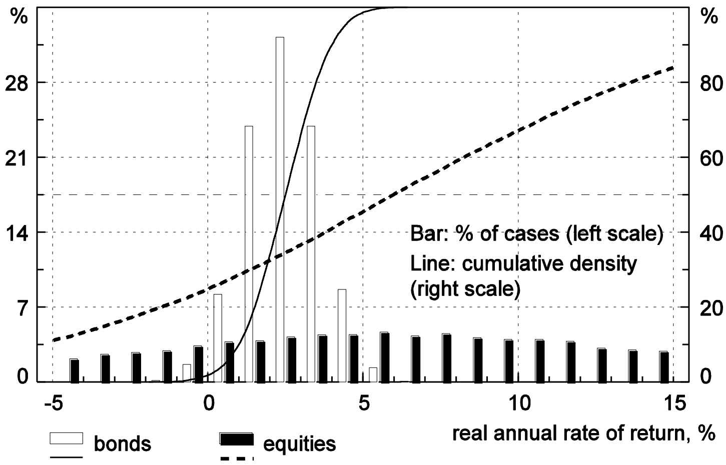


3.3 Previous FOG analysis with asset yield uncertainty

Lassila and Valkonen (2008c) analyze the financial sustainability of the Finnish public sector using stochastic projections to describe the uncertain future demographic trends and asset yields and also analyze policy options aimed at improving sustainability. The estimated stock and bond market yield distributions in Lassila and Valkonen (2008c) are modeled to determine the yield risk of pension funds and the asset/debt portfolio of the central government (but not to affect the saving and investment decisions of the private sector). 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 estimated variance of 10.97. The real interest rate data is from the IMF Financial Statistics. German bond data from years 1955-2005 is used, 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 estimated 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 to be non-correlated.

Figure 13 depicts the quantities of financial market risks that were used in the study. It shows the distribution of the real 5-year returns of bonds and equities, expressed as annual rates. Equity returns are truncated in the figure; the cumulative density function shows that the yield is below -5 % in over 10 % of cases, and higher than 15 % in over 15 % of cases. In the portfolio of private sector pension funds 40 percent is allocated in stocks and 60 percent in bonds. There is about 50 percent probability that the real rate of return is between 2-6 percents in each 5-year period. The expected real annual yield is 3.9 per cent.

Figure 13. Asset yield uncertainty in Lassila and Valkonen (2008c)



The investment risk is allocated to the pension contributions in the Finnish defined benefit pension system. A higher rate of return increases the proceeds that can be used to pay pensions, and lowers thereby future contribution rates. It affects the pensions only insomuch as the lower employers' pension contributions raise wages and thereby the indices that are used to upgrade pension accruals and paid pensions (the weights of wages and consumer prices are 0.8/0.2 during working years and 0.2/0.8 during retirement).

Lassila and Valkonen (2008c) consider three policy measures that are all motivated by sustainability problems. They all have strong implications on how demographic or economic risks are shared between different groups in the economy.

The first policy, longevity adjustment of pension benefits, addresses one demographic risk, the future length of life. The adjustment reduces the effect of future changes in old-age mortality to pension expenditure. The second policy is switching from defined-benefit pension system to non-financial defined contribution (NDC) system. It addresses both demographic and economic risks. Both these measures reduce sustainability risks. They either decrease or remove the expected problem and narrow the sustainability gap distribution, as Table 2 shows. In both these policy options a precondition for smaller financial sustainability risk is that any political risks due to lower pensions is not realized.

In the third policy, pension funds invest a larger share in equities and expect to get higher returns. This policy addresses the expected sustainability problem. At the same time it gives less weight to financial risks than the policy under current rules. The whole sustainability gap distribution shifts to towards smaller gap values and the total sustainability risk is reduced, even though the distribution gets wider.

All three policies concern earnings-related pensions. The third policy could equally well be carried out in other public portfolios. One could find counterparts and analogies in central or local government activities for the first two policies also. Although the results and the sustainability consequences are presented for the large public sector, the policies are applied only to the Finnish statutory private sector earnings-related pension system. The policy analysis was carried out by using the data provided by the base stochastic scenario, and thus does not include behavioural responses to the measures considered. These responses will be included in FIRSTRUN.

