Exploring Demographic Shifts: Aging and Migration Exploratory Group Model Specification & Simulation

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Abstract

Plausible dynamics of a major demographic shift –(societal) aging– is studied in this paper, both from a global perspective and from a national perspective. Several economic, political and social implications of aging and aging-related demographic shifts are explored using System Dynamics models as scenario generators for Exploratory System Dynamics Modeling and Analysis. In Exploratory System Dynamics Modeling and Analysis, a plethora of uncertainties (pertaining to model structures, functions, scenarios, parameters) are used to generate thousands of plausible transient scenarios. The dynamic complexity of the resulting 'ensemble of future worlds' is analyzed, ultimately in view of finding robust policies. The national model is used to explore plausible effects on the sustainability of (Dutch) national health and social security systems, the economy, and the housing sector. Deep uncertainty related to the national model was dealt with during an Exploratory Group Model Specification and Simulation workshop by generating and using alternative hypotheses for major uncertainties. Moreover, the global model is used to test the feasibility of the national model in the international context.

Keywords: Demographic Shifts, Demographic aging, World Migration, System Dynamics, EMA, ESDMA, EGMSS

1 Introduction

The Hague Center for Strategic Studies (2011) notes in its report on global and regional demographic shifts that:

> Demographics are a key driving force of many societal, political and economic developments. Their fundamental importance in shaping the key policy challenges of our society is quite often overlooked because of their ubiquity on the one hand and slow-pace-of-change on the other. Yet, demographic developments and their divergence within and across global regions have the potential to profoundly affect the future political, economic, social, and cultural order.
>
> [...] Societies with declining populations in the developed world may need more laborers to sustain their labor forces, which may lead to increased "competition" amongst regions for qualified migrants. [Greater demands on health care by graying populations may well produce new ethical, legal, and social issues. In these societies,] technology and [social] innovation will need to play an important role in boosting productivity. [...] Meanwhile, developing economies will have much younger populations, which on the one hand provide them with tremendous potential labor reservoirs but on the other hand means that they need substantial economic growth in order to ensure sufficient employment opportunities. While this may offer some tremendous economic benefits, others will struggle and may face the negative consequences of so-called youth bulges.

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> Developing countries that are further ahead on their demographic trajectories may face problems similar to the ones of developed countries and may see their informal networks of welfare provision challenged. Urbanization, a process that is expected to continue globally, may dramatically widen access to health care and education enrollment and may mark a leap into modernity for rural populations across the world. Yet, at the same time, unstructured urbanization may lead to slum formation and be a source of civil unrest.

The authors of this report, using their qualitative Metafore approach, text mined many demographic foresight studies for their insights, aggregate these regional insights, generated a series of conclusions, and explored –based on their (semi-automatic) literature review and expert interviews– the potential implications of the anticipated regional demographic developments.

The research presented in the paper at hand was initiated when the authors of the HCSS report –being aware of the dynamic complexity and deep uncertainty of the issue– asked our team to build exploratory System Dynamics simulation models to complement their qualitative Metafore approach. This paper therefore uses –as opposed to most forward-looking demographic studies that base their claims on United Nations Population Division data– system dynamics modeling and uncertainty exploration to identify thousands of plausible future scenarios. First the world level was focused on. Later, the (Dutch) national level became the focus of the research. Focusing on dynamic complexity under deep uncertainty, this paper provides a complementary perspective on the issue of demographic aging – both for world regions and for nation states.

The methodology is first of all briefly explained in section 2. The first applied part of this paper –in section 3– explores plausible demographic evolutions of eight world regions. The second applied part of this paper –in section 4– explores plausible effects on the sustainability of national health and social security systems, the economy, housing, et cetera, for a nation state, more precisely for the Netherlands. However, many nation states face the same problems. Hence, this national model may be seen as an instantiation of a more generic national aging model. Conclusions are drawn in section 5.

2 Exploratory System Dynamics Modeling & Analysis and Exploratory Group Model Specification & Simulation

2.1 Exploratory Modeling and Analysis

Exploratory Modeling and Analysis (EMA) is a methodology that can be used to explore the influence of a plethora of uncertainties – uncertainties related to initial values, parameters, specific formulations, generative structures, model formulations, model boundaries, different models, different modeling methods and paradigms, and different preferences and perspectives related to different world-views, and –last but not least– policies. It can also be used for directed searches into problematic areas of the uncertainty and scenario spaces, and for policy robustness testing (testing the effectiveness or acceptability of policies over the entire scenario space).

EMA consists more precisely of: (*i*) developing 'exploratory' models of the issue of interest, (*ii*) generating thousands of uncertain but plausible scenarios (the ensemble of future worlds) by sweeping uncertainty ranges and varying uncertain structures and boundaries, (*iii(a)*) simulating and analyzing the dynamic behaviors, bifurcations, et cetera, (*iii(b)*) and/or specifying a variety of policy options, and simulating, calculating, and comparing the performance of the various options across the ensemble of future worlds. For examples, see (Bankes 1993; Lempert and Schlesinger 2000; Lempert, Groves, Popper, and Bankes 2006; Agusdinata 2008) as well as (Bryant and Lempert 2009; Bankes, Walker, and Kwakkel 2010).

2.2 Exploratory System Dynamics Modeling & Analysis

Currently, special attention is paid by several researchers to the combination of dynamic complexity and deep uncertainty, more precisely to the combination of System Dynamics and EMA. The combination of System Dynamics and Exploratory Modeling and Analysis –referred to as Exploratory System Dynamics Modeling and Analysis (ESDMA)– is useful for exploring and analyzing deeply uncertain dynamically complex issues and for testing deep policy robustness. In this multi-method System Dynamics (SD) simulation models are –in a sense– abused as scenario generators for EMA to generate tens of thousands of plausible transient scenarios, which together are called an 'ensemble of future worlds' (Lempert, Popper, and Bankes 2003).

Simultaneously analyzing deep uncertainty and dynamical complexity was until recently feasible but rather demanding: As opposed to EMA, ESDMA goes beyond the calculation of end states or static values, which makes ESDMA much more difficult. This, however, is changing rapidly (see for example (Pruyt 2010; Pruyt and Hamarat 2010a; Pruyt and Hamarat 2010b) and (Pruyt and Kwakkel 2011; Pruyt, Kwakkel, Yucel, and Hamarat 2011; Kwakkel and Yucel 2011; Kwakkel and Slinger 2011; Hamarat and Pruyt 2011; Pruyt 2011).

Since EMA is appropriate for systematically exploring deep uncertainty and testing the robustness of policies, and exploratory SD models are particularly appropriate for generating plausible behaviors over time, it follows that ESDMA is particularly appropriate for *systematically* exploring and analyzing thousands to millions of plausible dynamic behaviors over time, and for testing the robustness of policies over all these scenarios.

Practically speaking, we currently use a shell written in Python to make an experimental design and to force Vensim DSS to execute the experiments of the experimental design. Using Python scripts, we store data during the simulation. Then we use a library of algorithms coded again in Python to analyze the artificially generated data set and visualize the most interesting findings.

Formerly, we used either Python or a SD software (Vensim, Powersim,. . .). Using both Python and Vensim together has many advantages: System Dynamics modeling is much easier and faster in Vensim, but Python outperforms Vensim when it comes to making, controlling, and playing with experimental designs, analyzing and visualizing outcomes of (thousands of) simulations, et cetera. Modeling specific ESDMA structures right into System Dynamics models enhances the power of using Python *and* Vensim.

2.3 Exploratory Group Model Specification & Simulation

The phrase Exploratory Group Model Specification & Simulation (EGMSS) is coined here for an interactive model specification workshop during which the widest variety of expert opinions / assumptions related to key uncertainties is generated and included in partly pre-specified SD models which are instantly used as ESDMA scenario generators in order to explore together with the group of experts the plausible effects of the combination of a variety of assumptions (see section 4.3.2). To our knowledge, the first EGMSS ever performed was the one described in this paper.

