

Societal Aging in the Netherlands: Exploratory System Dynamics Modeling and Analysis

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Abstract

Mismanagement of societal aging is an important threat to health care systems, social security systems, and the economy of many nations. a System Dynamics simulation model related to societal aging in the Netherlands and its implications for the Dutch welfare system is used here as a scenario generator for Exploratory System Dynamics Modeling and Analysis - a System Dynamics-based approach for exploring and analysing deeply uncertain dynamically complex issues and testing policy robustness many plausible futures. Key concerns derived from this exploratory research are (i) the existence of plausible futures with severe labour scarcity, especially in health care, (ii) unsustainable evolutions of health care costs, and (iii) insufficient labour productivity, especially in health care. Our analysis shows that labour productivity may be cause of and cure for many of the undesirable evolutions. We conclude that (i) sufficient increases in labour productivity in health care as well as labour productivity in general without pinching the necessary workers in care are needed, and (ii) sufficiently raising the retirement age only helps if both the willingness to work longer and the willingness to keep older employees increase. These conclusions are derived from systematic data analysis which is fully documented in the appendix.

Keywords: Demographic Shifts, Societal Aging, EMA, ESDMA, EGMSS

1 Introduction – Societal Aging in the Netherlands

The effect of future demographic changes in The Netherlands is investigated in this paper. Special attention is paid to the systems consequences in terms of health care, housing, social security, and the labor market. The main aim of this line of research is to identify relations that exist between the different aspects of the welfare state and to identify how demographic changes may possibly affect the welfare state. In other words, what are the consequences of demographic shifts and population aging in The Netherlands (in terms of labor supply, financing and societal costs in health care, social security, housing and the labor market) taking future uncertainties seriously into account? This question is answered in this paper by means of Exploratory System Dynamics Modeling and Analysis (see section 2) as a form of extreme scenario analysis.

Hence, we try to shed light on plausible influences of uncertain demographic changes, in particular aging, on welfare states (i.e. housing, social security and health care) and labor market. The Dutch case is really an illustration for many other nations. Demographic aging is mainly caused by a decrease in fertility rate and an increase in life expectancy and is expected to be a large problem in many industrialized and some industrializing countries.

Because of increasing life expectancy and declining birth rates, the age distribution of the population is changing towards a larger proportion of elderly – this effect is called demographic or societal aging. This causes a smaller part of the population being able to work, and thus paying social security for the ones in need, and the health care expenses to rise because health care expenses increase exponentially with age.

In the Netherlands, a large proportion of current employees, the so called ‘baby-boom generation’, is expected to retire in the coming decade. Additionally, as of 2010 the fertility rate is

1.66 children per woman (where 2.1 children is considered the ‘replacement level’ for a sustainable inflow). These figures show that the age distribution in The Netherlands will change within a few years. The question in this respect is the size of the problems created by this demographic change. Due to this demographic change the size of the work force will *ceteris paribus* become smaller compared to the total population, but the consequences of this change in age distribution are to a large extent unknown. The Dutch government has recently increased the retirement age (from 65 to 66 in 2020) but the system-wide effects of this policy may not be effective for dealing with Societal Aging in the Netherlands.

Most research on the consequences of demographic aging (e.g. research by the Dutch Bureau for economic policy analysis) does not thoroughly link all interrelated subsystems of interest, nor does it take all sorts of uncertainties into account. Considering all interrelated subsystems of interest simultaneously matters for this issue: a decreasing working population may for example lead to decreased availability of personnel in health care, which may influence the quality of health care, which may in turn influence the availability of healthy workers. This research explicitly takes relations between the interrelated subsystems as well as a plethora of uncertainties into account.

1.1 Organization

The methodology is introduced in section 2. The model, uncertainties, and key performance indicators are discussed in section 3. Base ensemble without migration scenarios and retirement policies are analyzed and explored in section 4. Hurried readers should focus their attention on subsection 4.2. Some preliminary policy analyses are discussed in 5. Conclusions and future research are discussed in section 6. Appendix A contains the detailed systematic analysis of the base ensemble. And appendix B displays the views of the System Dynamics model used for this research.

2 Methodology

2.1 Exploratory System Dynamics Modeling and Analysis

The methodology used in this paper is Exploratory System Dynamics Modeling and Analysis (ESDMA). ESDMA is a multi-methodology consisting of the combination of System Dynamics Modeling (Forrester 1961; Sterman 2000) and Exploratory Modeling and Analysis (Bankes 1993; Lempert, Popper, and Bankes 2003; Agusdinata 2008) for dealing with deeply uncertain dynamically complex issues. Issues are deeply uncertain if analysts do not know, or the parties to a decision cannot agree on (i) the appropriate conceptual models which describe the relationships among the key driving forces that shape the issue’s long-term future, (ii) the probability distributions used to represent uncertainty about key variables and parameters in the mathematical representations of these conceptual models, and/or (iii) how to value the desirability of alternative outcomes. In other words, although deeply uncertain issues could be modeled, the combination of a model, particular structures, and parameter values will at most be plausible, and so will be the outcomes of that combination. ESDMA consists of the following steps:

- (i) developing plausible ‘exploratory’ –ie fast and relatively simple– SD models of the issue,
- (ii) generating an ensemble (tens of thousands) of scenarios by sweeping uncertainty ranges and varying uncertain structures, boundaries, mechanisms, models, and modeling methods,
- (iii(a)) time-series clustering and further analysis of the ensemble of scenarios,
- (iii(b)) and/or specifying a variety of policy options (preferably adaptive ones), and simulating, calculating, and comparing the performance of various options across the ensemble.

In ESDMA, there is no base case, at most a base ensemble consisting of thousands of runs – here 10000 runs and 1000 runs for some analyses. All runs are considered plausible unless

rejected for one reason or the other. Probabilistic interpretations are avoided: the nature of the problems dealt with, the sampling method, and the uncertainties and models considered simply do not allow for probabilistic interpretations. Hence the focus lies on exploration of plausible scenarios and (time-series) data analysis. In ESDMA, one is more interested in the undesirable and abnormal than the desirable and normal: outliers are interesting cases for further research, causes of undesirable outcomes are valuable.

Although ESDMA is new, it has already been applied to many dynamically complex issues characterized by deep uncertainty, from pandemic shocks to uncertain resource scarcity (see for example (Pruyt and Hamarat 2010b; Pruyt and Hamarat 2010a; Pruyt and Kwakkel 2011; Pruyt, Kwakkel, Yucel, and Hamarat 2011; Kwakkel and Pruyt 2011; Auping et al. 2012)).

2.2 Techniques used as part of the ESDMA

Not all System Dynamicists may be familiar with the techniques and tools used in this paper. Hence, a short introduction to some of the techniques and (visualization) tools used in this paper:

- Lines plotting, Envelope plotting, Kernel Density Estimate (KDE) plotting, 3D Kernel Density Estimate (KDE) plotting, and multiplotting¹;
- The Random Forest algorithm² (Breiman 2001) and Feature Selection algorithm³ (R. Kohavi 1997) with non-binary classification functions: gives an impression of the most important uncertainties for a non-binary classification function;
- A new version of the Patient Rule Induction Method⁴ (PRIM) (Friedman and Fisher 1999) –one that can deal with categorical and continuous uncertainties– with a binary classification function and PRIM box plotting: gives uncertainty space boxes (with the fraction of positive matches and the mass of the box relative to the total scenario space) that perform below/above a particular threshold introduced in a binary classification function;
- A time-series clusterer algorithm –a more advanced version based on a novel approach to (dis)similarity (Yucel and Barlas 2011; Yucel 2012)– with a dendrogram and cluster plots: allows to cluster time series data based on attributes and select the (dis)similarity level at which to classify/plot clusters;
- Scripts for directed searches and data set splitting.