Table 2: Sustainability gap distributions, % of GDP

	p05	d1	Q1	Md	Q3	d9	p95
Base	-1.0	-0.6	0.3	1.4	2.3	3.4	4.1
Without longevity adj.	-0.6	-0.1	1.0	2.2	3.3	4.5	5.5
NDC	-1.7	-1.4	-0.9	-0.3	0.5	1.3	1.8
More equities	-3.3	-2.5	-1.1	0.3	1.7	2.7	3.8

4 Productivity

4.1 Productivity in the FOG model

Productivity appears in the FOG model in the production function of the firm. There is an exogenous parameter that defines the growth rate of labour productivity. The same parameter is used in the export demand equation, to keep the rest of the world also growing, and in households' welfare function, to prevent them from shifting their labour supply exorbitantly to the last years of working lives where productivity and wages are the highest.

Productivity growth affects debts and funds. For instance, higher growth rate has two notable effects on the finances of the earnings-related pension system. Firstly, higher growth means higher wage growth and higher wage bill, and since pension benefits are only partially indexed to wage growth, this reduces the required pension contribution rate. Secondly, existing pension funds are smaller compared to future pension accruals, and this increases the required contribution rate. The first effect dominates but the second is noticeable also. Growth – interest rate differential is of course important for figures concerning the public indebtedness in relation to GDP. Besides productivity growth, changes in labour input affect GDP.

4.2 Uncertainty in future productivity

Short term changes in productivity are not very interesting in the FOG model. They cause periodic variation in wages around the long-run trend, but this feature comes already from revised demographic forecasts. When firms realize that the supply of labour differs from what they expected, wages adjust up or down.

Uncertainty in trend growth, however, has effects that may bring new aspects when added to demographic and asset yield uncertainty. Unfortunately, there are not many studies on this issue.

Gillingham et al. (2015) note that "Forecasts of long-run productivity growth involve active debates on issues such as the role of new technologies and inventions (Brynjolfsson and McAfee 2012, Gordon 2012), potential increases in the research intensity and educational attainment in emerging economies (Fernald and Jones 2014, Freeman 2010), and institutional reform and political stability (Acemoglu et al. 2005). While the empirical literature on economic growth has provided evidence in support of various underlying models, no existing study contains sufficient information to derive a probability distribution for long-run growth rates. "

Gillingham et al. (2015) report an effort of the project team led by Peter Christensen, to develop estimates of uncertainties from an online survey of experts on economic growth. A panel of experts was asked to characterize uncertainty in estimates of global output for the periods 2010-2050 and 2010-2100. Growth was defined as the average annual rate of real per capita GDP, measured in purchasing power parity (PPP) terms. Experts were asked to provide estimates of the average annual growth rates at 10th, 25th, 50th, 75th, 90th percentiles. The estimates were assumed independent across experts.

It was found that most experts' estimates can be closely fitted by a normal distribution. Not surprisingly, the combined distribution can then be well fitted by a normal distribution. The resulting combined normal distribution has a mean growth rate of 2.29% per year and a standard deviation of the growth rate of 1.15% per year over the period 2010-2100. Growth rates based on these estimates, but amended to take into account the possible trend in labour supply, will be used in FIRSTRUN. The authors note that these values may be updated in a further report due to addition of further responses. We will consider applying the updated values when they are available.

As noted in Section 3, uncertainty in future productivity could also be used to include depression elements. Expectations of future productivity growth can be unduly pessimistic during a depression, which could be modeled with the negative financial shock variable. Pessimism need not prevail for long, it could e.g. disappear before the next 5-year period and thus have effects on just one period's policy reactions. Depending on the fiscal policy rule studied, these effects good be beneficial or harmful.

4.3 Previous FOF analysis with productivity

Stochastic productivity has not been used as an input in FOG before. The effects of a higher level of productivity (but the same growth rate) on fiscal sustainability have been calculated. If productivity level is 1 % higher both in the private sector and in publicly financed health and care services and public administration, sustainability gap is about 0,3 %-points smaller. If higher productivity occurs only in the private sector the decline in the gap is 0,2 %-points.