3 The Global Aging and Migration Model

3.1 Introduction

The goal of this world model is to explore plausible demographic developments in and between different world regions. This ensemble of future worlds generated with the world model are used to set the global ramifications for the explorative national model: for example, the Dutch capacity to attract highly educated immigrants in the national model will then be constrained by the relative European/Dutch capacity to attract them, i.e. in the global fight for scarce talent. This is one of the main issues for the Netherlands/Europe: the Netherlands/Europe may face serious problems if trying to migrate their way out of the aging problem if other regions are able to attract the globally sought-after 'pull' migrants and the Netherlands/Europe only attract 'undesirable' migrants – with reinforcing effects.

3.2 Structure of the World Model

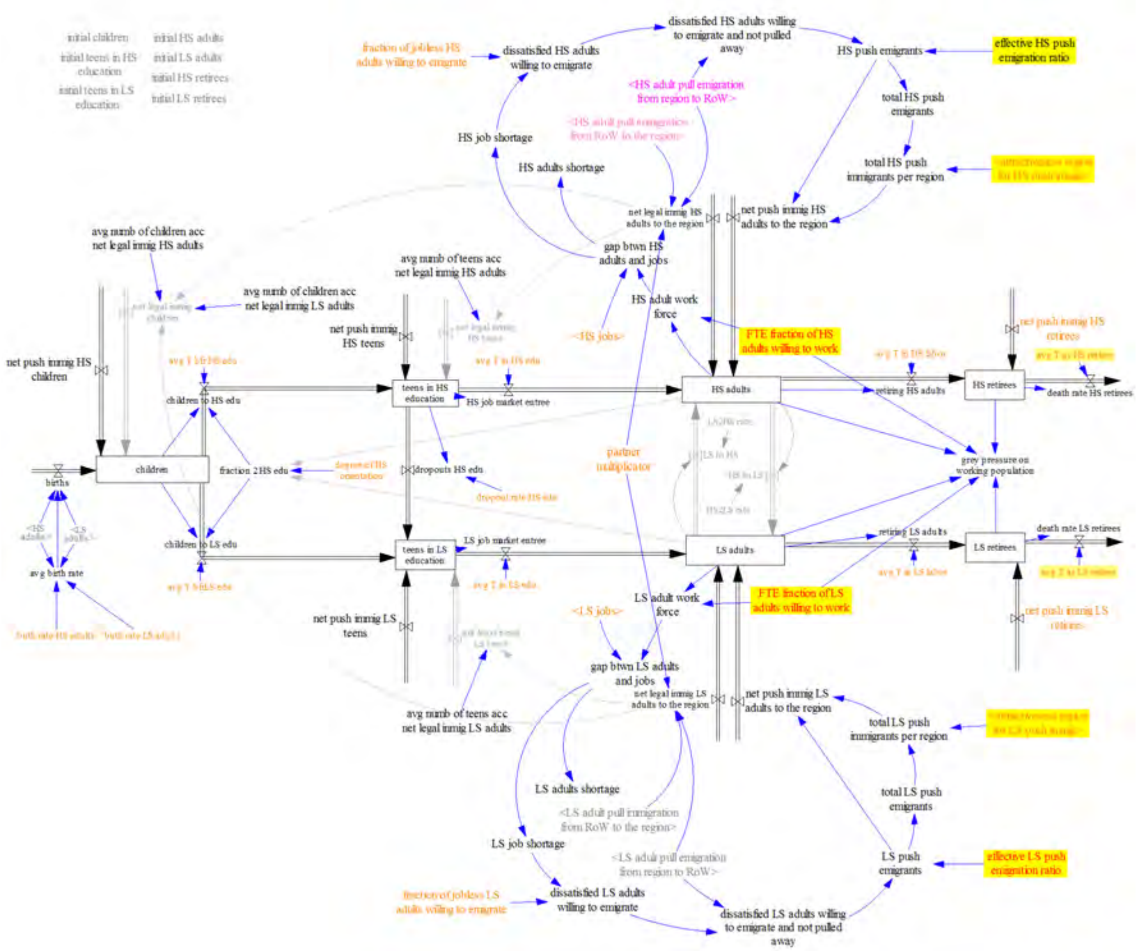


Figure 1: Regionally subscripted aging chain split out in high skill and low skill citizens

The basic world model consists of only 2 views. Figure 1 shows the regionally subscripted aging chain split out in terms of education level (highly skilled versus lowly skilled). Using subscripts (i.e. vectors), eight regions are represented by this aging chain:

r1: Sub-Saharan Africa

r2: Middle East and North Africa (MENA)

r3: Latin American and the Caribbean (LAC)

r4: Emerging Asia

r5: Advanced Asia

r6: North America, Australia and New Zealand

r7: Eastern Europe and Russia

r8: Western Europe.

The model considers both ‘pull’ migration and ‘push’ migration. Pull migration refers to active welcoming of –mostly highly skilled– migrants by regions in need of those migrants to fill in their vacancies. Push migration refers to migration of –mainly lowly skilled– unemployed migrants to regions hostile towards this type of migration. Push and pull migration are calculated according to different logics in the migration calculation view (see Figure 2). Figure 3 shows the same view without the web of links. An extended[1] migration calculation view is developed and used for the ESDMA.

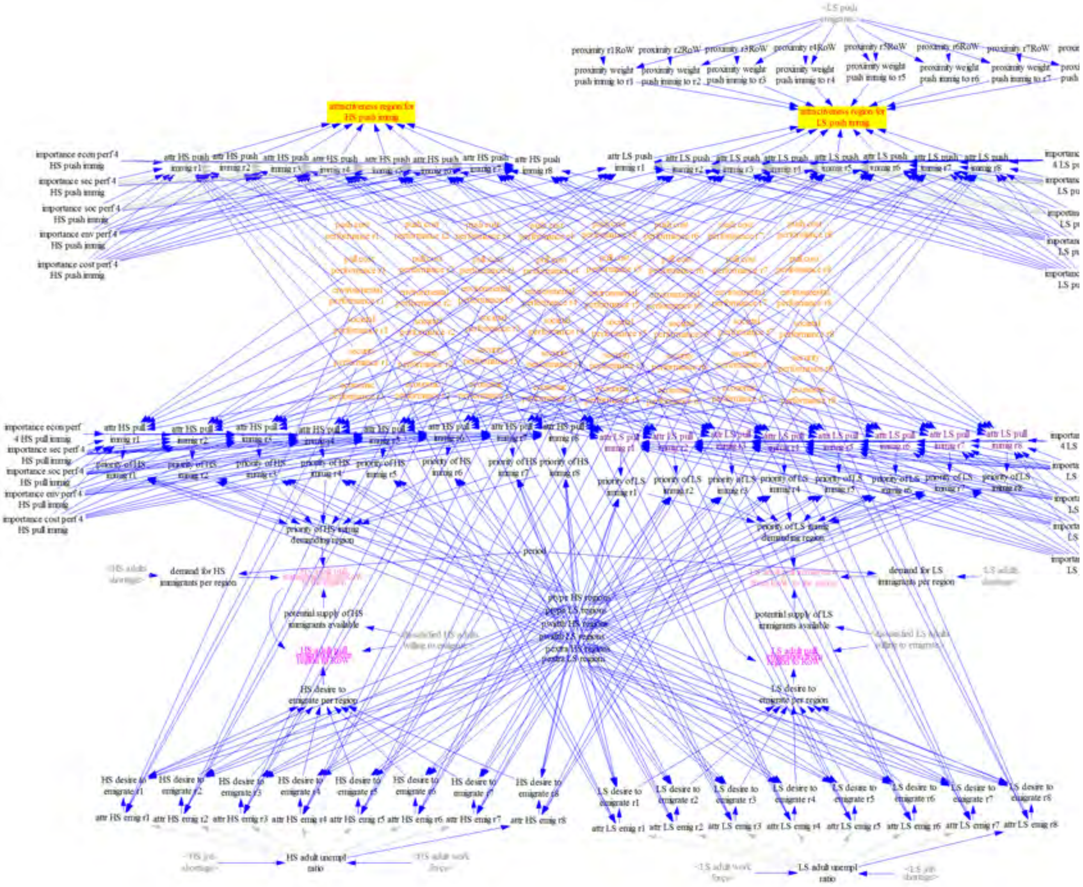


Figure 2: Calculation view of the interregional migratory flows with links between the variables

Several aspects that could influence the decision to migrate and the specific choice for migrating to a particular region (and not to other regions) are considered and varied in the model: the push migration cost of a region (only relevant for push migrants), the pull cost of a region (only relevant for pull migrants), the environmental performance of a region (relevant to all), the societal performance of a region (relevant to all), the security performance of a region (relevant to all), and the economic performance of a region (relevant to all). Varying values for their relative importance are attached to them. The most attractive regions are most able to attract desirable pull migrants. Push migrants also take the relative proximity of regions into account. The most attractive regions for push migrants are therefore closest-by regions with attractive attributes for push migrants.