2.3 Exploratory Group Model Specification & Simulation Workshop

The first ever Exploratory Group Model Specification and Simulation (EGMSS) Workshop was organized as part of this research in order to elicit and include uncertain information from different experts. The experts were asked to provide inputs for following (time-series) uncertainties: *average productivity per age, relative average labor productivity, relative average labor productivity in care, relative average labor productivity in cure, fraction smokers in population, fraction meeting standards of physical activity in population, fraction heavy drinkers in population, fraction obese in population, female life expectancy, male life expectancy, fertility rate, average labor participation male, average worked hours per week male, average labor participation female, average worked hours per week female.*

The workshop consisted of four phases: (i) presentation of model and the (re)main(ing) uncertainties (see Figure 1(a)), (ii) generation of trend lines for remaining uncertainties (see Figure 1(b)), (iii) ESDMA simulation and presentation of the preliminary ‘ensemble of scenarios’ (see

¹of existing correlations between output indicators in order to (i) select a useful set of output indicators and (ii) verify whether particular relationships that are known to exist work out fine in complex models

²With: default nrOfTrees = 100; default number of attributes = None

³With: default number of neighbors for each example 5; default use of all examples

⁴PRIM03b with: box init = None, peel alpha = 0.05, paste alpha = 0.01, mass min = 0.05, threshold = None, pasting=True

Figure 1(c)), and (iv) general discussion on improvements and generation of possible policies (see Figure 1(d)).



(a) Introduction to pre-modeled structures and remaining uncertainties (b) Harvesting and adding expert opinions to the SD model and python code (c) Front: adding different expert opinions – Back: methodological discussion (d) Post-analytic discussion based on ESDMA ensembles (pop. w/o function uncertainty (lkps))

Figure 1: Pictures of the EGMSS workshop

The participants were given a number of empty graphs on which they were asked to draw plausible evolutions for specific exogenous variables (ie how they thought they might develop over time) as well as relations for specific table functions. To prevent receiving a large number of (relatively) similar graphs, the participants were also asked to draw an upper and lower bound to the trend line. These upper and lower bounds were used in a later stage to implement extreme (but plausible) variables in the model.

The model used during the workshop had been prepared in advance, to be able to insert the evolutions and lookups fast (slightly lagging the filling in of the participants). During the break, our software developed an experimental design (combining the parametric and categorical uncertainties with the 15 sets of lookup functions provided by the workshop participants in subsection 3.3) and executed the design by forcing Vensim to simulate all runs of the experimental design.

3 Model, Uncertainties, and Key Performance Indicators

3.1 The Model

The System Dynamics simulation model developed and used for this research is described in detail in (Logtens 2011) and (Pruyt, Logtens, and Gijsbers 2011). The model consists of five subsystems (see appendix B): a submodel dealing with *demographics and population dynamics*, a submodel dealing with the *economy*, a submodel dealing with *health care*, a submodel dealing with *housing*, and a submodel dealing with the *social security system*.

The sector diagram (with the major switch uncertainties filled in during the EGMSS workshop indicated in yellow) is displayed in Figure 2.

3.2 Key Performance Indicators

The following key performance indicators focused on in this analysis are: the *total population*, the *elderly dependency ratio*, the *health care costs as a fraction of GDP*, the *governmental contribution to AOW as a fraction of GDP*, the *fraction of care FTE demand fulfilled*, the *fraction of housing demand fulfilled*, the *male life expectancy*, the *female life expectancy*, the *demand for accessible houses*, the *annual GDP*, the *fraction labour scarcity*, the *average labour participation female 55 to 64*, and the *average labour participation male 55 to 64*.

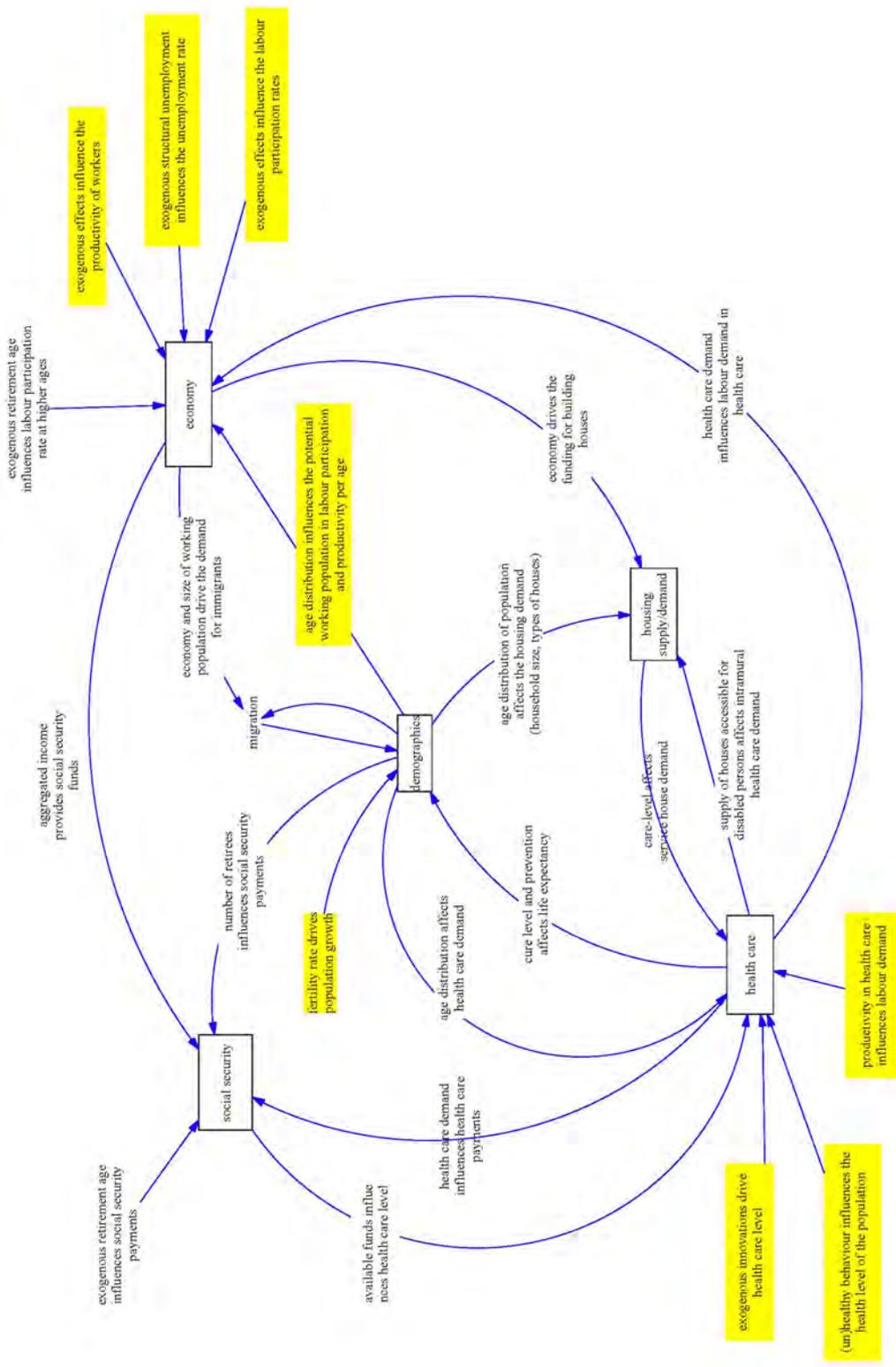


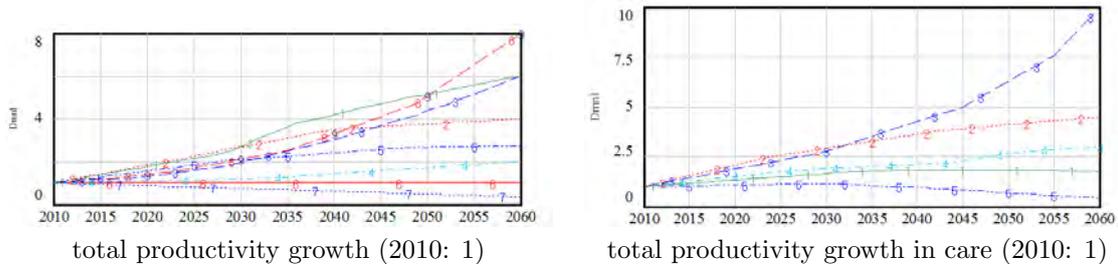
Figure 2: Sector diagram of the Societal Aging model

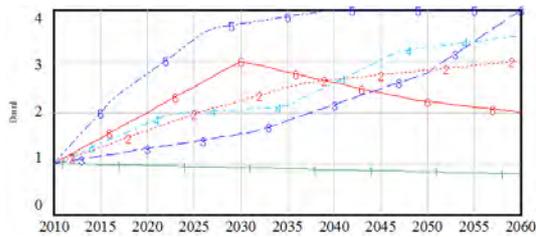
3.3 Uncertainties

Following parametric and categorical uncertainties were included in the analysis:

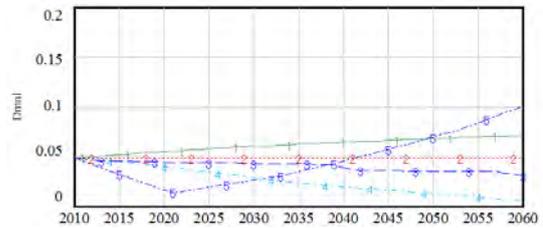
Variable	Lower bound	Upper bound	Type	Distribution
Initial Regular Houses Easily Modified	485571	1318459	Parametrical	Random uniform
trend in rules of admission to intramural care	0	0.01	Parametrical	Random uniform
delay time in behaviour effect on unhealthy expectancy	5	15	Parametrical	Random uniform
delay time in behaviour effect on mortality	10	20	Parametrical	Random uniform
trend in average regular house household size	-0.01	0.01	Parametrical	Random uniform
fraction of life expectancy increase due to cure level lived in good health	0.25	0.75	Parametrical	Random uniform
unspecified changes in cure costs	0.005	0.015	Parametrical	Random uniform
economic growth period1	0.03	0.035	Parametrical	Random uniform
economic growth period2	-0.01	0.03	Parametrical	Random uniform
economic growth period3	-0.01	0.03	Parametrical	Random uniform
economic growth period4	-0.01	0.03	Parametrical	Random uniform
economic growth period5	-0.01	0.03	Parametrical	Random uniform
average wage level increase period1	0	0.02	Parametrical	Random uniform
average wage level increase period2	0	0.02	Parametrical	Random uniform
average wage level increase period3	0	0.02	Parametrical	Random uniform
average wage level increase period4	0	0.02	Parametrical	Random uniform
average wage level increase period5	0	0.02	Parametrical	Random uniform
male willing to work 60 to 64 trend	0	0.03	Parametrical	Random uniform
female willing to work 60 to 64 trend	0	0.03	Parametrical	Random uniform
delay order in behaviour effect on unhealthy expectancy	1, 3, 10, 1000		Categorical	Random uniform
delay order in behaviour effect on mortality	1, 3, 10, 1000		Categorical	Random uniform
coefficient A relative attractiveness of working in health care	-1	0	Parametrical	Random uniform
coefficient B relative attractiveness of working in health care	5	20	Parametrical	Random uniform
coefficient C relative attractiveness of working in health care	0.5	5	Parametrical	Random uniform
coefficient D relative attractiveness of working in health care	-0.5	1	Parametrical	Random uniform
coefficient A relative attractiveness of working after retirement age	-5	0	Parametrical	Random uniform
coefficient B relative attractiveness of working after retirement age	0	20	Parametrical	Random uniform
coefficient C relative attractiveness of working after retirement age	1	5	Parametrical	Random uniform
coefficient D relative attractiveness of working after retirement age	-0.5	1	Parametrical	Random uniform
coefficient A relative attractiveness of working until retirement age	-1	0	Parametrical	Random uniform
coefficient B relative attractiveness of working until retirement age	5	20	Parametrical	Random uniform
coefficient D relative attractiveness of working until retirement age	0	1	Parametrical	Random uniform
coefficient A building houses delay time	10	90	Parametrical	Random uniform
coefficient B building houses delay time	2	6	Parametrical	Random uniform
annual fraction service houses demolished	0	0.01	Parametrical	Random uniform
annual fraction regular houses demolished	0	0.01	Parametrical	Random uniform
annual fraction of persons unnecessary in accessible houses willing to move away	0	0.03	Parametrical	Random uniform
fraction of accessible house demand fulfilled by modification of RHEM	0.6	1	Parametrical	Random uniform
fraction of accessible house demand fulfilled by modification of RHDM	0	0.4	Parametrical	Random uniform
average nursing homes building delay time	1	5	Parametrical	Random uniform
fraction of average wage increase to increase in aow	0	1	Parametrical	Random uniform
change in preference of employers for hiring workers	10	50	Parametrical	Random uniform

Following lookup variants are switched over for following 15 function uncertainties:

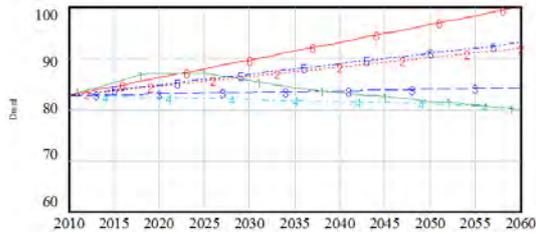




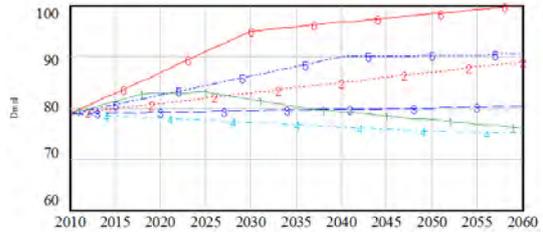
total productivity growth in cure (2010: 1)



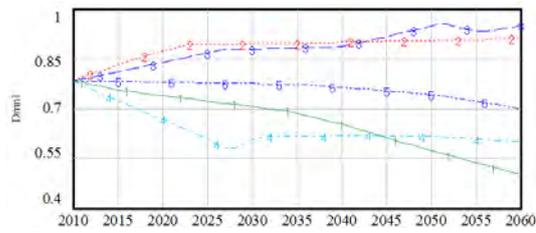
fertility rate (2010: 0.048/woman in fertile age)



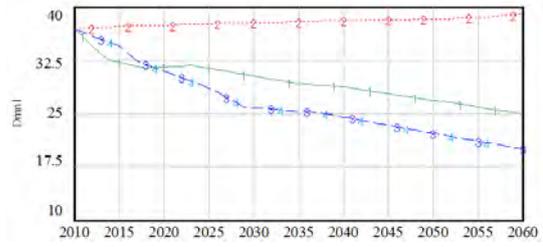
life expectancy female (2010: 82.71 yr)



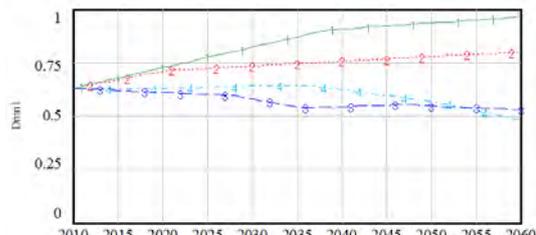
life expectancy male (2010: 78.82 yr)



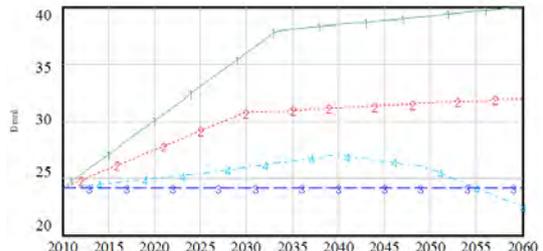
male labour participation (2010: 0.783)



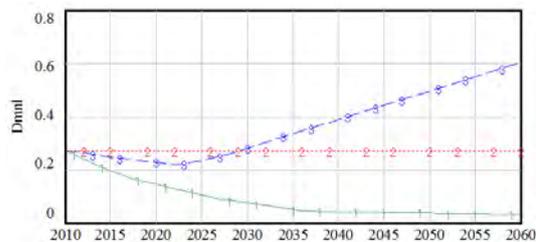
male worked hours per week (2010: 36.9 h/wk)



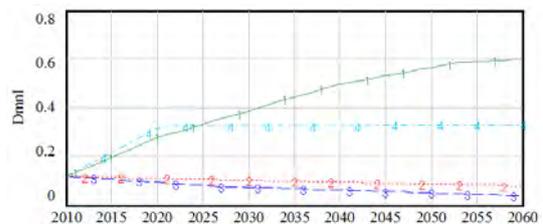
female labour participation (2010: 0.63)