5 Structural deficit assessments

Structural deficit, and the uncertainty related to it, is an entirely different issue from those we have considered earlier. Structural deficits are not observable, and are measured by proxies. Perceptions of the structural deficit are still an important part of fiscal policy discussions and analyses especially during recessions and depressions.

As a general equilibrium model, FOG does not deal with business cycles. Some short-term elements can and have be used in the model, such as exogenous shocks to public sector assets and liabilities. Structural deficit is not a variable in the FOG model, but it could be included e.g. in the form of an expectation that there will be an exogenous addition to public indebtedness sometimes in the future. This expectation could be wrong, which makes it different from the shock to current public debt. If such expectations are biased, that disturbs affects the outcomes of any forward-looking fiscal rules. Instead of twisting the view of future developments, loss function could take care of the need to be cautious.

Perceptions of the size of structural deficits vary. Figure 14 shows how the estimates of cyclically adjusted net lending (+) or net borrowing (-) of general government in Finland, concerning the year 2009, have changed in time. The x-axis denotes the time the estimate is published. The data concerns variable UBLGAP in the annual macro-economic database AMECO.

Figure 14. Estimates of cyclically adjusted net lending of general government in 2009 in Finland

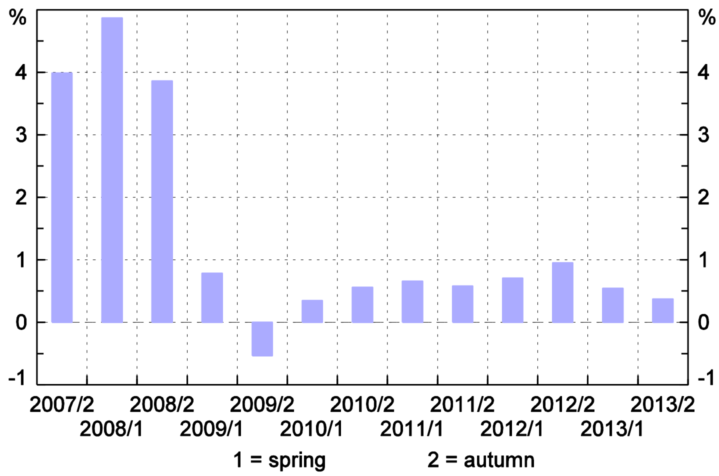
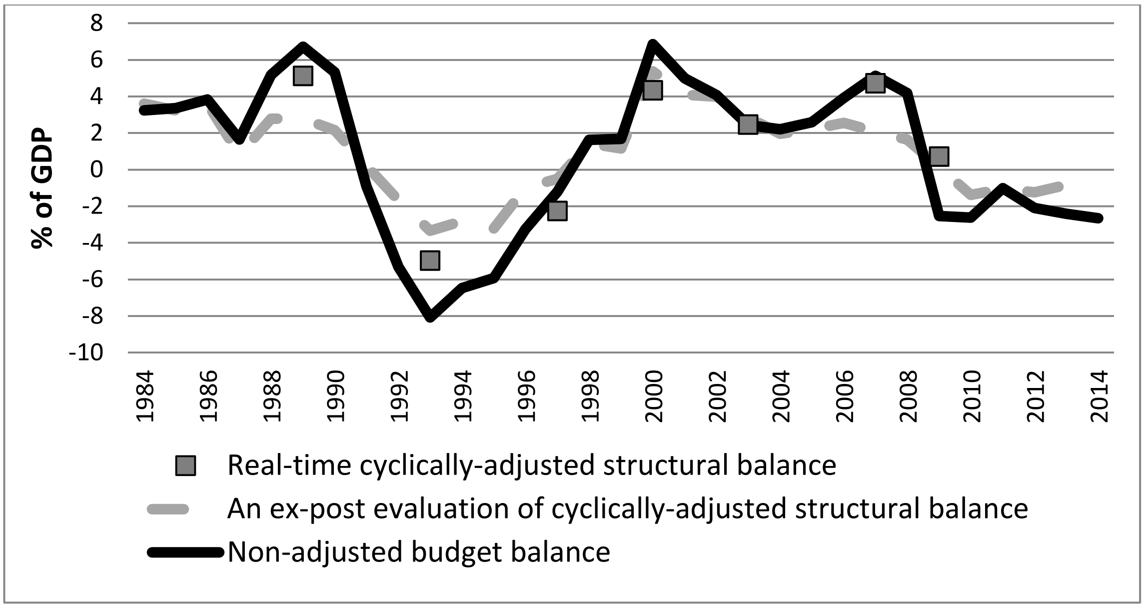