Major simplifications and omissions are the omission of an economic sector and economy-population loops, and the lack of knock-on mortality.

[1]Extended with randomly sampled scenarios/ lookup functions / . . . and parameter uncertainties.

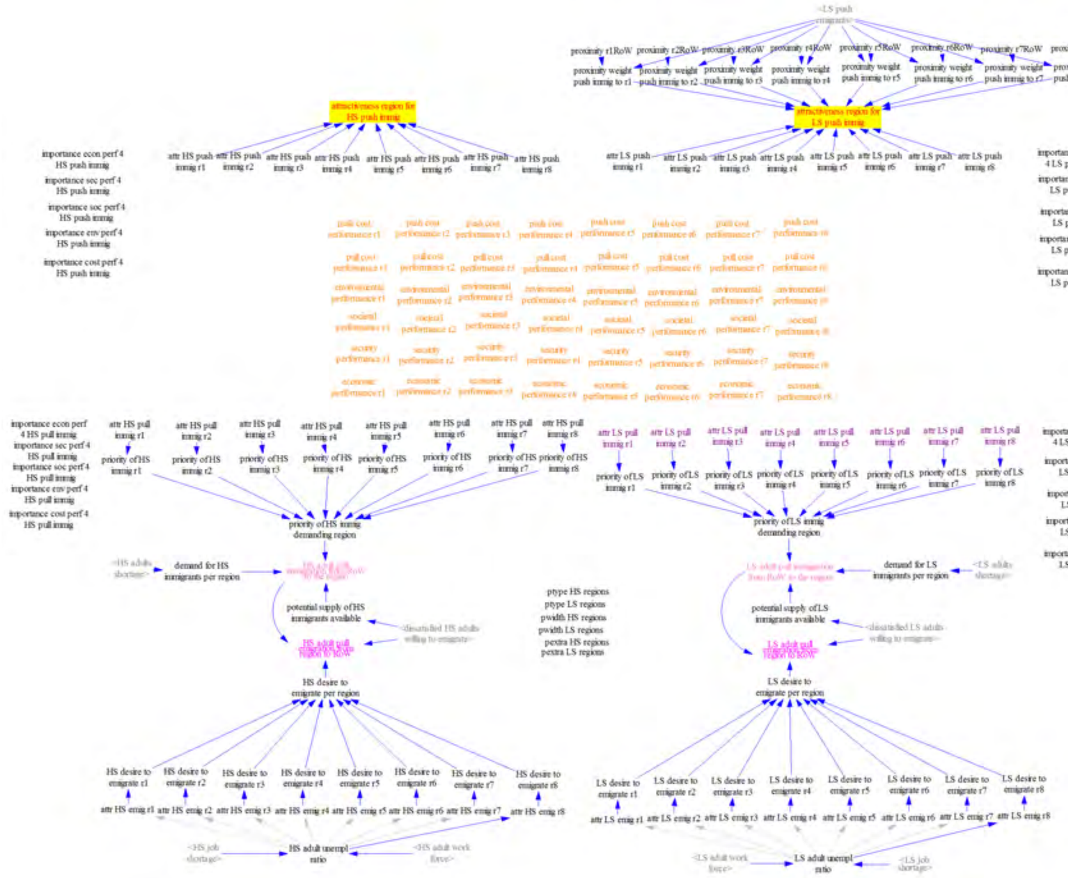


Figure 3: Calculation view of the migratory flows (from each region to each other region) without links between the variables: the variables in orange relate to regional performance on six different aspects that may or may not be taken into account to calculate the overall performance (and attractiveness) of regions

3.3 Behavior of the World Model

Figure 4 shows the behavior of two key output indicators for a relatively narrow (141 narrowly defined uncertainties) and small (2000 lines and envelopes of 10000 runs) ensemble of future worlds. The ensemble is small because it contains but 2000 (or 10000) samples. The ensemble is narrow because only relatively minor parametric uncertainties and a few lookup switches are varied uniformly[2].

Figure 4 shows the result of this relatively narrow exploration: according to the graph, world population could hit 11 billion but also 8.9 billion and all values in between. This 'narrow'

[2]**Following parameter uncertainties are currently varied:** fraction of jobless HS adults willing to emigrate[region] ; fraction of jobless LS adults willing to emigrate[region] ; effective HS push emigration ratio[region] ; effective LS push emigration ratio[region] ; avg T as HS retiree[region] ; avg T as LS retiree[region] ; push cost performance [region] ini ; pull cost performance [region] ini ; environmental performance [region] ini ; societal performance [region] ini ; security performance [region] ini ; economic performance [region] ini ; degree of HS orientation ; importance econ perf 4 [HS/LS] push immig ; importance sec perf 4 [HS/LS] push immig ; importance soc perf 4 [HS/LS] push immig ; importance env perf 4 [HS/LS] push immig ; importance cost perf 4 [HS/LS] push immig ;importance econ perf 4 [HS/LS] pull immig ; importance sec perf 4 [HS/LS] pull immig ; importance soc perf 4 [HS/LS] pull immig ; importance env perf 4 [HS/LS] pull immig ; importance cost perf 4 [HS/LS] pull immig. **Different lookup functions are also called by means of following categorical uncertainties:** lookup number evolution birth rate[region] ; lookup number evolution HS jobs[region] . Both lists above will be further extended and structural and model uncertainties will be added.

exploration is already much broader than most other (communications about) population forecasts. For example: According to the medium variant of the 2010 Revision of World Population Prospects –the official United Nations population projections prepared by the Population Division of the Department of Economic and Social Affairs– the current world population of close to 7 billion is projected to reach 9.3 billion in 2050 and 10.1 billion in 2100.

The remainder of the graphs in Figure 4 show projections about the grey pressure on the working population taking into account some uncertainties related to aging and migration: these graphs show that most areas may encounter aging related problems. Figure 5 displays the total net immigration to/from each of these regions. The potential to attract high-skilled immigrants instead requires further exploration. Note that immigration policies are not well elaborated at this point. Note also that these preliminary explorations cannot be used for predictive purposes, in the current form not even for ensemble prediction (yet). At this point they provide a broader perspective on plausible societal aging and migration in a regional world.

The global model is too high-level to be used directly for national policymaking purposes. It nevertheless generated enough interest and confidence in the approach for the project sponsors to approve the next stage: the development of a national model. The global perspective is nevertheless useful to cast the national perspectives and policies into a global perspective. National policies (e.g. a policy to attract highly educated immigrants) may fail in the international context. Many nations and regions are expected to have to deal –more or less simultaneously– with –more or less– the same problems and may themselves competing for scarce migrants when trying to migrate their way out of the aging problem. Hence the development of a national model linking together several subsystems of interest in section 4.

4 The National Societal Aging Model

The effects of future demographic changes in The Netherlands are investigated with special attention paid to the systems consequences in terms of health care, housing, social security, and the labor market. The main aims of this research were to identify the relations that exist between the different aspects of the welfare state and to identify how demographic change may 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 by means of Exploratory System Dynamics Modeling and Analysis as a form of extreme scenario analysis.

Hence, this second part of our societal aging research tries 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.