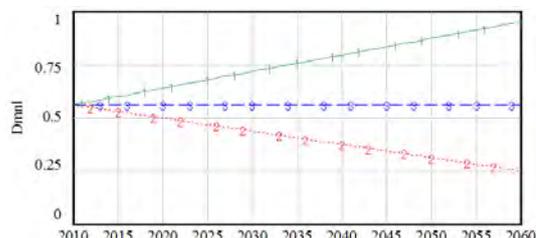
female worked hours per week (2010: 24.1 h/wk)



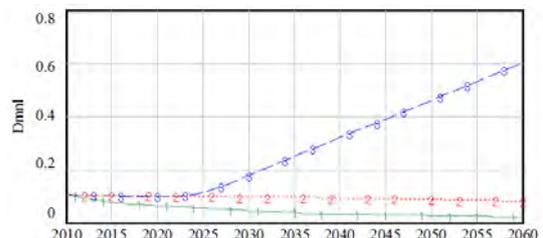
fraction smokers (2010: 0.271)



fraction obese (2010: 0.118)

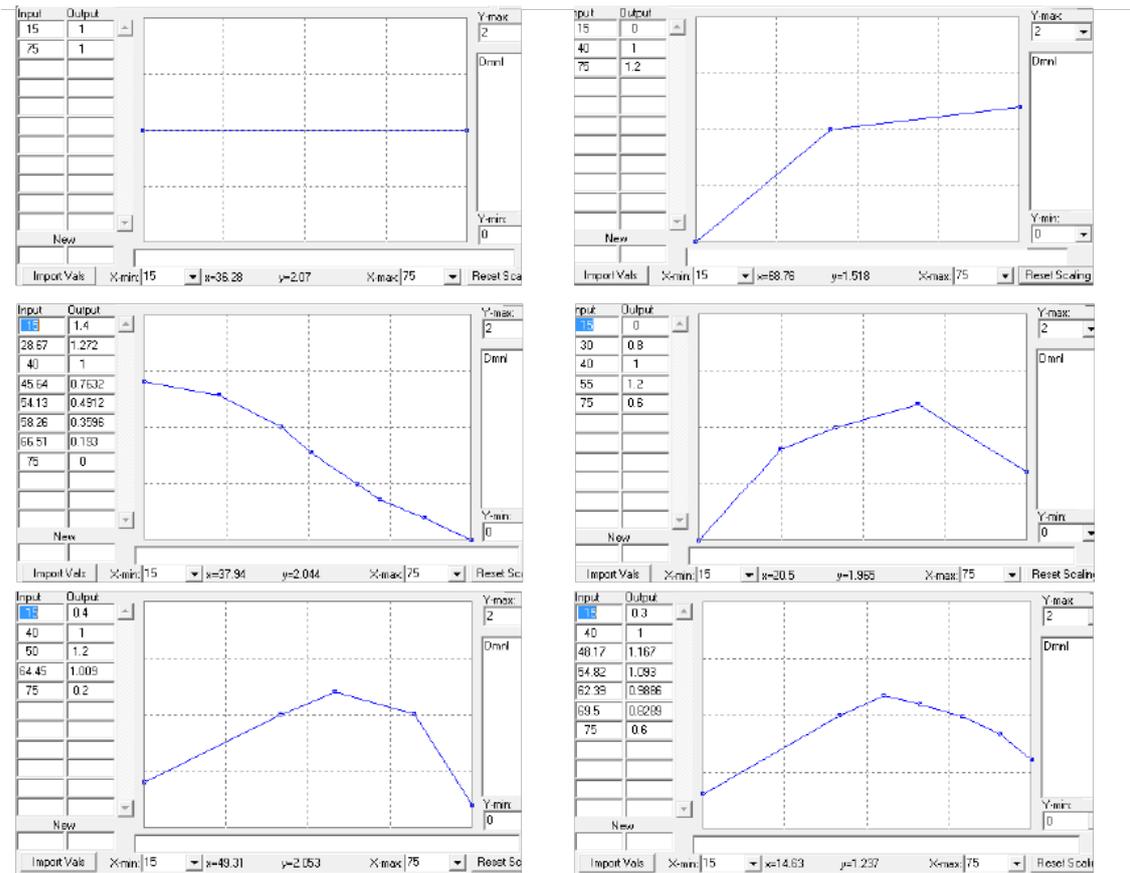


fraction physically active (2010: 0.56)



fraction heavy drinkers (2010: 0.104)

Average marginal productivity per age (productivity at age 40 is set at 1, 2 is twice as productive):



4 Exploration and Analysis of the Base Ensemble without Migration Scenarios or Retirement Policies

4.1 Data sets of the base ensemble

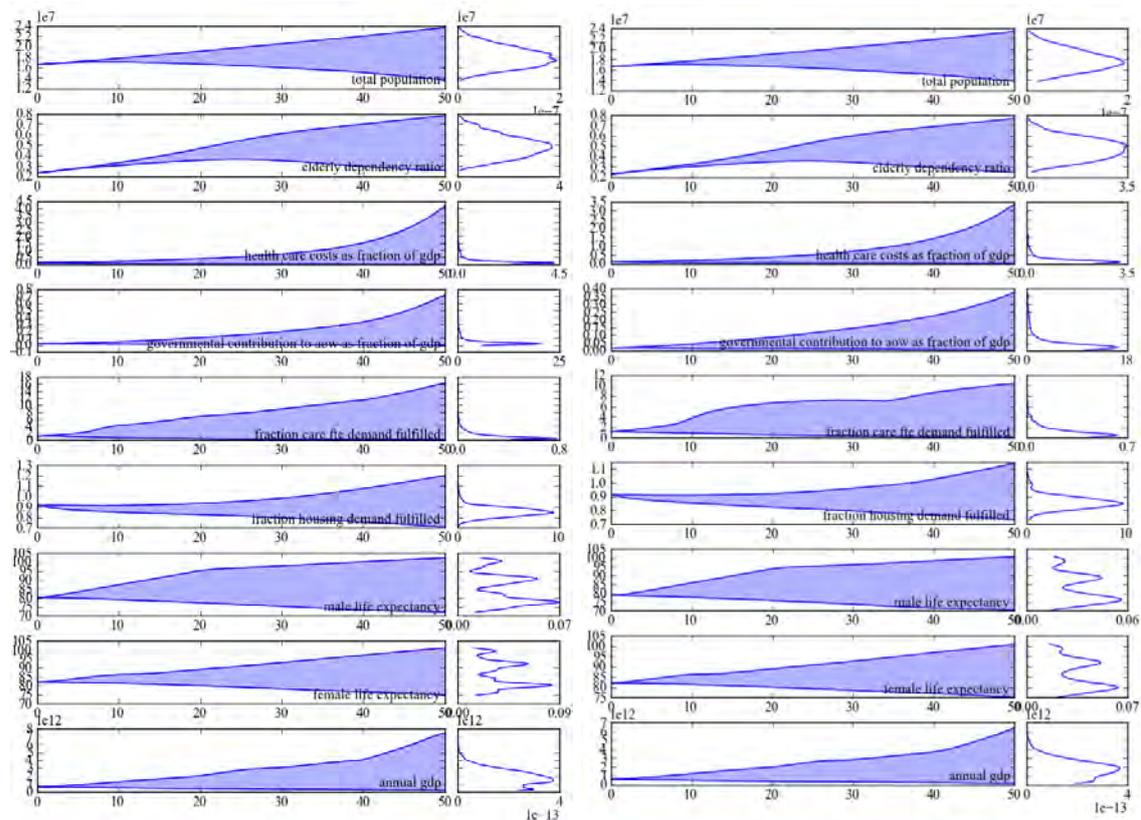
Two data sets were generated using Latin Hypercube sampling on the model described in subsection 3.1 and the uncertainties listed in subsection 3.3:

- result10000alluncertainties.cPickle : a set of 10000 runs for those analyses where 10000 runs are needed and/or fast enough⁵;
- result1000alluncertainties.cPickle : a set of 1000 runs for those analyses where 10000 runs are too many or too slow and 1000 runs are good enough⁶.

The two data sets –displayed below– were generated with the same settings (Latin Hypercube, the same uncertainties). The first set is ten times larger. Hence, somewhat more extreme runs are included in the larger set, widening the envelopes of the larger set, and marginally changing the KDEs. Overall, they are rather similar and both sets are used below.

⁵Envelopes can, and Prim needs to, be fed with as large –in terms of number of runs– a set as possible.