Figure 15 is from Kuusi (2016, Fig. 3). He notes that “Real time has a considerable effect on the indicator's functioning. When estimates of total factor productivity and structural unemployment are based on data which takes no account of the trend for future years, the structural balance proves to be considerably more procyclical. In real time, the structural balance has deviated materially from the ex post estimate in two of the three expansions in recent decades (1989, 2000, 2007). The structural balance would be overestimated by approximately 1.3 percentage points with respect to three business cycle peaks, on average. In addition, the real-time structural balance underestimated the deficit component due to the economic crisis when the downturn of the early 1990s had already begun. For example, the 1993 ex post estimate of the structural contribution to the total deficit would have been approximately 35 per cent, while the real-time estimate would have been approximately 60 per cent. "

Figure 15. Real-time and ex-post evaluated cyclically adjusted structural balance



Kuusi concludes that "The results reinforce the impression of the limited capacity of the output gap method to predict cyclical changes in real time, and therefore, its use for steering fiscal policy could lead to a procyclical fiscal policy."

There could be a link between structural deficits and the negative equity return shock– a financial crisis, or rather its depression interpretation. During a crisis, which has real elements and output has declined, people are often pessimistic. What later will be considered as a cyclical decline is often feared to be a permanent decline. What then is an observed deficit is largely interpreted to be a structural deficit. Technically this idea could be implemented by adding into the state's budget constraint a variable that heuristically describes real-time structural balance, is an expected negative future debt shock and is calculated utilizing the negative equity return shock variable.

6 Notes on uncertainty assessments in the EU's population ageing and fiscal sustainability evaluations

In the 2015 Ageing Report: Economic and budgetary projections for the 28 EU Member States (2013-2060), by the European Commission (DG ECFIN) and the Economic Policy Committee (Ageing Working Group), there are seven unchanged policy scenarios and one policy scenario, besides the baseline scenario. They are used to assess the impact of various elements on the macroeconomic and budgetary variables. The unchanged policy scenarios concern high life expectancy, lower migration, higher employment rate, higher employment rate for older workers, higher labour productivity, lower labour productivity and lower total factor productivity. The policy scenario concerns linking retirement ages with life expectancy. In addition there are twelwe scenarios concerning health care expenditure and eleven for long-term care.

The report (EC 2015, p. 48) states that "Sensitivity tests are an indispensable element of (long-term) budgetary projections, in order to quantify the responsiveness of results to changes in key drivers, such as macroeconomic and population variables, together with policy assumptions, thereby providing "confidence intervals" in order to gauge uncertainty."

Using citation marks in "confidence intervals" should be treated as a warning sign. The scenario approach is incapable of providing confidence intervals. This is one of the basic reasons of using stochastic simulations, as recently expressed in a Letter to the editor (2015) in Journal of Official Statistics. Scenarios often lead to very narrow ranges of uncertainty, as e.g. Lassila and Valkonen (2008a) pointed out with respect to the Commission's pension expenditure projections.

A fresh sustainability report (EC 2016) The 2015 Fiscal Sustainability Report by the European Commission (DG ECFIN) contains a much more thorough treatment of several uncertainties, but they concentrate on the short and medium term. Besides several scenarios there is a stochastic public debt analysis based on Berti (2013), with a five-year horizon. There are again scenarios for long-term uncertainty assessments, based on some of the alternatives in EC (2015).