A large problem in many industrialized countries nowadays is the effect of demographic aging. Because of increasing life expectancy and declining birth rates, the age distribution of the population is changing towards a larger proportion of elderly. 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. It is considered a fact that due to this demographic change the size of the work force becomes smaller compared to the total population, but the consequences of this change in age distribution are to a large extent unknown. The Dutch government is currently taking some measurements by

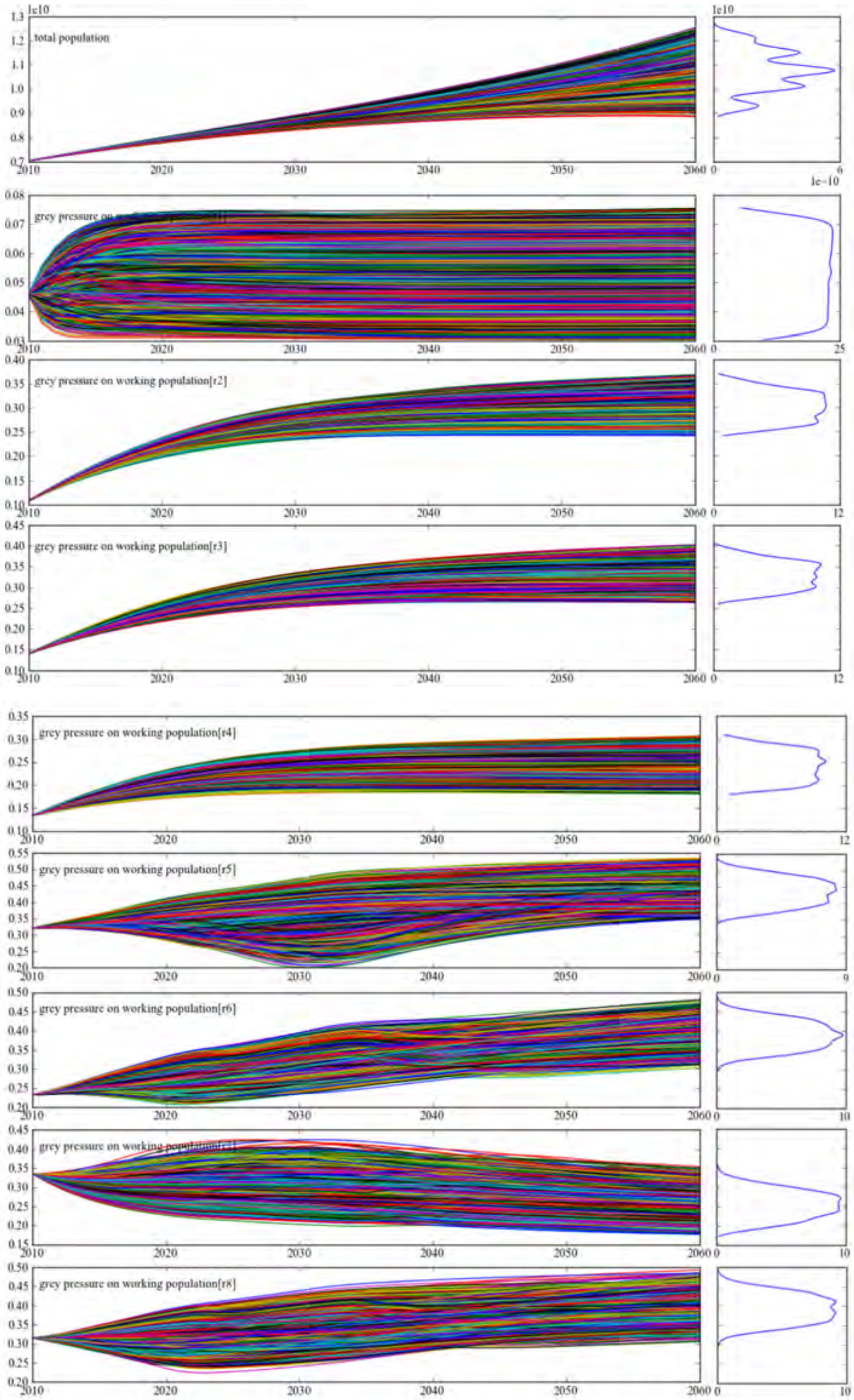


Figure 4: Line graphs: 2000 runs ; Envelopes: 10000 runs; r1 = Sub-Saharan Africa; r2 = Middle East and North Africa; r3 = Latin America and the Caribbean; r4 = Emerging Asia; r5 = Advanced Asia; r6 = North America, Australia & NZ; r7 = Eastern Europe & Russia; r8 = Western Europe

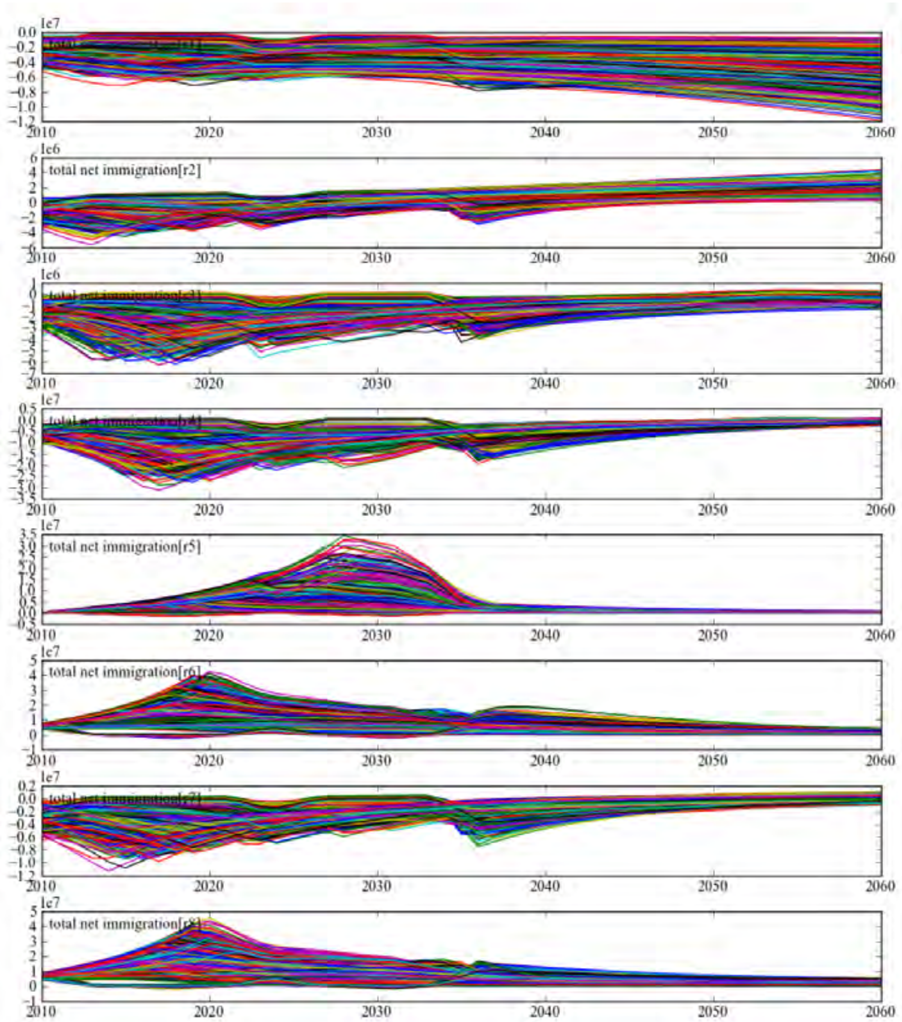


Figure 5: Line graphs: 2000 runs ; r1 = Sub-Saharan Africa; r2 = Middle East and North Africa; r3 = Latin America and the Caribbean; r4 = Emerging Asia; r5 = Advanced Asia; r6 = North America, Australia & NZ; r7 = Eastern Europe & Russia; r8 = Western Europe

increasing the retirement age with one year (from 65 to 66 in 2020) but the system-wide effects of this policy are still unclear.

The rising life expectancy and the decreasing fertility rate cause a shift in the age distribution of the Dutch population. When looking at the statistics of the Dutch population (see Figure 6), we see a shift towards a larger elderly dependency ratio (the ratio of the elderly compared to the working population). This means that a relatively smaller working population has to contribute to the expenses of a larger part of the population (the retired and other persons in need of social benefit). According to the CBS (Statistics Netherlands), the amount of persons over 65 (the current retirement age) will be 4.6 million in 2040, compared to 2.6 million in 2010. Additionally, the potential working population (between 20 and 65) will decrease from 10.1 million in 2010 to 9.3 million in 2040. Hence, the elderly dependency ration is expected to rise from 26 % (2010) to 49 % in 2040 (Van Duin and Garssen 2010).