⁶Clusterer and interactive plotting requires a relatively small number of runs.



4.2 Analysis of the base ensemble for each key performance indicator in isolation

The interpretation of the analysis of the base ensemble is briefly discussed in this section. A very detailed account of the analysis of the base ensemble, on which the interpretations in this subsection are based, is available in appendix A starting on page 20.

The total Dutch population continuously evolves in the base ensemble –i.e. without new migration and fertility policies– to a total population between (just under) 14 million and 24 million by 2060 (see Figure 3).

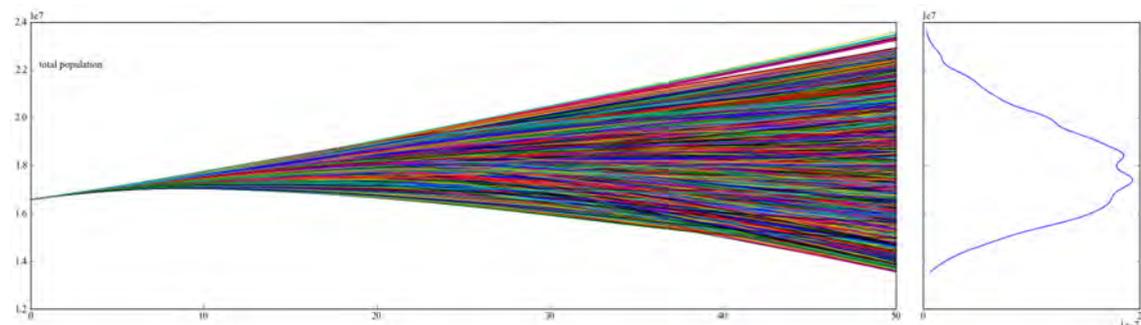


Figure 3: Lines for 10000 runs of the *total population*

The combination of this model and these uncertainty ranges, generates many scenarios with rather high *elderly dependency ratios*, either peaking in 25 years or rising at a slower rate after

25 years (see Figure 4). In about 25 years from now, the average babyboomer may reach (first) his and (then) her average life expectancy, which is treated as deeply uncertain. Three different modes –caused by different evolutions of a third uncertainty, the fertility rate– occur after this breakpoint: S-shaped decrease, stabilization, or linear to slightly exponential growth. Major uncertainties determining the maximum *elderly dependency ratio* are of course the evolutions of the male and female life expectancy, and the evolution of the fertility rate. Especially the high-end evolutions of the life expectancies (rising to above 90 years) lead to many runs with maximum elderly dependency ratios above 55%. Three moderately concentrated boxes contain 1831 out of 2648 cases with an elderly dependency ratio above 55%. However, high elderly dependency ratios are not per definition undesirable – the undesirability of the *elderly dependency ratio* relates to the consequences on other key output indicators: health care and governmental AOW⁷ costs as a fraction of GDP, as well as scarcity of housing and labour (in care).

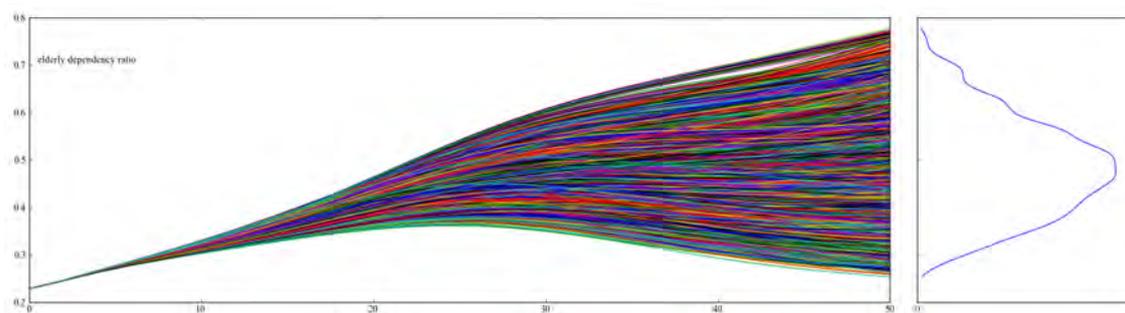


Figure 4: 10000 runs for the *elderly dependency ratio*

Although the evolution of the GDP is of secondary importance to this paper, it is interesting to visualize its development (see Figure 5). Its main driver –the *total productivity growth*– also directly influences two key output indicators, namely the *health care costs as a fraction of GDP* and the *governmental contribution to AOW as a fraction of GDP*, and indirectly many of the other key output indicators. From this perspective it may be useful to know something about the evolution of the annual GDPs in the base ensemble: out of 10000 runs, 1501 runs have annual GDP end state values below €570 billion per year (\sim the Dutch GDP in 2010), 1561 runs have annual GDP end state values between €570 and €1140 billion per year (\sim between the current and double the current GDP), 4096 runs have annual GDP end state values between €1140 and €2280 billion per year, 2734 runs have annual GDP end state values between €2280 billion and €4560 billion per year, and 108 runs have annual GDP end state values above €4560 billion per year. Two concentrated areas in uncertainty space generate almost all undesirable cases (1473 out of 1501 cases with GDPs below the 2010 GDP): the main cause is a decreasing productivity. These evolutions are by no means predictions, not even ensemble predictions, because the economic sector of the model was not developed for that purpose.

The main uncertainty determining the outcomes of the *health care costs as a fraction of GDP* (see Figure 6) is the productivity growth. High productivity growth seems to be, on the one hand, an appropriate solution for keeping the *health care costs as a fraction of GDP* sustainable in cases of increasing life expectancies. On the other hand may decreasing –and to a lesser extent, stabilizing– *total productivity growth* be a prime cause for unsustainable *health care costs as a fraction of GDP*: decreasing *average labour productivity* leads in (almost) all cases to *health care costs as a fraction of GDP* of more than 25% (compared to 10.1% in 2010), and constant *average labour productivity* leads in many cases to *health care costs as a fraction of GDP* of more than 25%.

Hence, productivity growth is needed for this key performance indicator in order to avoid unsustainable *health care costs as a fraction of GDP*. The combination of this model and these

⁷AOW stands for ‘Algemene ouderdomswet’ or ‘General Old Age Law’

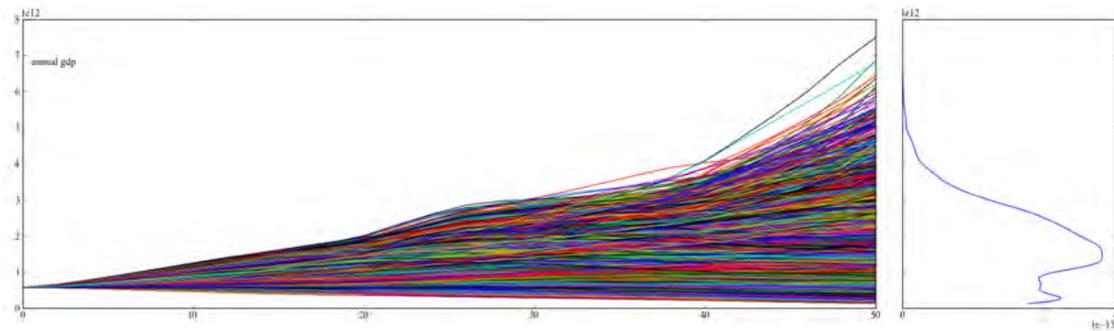


Figure 5: Lines of 10000 runs for the annual GDP

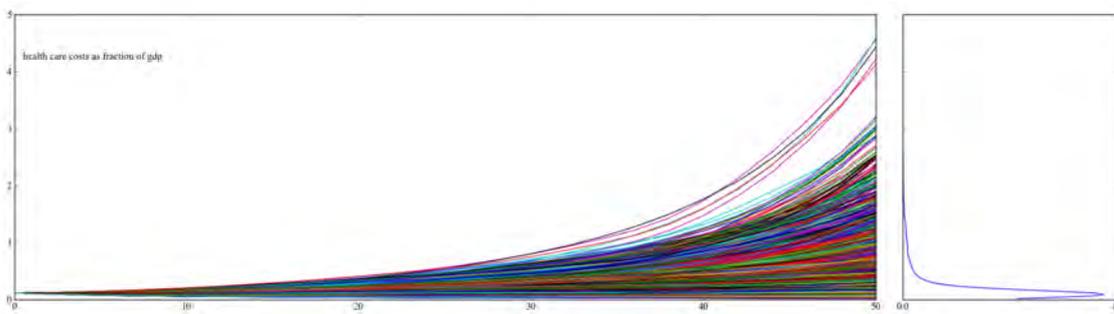


Figure 6: Lines for 10000 runs of the *health care costs as a fraction of GDP*

uncertainties, generates two concentrated regions in the uncertainty space –accounting together for 1571 out of 2142 cases with undesirable maximum *health care costs as a fraction of GDP* greater than 25% (see Figure 7).