7 Concluding remarks

7.1 Limiting the analysis

The FOG model will be used in FIRSTRUN to study fiscal policy and long-term fiscal sustainability under uncertainty. We ask whether a fiscal policy, that follows a rule describing how pensions, public transfers and health and long-term care services are provided and financed, is sustainable or whether it leads to excessive indebtedness or intolerable levels of taxation. As the future is inevitably uncertain, no definite answer can be given. We can, however, quantify the uncertainties and illustrate and evaluate their effects. We can form a probabilistic view of the public debt and taxation developments that the policy rule will cause. This view then serves as a basis for our evaluation of the sustainability of the system and its intergenerational nature.

Technically all the uncertainties considered in this paper can be used as inputs in FOG, although correlation considerations are needed when the shocks are simulated (see e.g. Alho and Vanne, 2006), especially concerning the negative equity return shocks (see Ronkainen, 2012, sections 5.3 and 5.4). The hard parts are 1) running the FOG model with multiple uncertainties, 2) collecting and going through the results, and 3) presenting the results in an understandable and hopefully also insightful way.

Point 1) is obvious. There numerous possible relevant policy rules, with many parameters, thresholds and trigger values. The number that can be studied in FIRSTRUN is strongly restricted by computational limits.

Point 2) became obvious to the authors of Lassila, Valkonen and Alho (2014). Their analysis produced a vast amount of simulation results. The economic model output consists of stylized national accounts for each period, supplemented by household behaviour specified using 5-year birth cohorts, three educational groups and a maximum age of 100 years. 50 years with a 5-year unit period and a 50-year horizon for forecasts means that the baseline alone consisted of 100 national accounts for each of the 200 population paths used, i.e. a total of 20 000 national accounts. This amount is then multiplied by the policy alternatives.

Of the vast amount of data and results, Point 3) concerns the choices of what to present and how. Economic projections based on stochastic simulations are often difficult to explain and require substantial time and attention from the users. This is especially true for stochastic population simulations. Insight about the reasons and mechanisms behind the results may not always be obtained. Adding other uncertainties to demographics does not make things easier; yet that is what we will do in FIRSTRUN. Lassila (2015) considers using decompositions, aiming at gains on pedagogic aspects and intuition while giving up as little as possible on quantitative realism. Here we could introduce various uncertainties one at a time. This is costly also, so the final choices will need a lot of thought. On a more positive note, there certainly is room for improvement in techniques of communicating uncertainty to the users and the general public. A recent Letter to the editor (2015) in Journal of Official Statistics, by experts who do stochastic population projections, notes that better attitudes and practices with respect to uncertainty analysis could perhaps be learned from, for example, aviation, meteorology and climatology.

7.2 Time horizon

One objective in WP 5 is that the fiscal strategy should also be intergenerationally as fair as possible. This leads to a practical question: How long projections should we use? This concerns especially the demographic projections. 50 years is very short a time to consider generational aspects. Lee and Anderson (2005) note that 75 years is too short in analysing the sustainability of U.S. social security, and suggest 500 years as a suitable representation of infinite horizon. They note that “The very phrase ‘infinite horizon forecast’ makes many people snicker, and indeed many serious demographers believe it is pointless and misleading to forecast population beyond 25 years or so” (p. 83).

Stochastic population simulations used in this report were produced by the Program on Error Propagation (PEP). The uncertainty of future fertility and mortality were empirically determined to represent the level of uncertainty observed in the past, and the error model for migration was based on a time series analysis, but was judgmentally calibrated. Thus the uncertainty in simulated futures is based on careful empirical research. But there seems to be a limit, in the researchers’ minds, on the length of the time horizon during which the past uncertainties provide a realistic base to assess future uncertainties. For long term forecasting PEP has the option of keeping error variances at a fixed level from some forecast year on. In this study the limit year was 50 years into the future. After that limit year the errors follow a matching AR(1) process. Extending the limit by

30 years would be good in tracking the demographic effects, but we need to consider whether our empirical knowledge is sufficient for such an extension.

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