On the other hand, the change in age distribution and the decreasing fertility rate will lead to a smaller proportion of youngsters (under 20) that do not financially contribute to the social security system. Current estimates by CBS show a decrease in youngsters to 3.7 million in 2020,

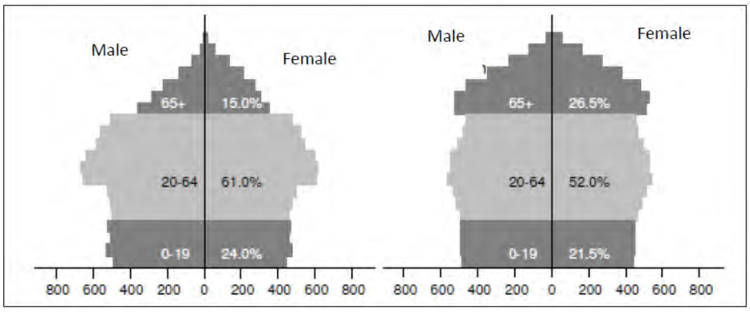
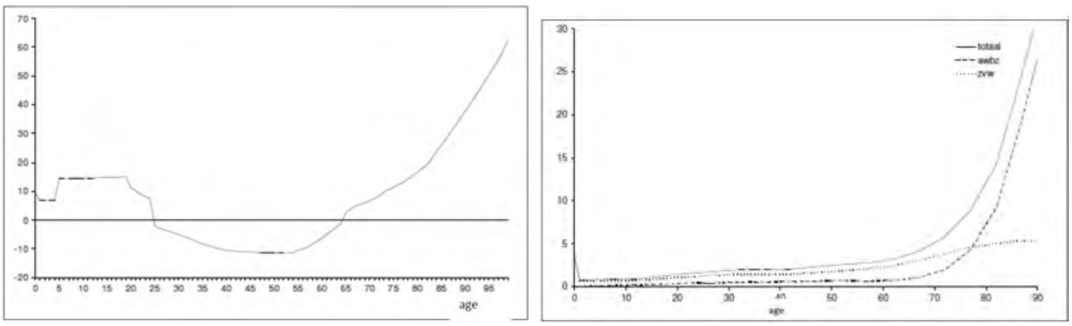


Figure 6: Demographic pyramid of 2010 (left) and 2040 (right) (source: CPB/CBS 2010)

which is a decrease of 5% compared to 2010 (Van Duin and Garssen 2010). Figure 7(a) in the appendix shows the average net benefit of government payment per age. For youngsters, this funding mostly entails day care and education subsidy, for older persons it mainly consists of retirement benefits and health care. The main issues regarding demographic aging are illustrated by fig. 2 in the appendix: fewer contributors (persons aged 20-65) and more beneficiaries (mainly elders) (Van der Horst, Bettendorf, Draper, et al. 2010). The causes of the declining fertility rates are rather unsure, but female participation in the labor market, the costs of raising children, better access to contraceptives and decreasing child mortality are generally considered reasons for women getting fewer children (Grant, Hoorens, Sivadasan, et al. 2004). Improved hygiene and better health care (availability) is considered the major reason for the increasing life expectancy, although current research already focuses on a health level decline due to unhealthy living.

This research focuses on the consequences of demographic aging in four different fields: health care, labor market, housing and social security. Consequences of aging in terms of health care can be found in different areas. First, the larger proportion of older persons will cause an increase in health care expenditures, as health care expenses per year increase exponentially with age (see Figure 7(b)). Second, fewer workers may lead to labor problems in health care, causing quality loss or increased efficiency demand or automation.



(a) Net benefit of government spending at certain age – source: (CPB/CBS 2010)

(b) Health care expenditure per age in 2008, describing total health care expenditures (totaal), consisting of: long term health care (awbz) and short term health care (zvw) – source: (CPB/CBS 2010)

Figure 7: Graphs of key non-linear age-related health care expenditures

Ageing problems that might arise in the labor market consist of older persons being less productive in physical employment, as well as persons being forced to work until a higher age. Government and company policy might focus on benefiting of advantages that older workers have over younger workers, due to experience (e.g. to use them as a coach or teacher). Problems with social security and pensions might arise when a relatively smaller part of the population contributes to social security and pension funds. This will either mean that less money is available for social security or contributions (taxes) will have to be raised. Problems regarding the pension system are more difficult because only a part of the pensions retired persons receive is provided by the government (i.e. indirectly by the working population). The other part of the pensions is saved by workers during their career and the problems with these pension funds are not directly caused by an aging population but by a weakened financial position due to over- estimations of the economy during the nineties (Jacobs 2006).

Finally, because of aging, the housing demand changes: although a large part of the elders in the near future will have built up sufficient capital (houses and pensions), the amount of elders with a small income will increase and might need more service-apartments that provide basic help instead of regular social housing in the near future (Van der Schaar and Buys 2006). Current government policies regarding population aging are mainly aiming on increasing the retirement age and improving government finances. But are these measurements enough? Will cuts in governmental budgets lead to sustainable state finances? And will an increased retirement age lead to more workers? Or will the increased proportion of older workers lead to more health care expenses by employers? In the long run, investments in health care or disease prevention might ultimately lead to savings. But what investments should be focused on to gain the largest benefits? Or does the government need to look for other solutions, e.g. increase migration of individuals to increase the working population?

Current research on the consequences of demographic aging mainly focuses on macro-economic calculation of statistical trends, e.g. research by the CPB (Netherlands Bureau for economic policy analysis). That research takes into account the situation as is and projects it towards the future. But it does not thoroughly take into account uncertainties related to the future, and perhaps more importantly, it does not link all interrelated subsystems of interest. 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.

4.1 Structure of the National Societal Aging Model

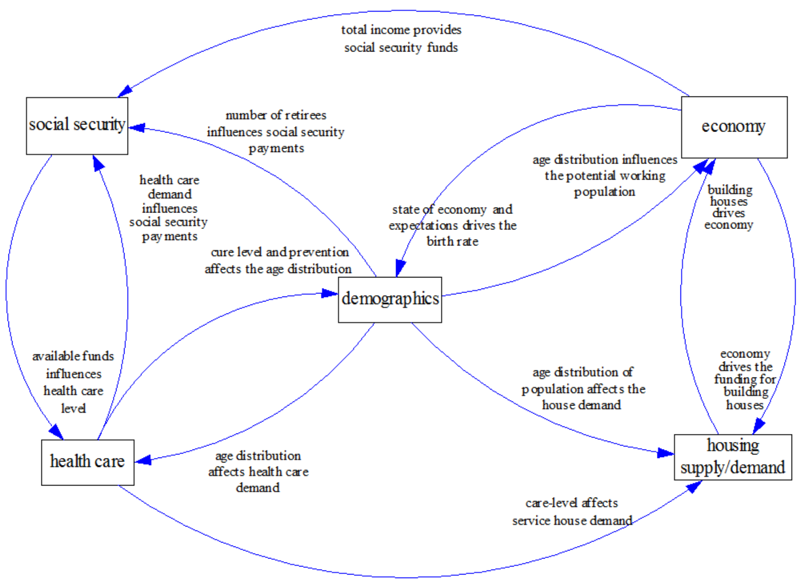


Figure 8: Sector diagram of the national aging model

Figure 8 shows a sector diagram of the exploratory model developed for this research. This sector diagram shows the main subsystems of interest and some of the main links between them.

The different subsections of the model consist of submodels on health care, labor demand and supply, social security, and housing demand and supply. The basic system structures were determined in 1-on-1 expert interview sessions. During these interviews the system was discussed and the SD-model updated immediate so as to show the effects of structures and structural changes. The final draft version of the model was reviewed during a 'validation workshop' and adapted according to the main criticisms. The adapted version of the model was expanded with uncertainty structures and used during an Exploratory Group Model Specification and Simulation workshop (see subsection 4.3.2). The various assumptions gathered during this workshop were used subsequently for further ESDMA analysis (see subsection 4.4).

4.1.1 Subsystem I: Demographics and population dynamics

The demographic sector is the main sector of the SD-model. Dynamics of a population are the driver of aging and problems or benefits that are caused by them. Therefore, a well structured submodel corresponding properly to the real life situation is vital.