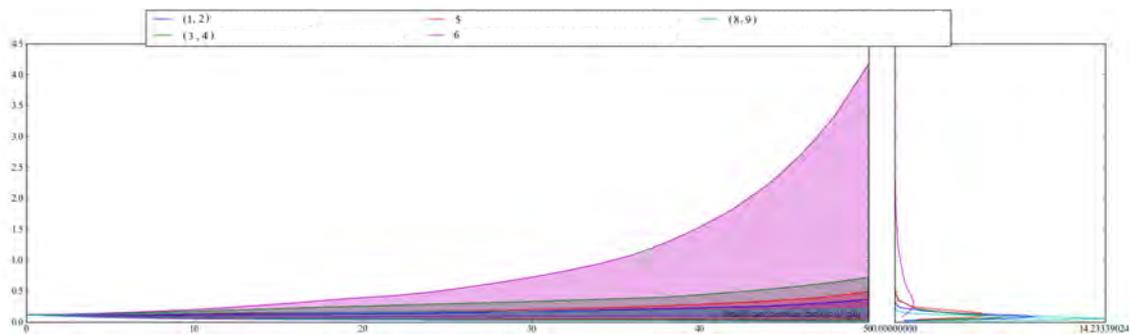


Figure 7: Envelopes of the *health care costs as a fraction of GDP* for different values of the most important uncertainty (total productivity growth main switch)

The combination of this model and these uncertainty ranges, generates almost 500 out of 10000 runs with *governmental contributions to AOW as a fraction of GDP* above 20% (see Figure 8), compared to 1.7% in 2010. Major uncertainties determining the maximum value of *governmental contributions to AOW as a fraction of GDP* are the *total productivity growth* and the *fraction of average wage increase to increase in AOW*. A decreasing –and to a lesser extent, a stabilizing– *average labour productivity* leads here to many unsustainable cases in terms of their *governmental contribution to AOW as a fraction of GDP*. *Productivity growth* could once more be the cause of

problems and the cure for problems related to the *governmental contribution to AOW as a fraction of GDP*. Two boxes in the multi-dimensional uncertainty space cause 931 out of 1184 undesirable outcomes in terms of the maximum *governmental contributions to AOW as a fraction of GDP* (see FIG6). There are also cases in which the *governmental contribution to AOW as a fraction of GDP* decreases – these cases may be analyzed in order to discover policy opportunities.

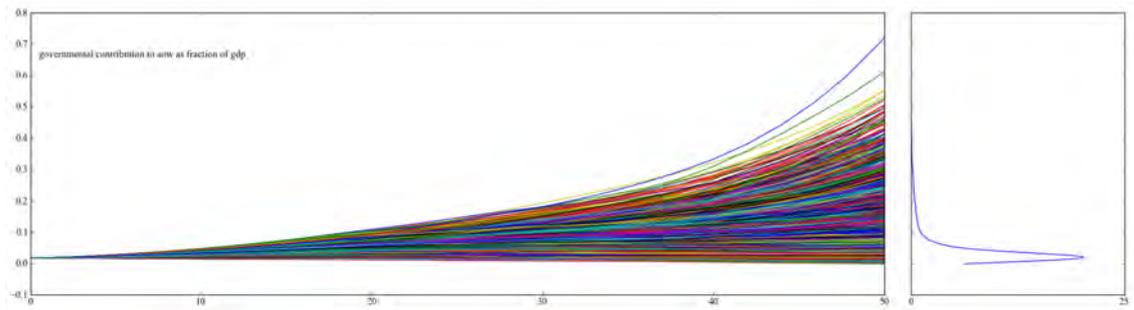


Figure 8: Lines for 10000 runs of the *governmental contribution to AOW as a fraction of GDP*

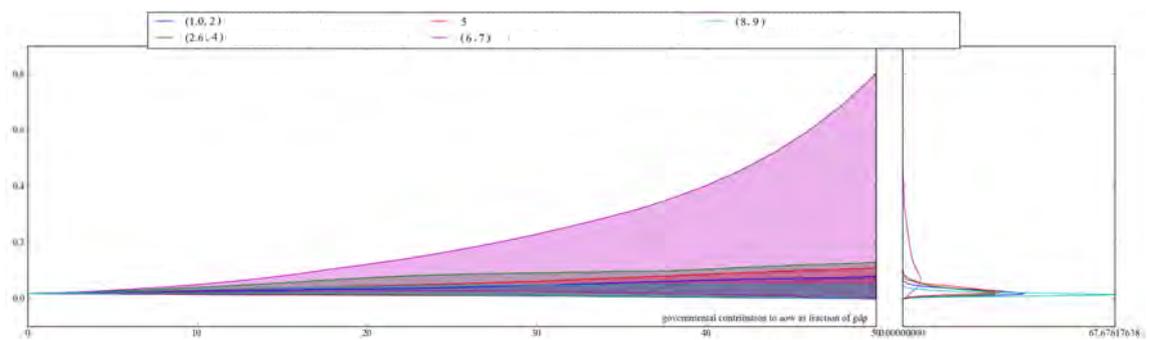


Figure 9: Envelopes for 10000 runs of the *governmental contribution to AOW as a fraction of GDP* for different values of the main uncertainty (*total productivity growth main switch*)

The combination of this model and these uncertainty ranges in the absence of additional policies, generates many cases (3964) with very serious scarcity of labor supply in care (*fraction care FTE demand fulfilled* smaller than 50% – see Figure 10). There are 4 uncertainty subspaces –in total accounting for 2532 out of 3964 cases– with high concentrations of runs that have a tendency to generate labor scarcity in care at one or more moments during the 50 year runs.

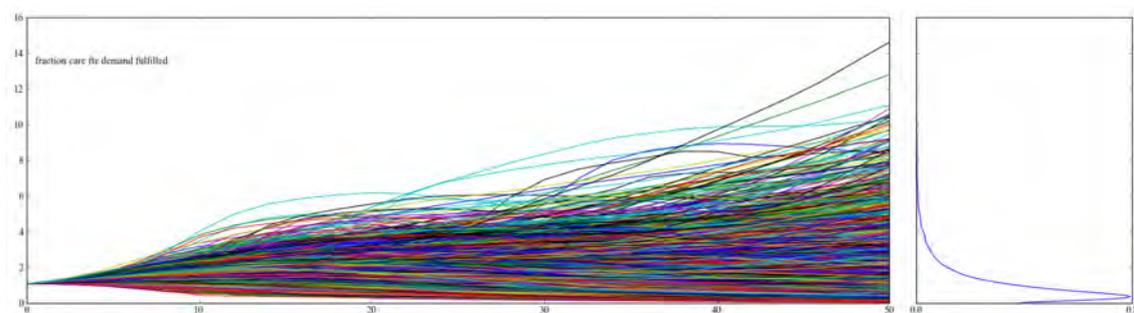


Figure 10: Lines for 10000 runs of the *fraction care FTE demand fulfilled*

Major uncertainties determining the split in abundance/scarcity are the developments of the