In order to do so, the model is subdivided in two populations: female and male. This subdivision for reasons of difference in these populations on certain aspects. For example death rates (and thus life expectancy) and labor participation differ in such a way that averaging these properties will cause major irregularities[3].

Each population model is concentrated around the population level with inputs: births, net migration and aging, and outputs: mortality and, again, aging. The aging chain is build up as a regular aging chain with cohorts of 1 year, but then concentrated in one level by using subscripts. Each cohort represents a part of the population with the same age at a certain point in time and ages with a first order delay of 1 year. By formulating the aging chain using subscripts, the model is relatively accurate, but still relatively small. As with a normal aging chain, the different cohorts can be regarded separately, e.g. when adding health care consumption to a certain age, but can also be added up to calculate the total population.

The initial demographic data is taken from the database of Statistics Netherlands and contains structured data in different levels of detail of several features of the Dutch population. Population size data is available for the separate age cohorts, from age '0' to age '99 and older'. This last cohort, age 99 and up, are all persons aged 99 and older. Because the time spent in this cohort differs from that of the other cohorts, the outflow out of cohort 99 and up due to aging is made dependent on the mortality rate of the population. In order to do so, a mathematical function is fitted to the available mortality data and integrating this function to from age 99 to the point where mortality rate equals 1, provides the average time a person turning 99 will spend in this cohort.

Regarding net migration, the model contains different scenarios that can explain net migration during the simulation. As stated by several sources, aging causes the working population to decrease and immigration of workers might be a solution to fill the gap in supply and demand of labor (Berkhout and van de Berg 2010) (CPB 2007). In this respect, 3 plausible scenarios were determined during expert interviews and workshops:

1. The Netherlands are able to attract the necessary number of immigrants to provide the necessary labor.

2. The Netherlands are not able (or not willing) to attract the required labor from elsewhere, but is able to keep the available labor stock.

3. The Netherlands are not able (or not willing) to attract the required labor from elsewhere and emigration of the current labor stock is happening. This is possible when other countries are more attractive to Dutch workers.

These scenarios are implemented in the model and are explored in the uncertainty analysis.

[3] `http://statline.cbs.nl`

4.1.2 Subsystem II: economy

Labor Demand: Subsystem II contains the structure representing the economy. For this research, the economy is built up of labor supply and demand, where a certain exogenous economic growth drives the demand of labor. In this respect, the simplest form of labor defined output is taken: $Y = L * q/l$. This function calculates aggregate output (Y) labor (L) and output per unit of labor (q/l). This function is chosen in order to easily define the relation between labor and output and thus define labor demand growth (∂L) at a certain economic growth (∂Y): $\partial L = \partial Y - \partial(q/l)$. So, economic growth and change in output per unit of labor define the amount of labor necessary to fulfil the defined economic growth. The output per unit of labor is defined by OECD as labor productivity[4].

Aggregate output growth is regarded the exogenous economic growth and thus determined as the potential growth that might occur and is simulated in the model as a random function, as explained in (Pruyt, Kwakkel, Yucel, and Hamarat 2011): economic cycles are simulated with a random value between -0.01 and 0.03 for each cycle of 10 years and then smoothed in order to create several different possible functions to create an economic cycle for the next 50 years. Because the Dutch economy is to a large extent influenced by the economic growth on a world level and the influence of the Dutch economy on this level can be considered relatively small, the exogenous economic growth is taken is a main factor of output growth in The Netherlands. Labour productivity can be defined by certain aspects. According to OECD, driving forces behind labor productivity are 'the accumulation of machinery and equipment, improvements in organisation as well as physical and institutional infrastructures, improved health and skills of workers ('human capital') and the generation of new technology'[5]. When regarding the problem of aging, labor productivity growth is defined by adding up two aspects: general productivity growth and age defined productivity growth (age defined human capital). This is due to research that show a decreasing productivity of older workers because the wages increase with age but productivity stagnates. Other research shows an increasing productivity of older workers due to experience and a stagnating wage level from a certain age. General labor productivity growth and age defined human capital are implemented as uncertain inputs and explored in the uncertainty analysis. Productivity in health care is regarded a special case because of the 'Baumol- effect' (VTV, 2010) which shows that productivity in health care will always lag behind on productivity in industry, mainly because of the labor intensive processes taking place. Economies of scale in health care will not pay off in the same way as industry. Therefore, labor productivity in health care are taken as separate inputs (see section 4.3.2).

Hiring of workers is defined by a priority structure. Initially, employers have a preference for younger workers (around age 25) and a decreasing preference for older workers (defined during the validation workshop). In the model, at a certain point in time, this preference will change to a more evenly distributed preference. The time this switch takes place is uncertain as well, and explored in the uncertainty analysis.

Labour supply: The labor supply side of the economy is driven by the demographic subsystem. For labor participation, data of the CBS (2009) are used to calculate the average fraction of fte (full time equivalent) of male and female workers for certain ages. The labor participation is influenced by the retirement age (increased retirement age will cause a increased labor participation in older cohorts of workers).

A striking observation is the labor participation of workers between 55 and 65, which is relatively low compared to labor participation at younger ages. During the validation workshop, this effect is contributed to labor market effects induced by early retirement of persons. This effect is currently fading out and expectations are that the labor participation at higher ages will increase slowly in the coming years. This is implemented in the model as well. Changes in the

[4]According to the OECD: 'Economic growth in an economy or a sector can be ascribed either to increased employment or to more effective work by those who are employed. The latter can be described through statistics on labor productivity.' `http://stats.oecd.org/glossary/detail.asp?ID=4819`

[5]OECD via `http://stats.oecd.org/glossary/detail.asp?ID=4819`

average labor participation are implemented as an uncertain input over time and explored in the uncertainty analysis (see section 4.3.2).

Labour supply and demand in Health Care: As stated previously, labor supply and demand in health care is different from general labor demand and thus regarded separately. According to VTV 2010 (RIVM 2010), 25% of all females and 5% of all males work in the care sector, and according to CBS (employment data of 2009) 196260 fte work in cure and 212530 fte work in care. Comparing these data provides a number of 50% of all care workers working in the areas under research (so 2.5% of all male workers and 12.5% of all female workers as of 2009).

To be able to research the potential labor supply, an additional function is added to the model that determines the 'relative attractiveness of working in health care'. This variable is simulated as an S-shaped function in which different coefficients are made uncertain. The function gets the shape of: $f(t) = \frac{a}{b+e^{ct+d}}$. By exploring the coefficients a, b, c and d, the curve can show different S-shaped behaviours.

Labour demand in health care is determined by health care demand and productivity (or efficiency) which is, as previously stated, determined as an uncertain input (see section 4.3.2).

4.1.3 Subsystem III: health care

This subsystem is subdivided in 2 parts: cure and care. This subdivision is made due to differences in funding and differences in the usage. Cure is considered acute specialist or primary health care and is aimed on curing a person (i.e. medical care, hospital care, acute psychological care). Care is considered long term (health) care that is aimed on sustaining one's health position (in which one can think of nursing, personal care or domestic help).

Cure supply and demand: Regarding cure, the usage of the most used and most costly parts are simulated: primary care, specialist care (including hospital surgery) and prescription drug usage. The used data is taken from the databases of Statistics Netherlands (CBS), Board of Health Insurances (CVZ) and the National Institute of Public Health and the Environment (RIVM).

Data of RIVM for age dependent costs of diseases (KVZ, 2008) are used as initial input for costs of cure and used for defining the age-specific cure-costs increase. Additionally, according to VTV 2010 the health care costs increase are only for a relatively small part explained by an aging population. Other important factors are wage increases (as health care is a labor intensive sector) and increase care demand because of an increasing health care level (more possibilities mean more persons making use of these possibilities). These two factors are implemented as uncertainties (see section 4.2).

Behaviour of persons is considered another important aspect of cure demand (and life expectancy). In this respect, four main unhealthy behaviours are implemented in the model, i.e. smoking, alcohol abuse, obesities and physical inactivity. The model shows two main levels in this respect: change in mortality rate and change in unhealthy life expectancy. Mortality rate is influenced by behaviour, but also by increasing life expectancy due to increased medical opportunities (VTV, 2010). This level provides a feedback to the demographics subsystem, a decreasing mortality rate increases life expectancy. Unhealthy life expectancy is considered the part of life expectancy which is not lived in good health (Perenboom, 2004) and this can be regarded as a measure for health level in a society. Unhealthy behaviour influences both mortality rate (and thus life expectancy) and health level (i.e. unhealthy expectancy). These two values do have a relation to one another, but an increase in life expectancy does not imply an increase in unhealthy expectancy. In this sense, health care costs are not assumed to be solely age defined, but also the result of a change in unhealthy expectancy. The model contains an uncertain variable that determines the part of life expectancy growth that is lived in good health (i.e. the increase in healthy life expectancy). This is done because of the 'cure level effect': when cure level increases, persons will live longer but not only in good health, as the prevalence of chronic diseases will increase (partly due to better detection of certain diseases) and the unhealthy life expectancy increases.

Care supply and demand: Regarding care, a subdivision is made between intramural and extramural care. Intramural care is considered personal care and nursing in an institution and extramural care is considered personal care and nursing at home and domestic help. In both cases, care demand is determined by data from Statistics Netherlands, out of a research aimed on the health position of the Dutch population (POLS, 2009). The CBS database contains very specific data on the fraction of different age cohorts of the population that need certain types of care and how many hours of care per year they receive (on average). This data is implemented in the model provides, together with demographic data, a specific overview of the amount of care that is required. As previously stated, the unhealthy expectancy is a measure for health level in society and thus an indication of increasing demand of care. The influence of this unhealthy life expectancy on care demand is taken as an uncertain variable and explored in the uncertainty analysis.

Supply of extramural care is basically a matter of labor input. As care is relatively labor intensive, an increase in care demand means a similar increase in labor. This also counts for intramural care, but an important other factor that differs intramural from extramural is the delay time that exists in building intramural care institutes. This delay time is made dependent on the amount of potential labor supply in health care. Additionally, the government currently stimulate elders to stay at home instead of going to nursing homes. This is mainly induced by the higher costs of intramural care compared to extramural care and the shortage of intramural care institutes. This effect is simulated in the model as an uncertain variable.

Increasing health care costs are to a large extent caused by increasing costs due to an aging population and an increase in wages in health care. Government policies are currently aimed on decreasing the amount of care persons are entitled to, as well as governmental contributions to the costs of long term health care. This effect is simulated in the model as a maximum amount of government contribution, when this maximum is reached, less hours of extramural care are funded.

4.1.4 Subsystem IV: housing

In order to simplify the housing market and to aim the subsystem on the most important aspects of housing when considering health care, the housing system is built up of regular houses and accessible houses. Accessible houses are houses that are accessible for physical disabled persons (e.g. without stairs, wide doors, no doorsteps). As of 2007, out of the total Dutch housing stock of 7 million houses, 1.5 million are considered accessible. Additionally, the stock of less accessible houses consists of houses that can be easily modified and houses difficult to modify in order to become accessible. In this respect, persons living in easily modifiable houses are assumed to stay in their house when becoming physically less able (and these houses will be modified). Persons living in house that is difficultly modified are assumed to be moving away to an accessible house.

The division between these two types of houses is made from a certain building year. From 1997 a new 'bouwbesluit' (building regulation) has been initiated in which new rules on accessibility were specified that construction companies had to take into account[6]. Because construction data (including building year) is only available per ten years, the initial amount of will be somewhere between the value of 1990 and 2000. In order to explore all possibilities, the initial stock of the two types of houses is made uncertain in the range between the 1990 and 2000 values[7].

The demand for accessible houses is based on the health data by CBS of persons encountering physical problems in their daily life[8]. Adding these values to the household size will determine the demand of accessible houses. The housing demand (for regular houses) is determined by the household size and the amount of persons demanding a particular house. Housing supply is determined based on demand and the demolishing rate of the type of houses. Additionally there is a possibility of adapting regular houses in order to make them suitable for older persons.

[6] `https://zoek.officielebekendmakingen.nl/stb-1997-34.html`
[7] `http://statline.cbs.nl/StatWeb/publication/`.
[8] `http://statline.cbs.nl/StatWeb/publication/`.

4.1.5 Subsystem V: social security

The social security subsystem made of three funds of certain aspects of the social security. As determined by several sources (CPB, CBS, SCP) the parts of the social security system that suffer from the consequences of aging are health care funds and retirement benefit. Demand of funding is mainly based on the other subsystems: demand for retirement benefit is determined by the size of population aged 65 and older, demand for care by the care subsystem.

Retirement benefit: The Dutch pension system is build upon 3 pillars:

1. AOW, which is a pay-as-you-go system: working population pays for retired population,
2. additional pension: pension funds are arranged collectively between employers & employees,
3. individual pension savings: pension savings by and for individual workers.

AOW is funded by payments of the working population (currently up to age 65). Everyone having an income (either salary, (unemployment) benefit, etc.) will have to pay 17.9% of the first €33.436 of income (as of 2011). The part of the AOW-expenditures that cannot be paid from this system is paid from general funds. Everyone living in The Netherlands is entitled to AOW-benefit. Only in case a person has not lived his/her whole working age (age 15 to age 65) in The Netherlands, the AOW payment is decreased with 2% for every year not lived in The Netherlands.

In the model this is implemented in a simplified way: payments by the working population are simulated according to the amount of persons in their working ages, the part of their income that goes to AOW funds and their wage increases. The part of income that goes to AOW funds is fixed and is thus not increasing in the model. The only aspect influencing the height of the contribution are wage increases (see section wage increase).

The same counts for the AOW-payments. All retirees receive an average AOW-benefit and the total of these payments are the AOW payments. Average AOW payments increase with a fraction of average wages increase. This fraction is made uncertain in the model, as it is not a sure thing that AOW benefits increase similar to wage increases.

Individual pension funds: Although an important part of income of retirees, the individual pension savings (pillar 2 and 3 of the pension system) are not implemented in the model in much detail. This is mainly done because of priorities set in advance (which is to research the affordability of the pension system for the Dutch government). In that sense, the government is not very much involved in regulating the savings of individuals, although the pension system is initiated by the government. The most important consequence of pension savings in this research is the willingness (or necessity) of workers to work until or after reaching the retirement age. This is implemented in the model as a rate of willingness to work until retirement age and willingness to work after retirement age. These values are simulated as S-shaped curves (similar to the S-shaped curves of attractiveness of working in health care in the economy section) where labor participation increases or decreases in a certain way that a wide range of possibilities are explored.

Cure (ZVW) fund: Cure (or in Dutch ZVW) is funded by an insurance system. Every inhabitant of The Netherlands is legally required to have a health care insurance. This insurance is paid in two ways: (i) by subscribing to a private health insurance company and (ii) by a percentage of income (7.75% of the first €33.436) as of 2011). Every person of 18 and older contributes to this fund and this is modelled similar to the AOW fund: changes in the amount of persons of 18 and older change the total contribution to ZVW, as well as wage increases (as the contribution is a certain part of income). When shortages in funding occur, the contribution has to rise, as the system is in principal private (although it is governmentally initiated and regulated). The system is simulated in this way, so the contribution changes when shortages occur. Besides this effect, 2 other policies are added: (i) the government contributes the difference between benefits and costs and (ii) the coverage of the insurance is decreased. The latter will eventually result in an unhealthier population. The level of influence on the health level is, again, made uncertain.

Care (AWBZ) fund: Care is, similar to ZVW, also funded by an insurance system. Care funding, or AWBZ as it is called in Dutch, is part of the people's insurances. Every inhabitant of The Netherlands is contributing a certain part of their income to these people's insurance, of which a major part is used for paying AWBZ care costs.

Every person of 15 years and older is contributing to this fund, and when needed, allowed to benefit from it. This is modelled similar to the AOW funding, changes in wage level, amount of persons of 15 and older and changes in average payments change the AWBZ fund. The difference between benefits and costs is contributed by the government. Other social security benefits

Besides the mentioned social security, The Netherlands provide a large amount of other social security benefits, mainly aimed on persons not able to work. As this research is done into the effects of an aging population and the part of the population not able to work is a relatively fixed fraction of the total population , these benefits are not implemented in the model.

Changes in wage level: Average wage level increases are considered similar to the exogenous economic growth. As wage level increases are relatively uncertain over time, the value is taken as a random trend[9] and then smoothed over 10 years. This makes sure that all plausible behaviour is taken into account, instead of staying too narrow and missing some plausible behaviour.