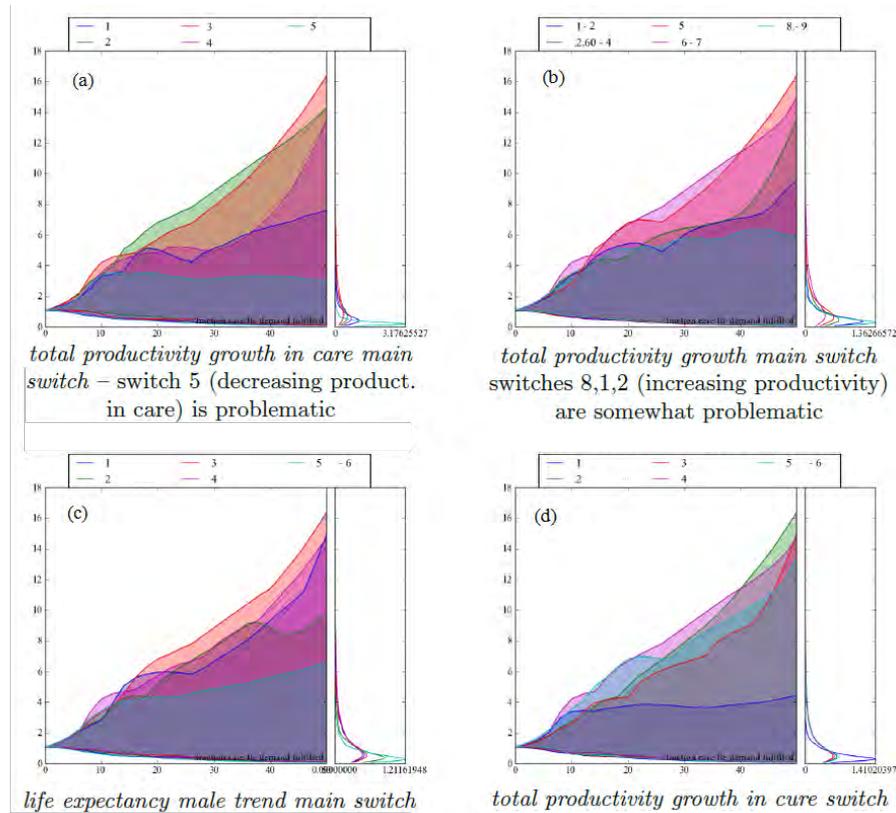
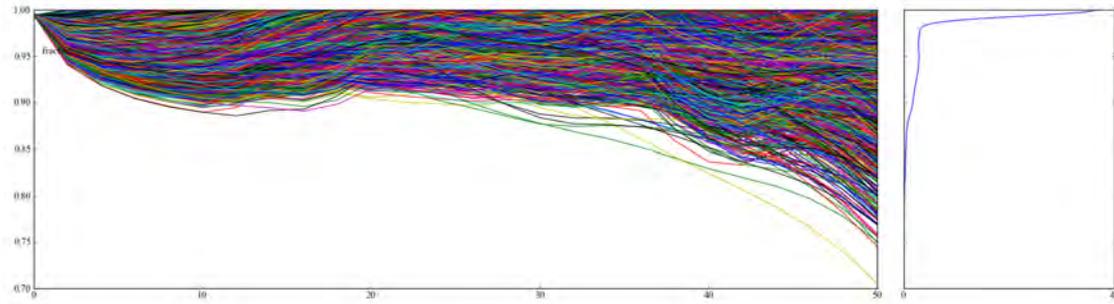
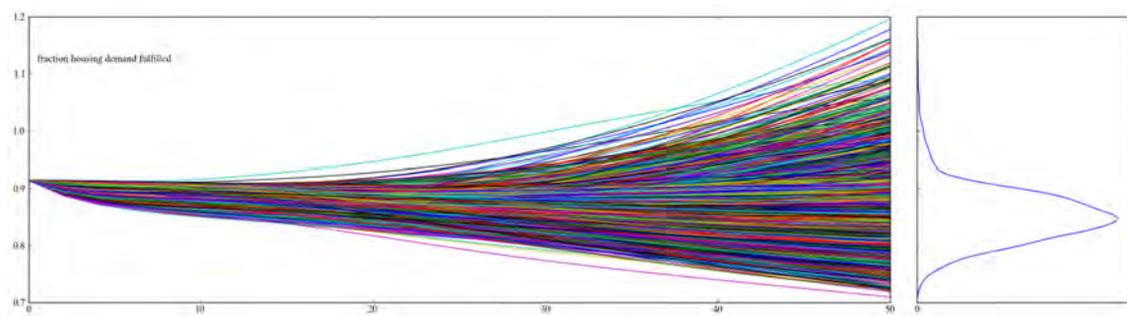


Figure 11: Major uncertainties determining the split in abundance/scarcity

productivities –especially the productivity in care (see Figure 11): a decreasing *average labour productivity in care* leads in many cases to shortages in labor supply in care – at least for this model and the uncertainties considered. Contrary to the *average labour productivity in care* does an *increasing average labour productivity* lead to shortages in labor supply in care. Hence, the cure for the *health care costs as a fraction of GDP* and the *governmental contributions to AOW as a fraction of GDP* may well be the cause –without additional policies– of problematic labour shortages in care. Other key uncertainties contributing to labour shortages in care are the average life expectancies.

The general *fraction labour scarcity* is problematic in case of decreasing average labour productivity in general (see Figure 12). Hence, productivity needs to increase, but additional policies need to ensure that productivity growth in the rest of the economy does not lead to shortages of the necessary employees in care.

The combination of this model and these uncertainty ranges, generates –in the absence of specific housing policies– many runs with larger *unfulfilled fractions of housing demand* than today (see Figure 13). Shortages are especially the case for high-end evolutions of the *male life expectancy*, and to a lesser extent for high-end evolutions of the *trend in female life expectancy*, strongly decreasing *house household sizes*, and longer delays in construction of houses. The demand for accessible houses is positive in the first 25 years. After 25 years, it could become negative too.

Figure 12: Lines of 10000 runs for the *fraction labour scarcity*Figure 13: Lines for 10000 runs of the *fraction housing demand fulfilled*

4.3 Analysis of the base ensemble jointly for three key performance indicators of concern

The most undesirable outcomes on three critical KPIs –the *health care costs as fraction of GDP*, the *governmental contribution to AOW as a fraction of GDP*, and the *fraction care FTE demand fulfilled*– are defined here as cases that satisfy all three of the following inequalities:

- a maximum over the *health care costs as fraction of GDP* greater than 0.25
- a maximum over the *governmental contribution to aow as fraction of GDP* greater than 0.10
- a minimum over the *fraction care fte demand fulfilled* smaller than 0.5

A total of 293 cases satisfy all three cut-off criteria. One small area in the multidimensional uncertainty space concentrates more than 60% of these highly undesirable cases. These cases are subject to a decreasing general productivity, a decreasing productivity in care, and a male life expectancy increasing to (more than) 90 years.

The most desirable outcomes over the three critical KPIs –the *health care costs as fraction of GDP*, the *governmental contribution to AOW as a fraction of GDP*, and the *fraction care FTE demand fulfilled*– are defined here as cases that satisfy all three of the following inequalities:

- a maximum over the *health care costs as fraction of GDP* smaller than 0.15;
- a maximum over the *governmental contribution to aow as fraction of GDP* smaller than 0.05;
- a minimum over the *fraction care fte demand fulfilled* greater than 0.9.

A total of 2119 cases out of 10000 cases satisfy the three cut-off criteria. A total of 969 of these 2119 cases are concentrated in two small areas of the multidimensional uncertainty space. These cases are at least subject to increasing general productivity, increasing productivity in care, and not to excessive life expectancy increases (see box plots in the appendix for more information).

From these boxes, one could derive the conditions that need to be satisfied to end up in desirable futures, and hence, the conditions that –if not all simultaneously satisfied– tend to lead to undesirable (but not necessarily fully undesirable cases as in subsection ??). The outcomes thus tend to be desirable if and only if:

- either
 - the life expectancies do not increase (without decreasing)
 - and the productivity of the Dutch economy and the productivity in cure increase
 - and the productivity in care increases to more than 4.5 the 2010 productivity by 2060
- or
 - the average female life expectancy does not increase to about 100 or more in 2060
 - and the average male life expectancy (increases but then) decreases below the current value
 - and the productivity of the Dutch economy and the productivity in cure increase
 - and the productivity in care increases to about 3 times or more the 2010 productivity by 2060

In other words, the outcomes are undesirable in these concentrated areas of the uncertainty space:

- either
 - if the life expectancies increase and do not decrease
 - or if the productivity of the Dutch economy or the productivity in cure remain constant or decrease
 - or if the productivity in care does not increase to about 4.5 the 2010 productivity by 2060
- or
 - if the average female life expectancy increases to about 100 in 2060
 - or if the average male life expectancy does not decrease below the current value
 - or if the productivity of the Dutch economy or the productivity in cure remain constant or decrease
 - or if the productivity in care does not increase to about 3 times the 2010 productivity by 2060

This information could be used to develop an advanced policy with an associated monitoring systems and actions that could be triggered if the system moves into the direction of areas with high concentrations of undesirable outcomes as in (Hamarat, Kwakkel, and Pruyt 2012). This is part of our future research on societal aging, with this model and with the ESDMA approach.

5 Different Migration Regimes & Retirement Age Policies

5.1 Base ensemble under different migration regimes

Three regimes with regard to migration of workers (immigration in case of labour shortages and emigration in case of a relatively unattractive Dutch labour market) are compared in this section: blue represents the base ensemble, red the immigration regime, and green the emigration regime (between 0.5 and 3% annually). [The word regime is used here instead of policy or scenario because immigration and emigration are in between policies or scenarios.]

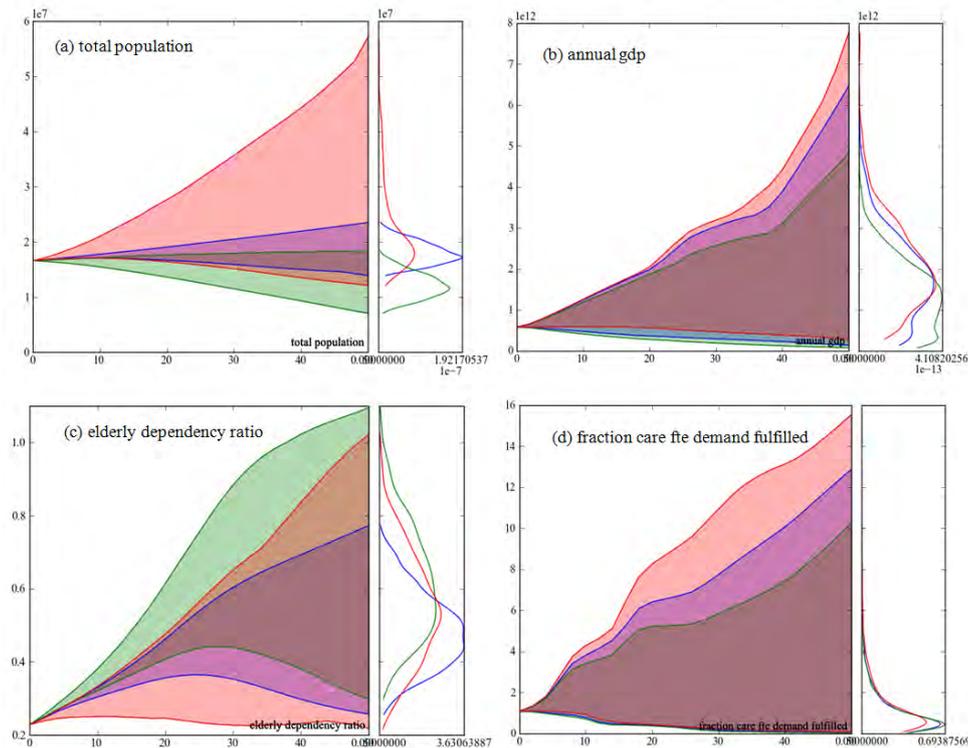


Figure 14: Effects of 3 different migration regimes on 4 key performance indicators

The results of the uncertainty analysis using the emigration and immigration for population size are shown in Figure 14(a). From this figure, one can notice the differences between the different scenarios: scenario emigration shows a considerable decrease in population size, while the maximum values for scenario immigration are relatively high, amounting up to 58 million inhabitants. The large differences between the scenarios might solve a number of problems, but might also cause new problems or increase existing ones.

The effects of the different migration scenarios on GDP are shown in Figure 14(b). Note the small difference between the base ensemble and the immigration scenario. The end state values for the emigration scenario are in general small compared to the values for base ensemble and immigration policy: in the emigration ensemble, labour becomes the main constraint for economic growth, hence always resulting in lower end state values.

Another problem which may be solved by labour migration is the age distribution of the population. Figure 14(c) shows the different in elderly dependency ratios. Here it should be noted that immigrants retire too.

Figure 14(d) sheds some light on whether the mismatch between labour supply and demand in health care could be solved by migration. Although some difference is visible, it is much smaller than anticipated given the difference in migration regimes. However, the willingness to work in

health care has a strong influence on the number of persons working in health care. So, immigration will not do the job: health care immigrants need to be sought after actively.

Governments could exert some influence on migration flows, but the relative attractiveness of a country may well be an important factor in migration decisions. If the Netherlands is a relative attractive country for (skilled) labour, then it will most likely be able to attract the necessary labour from elsewhere and to keep (skilled) labour inside the country. But the question whether The Netherlands is able to become and stay attractive for skilled labour still needs to be answered. Another question that needs to be answered is whether the Dutch government, Dutch employers and Dutch citizens are willing to welcome large workforce immigration flows.

5.2 Base ensemble with different retirement age policies

The current administration has the intention to raise the retirement age to 66 as of 2020 in order to reduce the costs for AOW pensions - expected to save 0.4% of GDP per year. Critics of this bill argue that increasing the retirement age with just 1 year is not enough for making the government finances concerning pensions sustainable. In order to test different types of policies and compare them, three different models were made:

1. a model in which the retirement age is increased to 66 in 2020 and after that stays at 66
2. a model in which the retirement age is gradually increased to 66 in 2020 and to 67 in 2025
3. a model similar to the second one, but with a retirement age increases with life expectancy from 2025 on.

Although there are visible differences between the envelopes generated with these different models, particularly in the elderly dependency ratio, they are rather minor differences. The main explanation for these small differences is a low real labour participation rate of older persons. Two plausible causes of low real labour participation rate of older persons are (i) employers are not willing to hire older employees, and (ii) older persons cannot or do not want to work until the official retirement age.

From these minor differences, one may conclude that the different policies do not go far enough in getting older persons to participate in the labour market. An alternative conclusion may be that raising the retirement age with 1 or 2 years is insufficient: raising it with 1 year would at best lead to a lower decrease with 2%.

6 Concluding Remarks and Future Work

Based on the simulation results and analyses, it could be concluded that:

- Although relatively few runs show catastrophic dynamics, health care costs may pose a major financial threat. Undesirable health care cost futures may necessitate (i) societal discussion regarding the public willing to pay for age related health care costs (not modelled endogenously) in case such undesirable futures occur, or (ii) avoiding those catastrophic futures altogether by implementing appropriate adaptive policies.
- Many runs show scarcity of labour supply in health care and cure. The problem in cure may be more pressing given the fact that the majority of persons working in cure are highly educated, possibly limiting the supply side of cure. Shortages in labour supply in care may have to be solved by technology solutions, support by relatives and friends, or labour import, that is if the Netherlands are relatively attractive.
- Supply of appropriate housing will most likely be a problem, unless action is taken in time, given the fact that shortages are already visible now. Further geographically disaggregated research is needed related to housing.

- Many runs show problematic labour shortages, ie unsustainable labour shortages. Considering the labour participation is already relatively high in almost all age cohorts and the labour participation of older workers is expected to increase, the necessary fulfilment of labour demand may have to come from increases in productivity or labour immigration.
- Affordability of retirement benefits may in a few futures become somewhat problematic, but the affordability of the system does not seem to cause problems in case of increasing productivity.
- The Netherlands need to keep highly educated workers, especially in cure and care workers, and may have to develop a focused strategy to attract many more to fill the gap between labour demand and supply, which may be problematic if it is relatively less attractive to migrate to the Netherlands. Hence the importance of the health of the economy and a welcoming climate.
- Raising the retirement age without with 1 or 2 years without taking additional measures, only slightly decreases the elderly dependency ratio and governmental contribution to AOW: a retirement age increase by 1 year leads to a maximum theoretical increase of 2% in terms of labour supply. Accompanying measures to increase the real participation rate are needed.

Hence, the following challenges – which require further research– could be formulated:

1. **How to increase the labour participation of older workers?**
2. **How to increase the relative attractiveness of working in health care?**
3. **How to make and keep the Dutch economy and labour market attractive?**
4. **How to better prepare the Dutch housing market for societal aging?**

This work will be continued: the model and methodology will be used in the near future for analysis and robustness testing of adaptive policies (as in (Hamarat, Kwakkel, and Pruyt 2012)) to fuel the societal aging debate, in the Netherlands, and possibly in other nation states.

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