4.2 Uncertainties

Table 1 contains a list of the uncertainties with their types and ranges. Following types of uncertainties are distinguished here:

- Parameter uncertainties: pertaining to uncertain values of a parameter
- Function uncertainties: pertaining to various plausible functions
- Lookup uncertainties: pertaining to various plausible lookups
- Structure uncertainties: pertaining to various plausible model structures

Parameter uncertainties are sampled uniformly between the upper and lower bounds. Categorical uncertainties can only reach pre-determined values, e.g. when the variable is designed as a switch between different structures or lookups. Additionally, a distribution can be chosen in order to create a certain probability structure.

4.3 Workshops

Process-wise, the work related to the national aging model consisted of following 3 workshops and 3 modelling phases:

1. Introductory workshop related to 'Societal Aging'
2. Model building phase
3. SD model validation workshop
4. Model correction and adaptation for EGMSS workshop
5. Exploratory Group Model Specification & Simulation workshop
6. Extended ESDMA based on EGMSS workshop

A number of uncertainties that are part of the model that were found to have a large influence on the results of the model, but difficult to reach consensus on their values (or distribution of functions). To be able to implement these uncertainties in a proper, plausible, way in the model, the uncertainties were discussed during 2 workshops, attended by experts in particular fields of research with affinity to this research. The organisation of these workshops is described below.

[9]See (Pruyt, Kwakkel, Yucel, and Hamarat 2011) for an explanation about this and other uncertainty mechanisms.

Variable	Lower bound	Upper bound	Type	Distribution
initial Regular Houses Easily Modified	618000	1678039	Parameter	Random uniform
trend in rules of admission to intramural care	0	0.01	Parameter	Random uniform
delay time in behaviour effect on unhealthy expectancy	5	15	Parameter	Random uniform
delay time in behaviour effect on mortality	10	20	Parameter	Random uniform
trend in average regular house household size	-0.01	0.01	Parameter	Random uniform
fraction of life expectancy increase due to cure level lived in good health	0.25	0.75	Parameter	Random uniform
unspecified changes in cure costs	0.005	0.015	Parameter	Random uniform
economic growth period1	0.03	0.035	Parameter	Random uniform
economic growth period2	-0.01	0.03	Parameter	Random uniform
economic growth period3	-0.01	0.03	Parameter	Random uniform
economic growth period4	-0.01	0.03	Parameter	Random uniform
economic growth period5	-0.01	0.03	Parameter	Random uniform
average wage level increase period1	0	0.02	Parameter	Random uniform
average wage level increase period2	0	0.02	Parameter	Random uniform
average wage level increase period3	0	0.02	Parameter	Random uniform
average wage level increase period4	0	0.02	Parameter	Random uniform
average wage level increase period5	0	0.02	Parameter	Random uniform
male willing to work 60 to 64 trend	0	0.02	Parameter	Random uniform
female willing to work 60 to 64 trend	0	0.02	Parameter	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	Parameter	Random uniform
coefficient B relative attractiveness of working in health care	5	20	Parameter	Random uniform
coefficient C relative attractiveness of workingin health care	0.5	5	Parameter	Random uniform
coefficient D relative attractiveness of workingin health care	-0.5	1	Parameter	Random uniform
coefficient A relative attractiveness of working after retirement age	-5	0	Parameter	Random uniform
coefficient B relative attractiveness of working after retirement age	0	20	Parameter	Random uniform
coefficient C relative attractiveness of workingafter retirement age	1	5	Parameter	Random uniform
coefficient D relative attractiveness of workingafter retirement age	-0.5	1	Parameter	Random uniform
coefficient A relative attractiveness of working until retirement age	-1	0	Parameter	Random uniform
coefficient B relative attractiveness of working until retirement age	5	20	Parameter	Random uniform
coefficient D relative attractiveness of workinguntil retirement age	0	1	Parameter	Random uniform
coefficient A building houses delay time	10	90	Parameter	Random uniform
coefficient B building houses delay time	2	6	Parameter	Random uniform
annual fraction service houses demolished	0	0.05	Parameter	Random uniform
annual fraction regular houses demolished	0	0.05	Parameter	Random uniform
annual fraction of persons unnecessary in accessible houses willing to move away	0	0.03	Parameter	Random uniform
fraction of accessible house demand fulfilled by modification of RHEM	0.6	1	Parameter	Random uniform
fraction of accessible house demand fulfilled by modification of RHDM	0	0.4	Parameter	Random uniform
annual unhealthy life expectancy increase due to budget cuts in cure	0	0.5	Parameter	Random uniform
average nursing homes building delay time	1	5	Parameter	Random uniform
fraction of average wage increase to increase in aow	0	1	Parameter	Random uniform
change in preference of employers for hiring workers	10	50	Parameter	Random uniform

Table 1: Uncertainties in the Dutch societal aging model

4.3.1 'Validation' Workshop

Workshop I was organized for verification and validation of the model, and to define important structures and trends in the model, in order to generate important uncertainties that can be defined during workshop II. During workshop I, a presentation of the model and main structures was given, together with the main assumptions behind the structures and variables in the model. The participants were given the opportunity to come up with improvements that were implemented in the model before starting workshop II.

4.3.2 Exploratory Group Model Specification & Simulation Workshop

The second workshop was organized in order to bring together different experts from different fields of research and with general knowledge on the issued involved with aging. The purpose was to generate trends in uncertainties that have a potentially large influence on the aging system. Following uncertainties were discussed during the workshop:

1. Average productivity per age main
2. Relative average labor productivity
3. Relative average labor productivity in care
4. Relative average labor productivity in cure
5. Fraction smokers in population
6. Fraction meeting standards of physical activity in population
7. Fraction heavy drinkers in population
8. Fraction obese in population
9. Female life expectancy
10. Male life expectancy
11. Fertility rate
12. Average labor participation male
13. Average worked hours per week male
14. Average labor participation female
15. Average worked hours per week female

The workshop consisted of four phases:

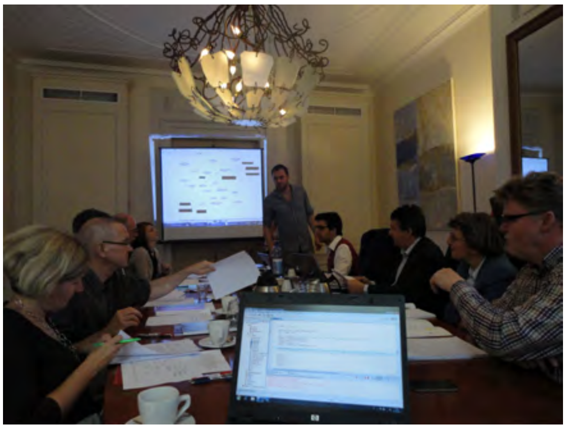
1. presentation of model and the (re)main(ing) uncertainties (see Figure 9(a))
2. generation of trend lines for remaining uncertainties (see Figure 9(b))
3. ESDMA simulation and presentation of the preliminary 'ensemble of future worlds' (see Figure 9(c))
4. general discussion on improvements and generation of possible policies (see Figure 9(d)).

The participants were given a number of empty graphs on which they were asked to draw trend lines of specific variables and how they were expected to change over time. 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 can in a later stage be used 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 trend lines fast and simultaneously to the filling in of the participants. This was done by implementing a number of lookup function, corresponding to the number of participants to be able to fill in the drawn lines instantly (see Figure 10).

The python code then randomly selected a lookup for each variable per simulation and by performing a large amount of simulations many plausible runs were generated and explored. Figure 11 shows 2000 Latin Hypercube samples over 50 uncertainties (parametric uncertainties, categorical uncertainties, 15 function uncertainties filled in by EGMSS participants).

The resulting ensemble of future worlds in Figure 11 for 2000 samples for four key output indicators is wider than other studies:

- the *total population* of the Netherlands is projected by means of this model to grow / shrink to a number between 14 and 22 million;



(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 9: Pictures of the EGMSS workshop

- the *government contribution to AOW* increases at first but could over a period of fifty years rise six-fold or return to current values (or any value in between);
- the *fraction care fte demand fulfilled* becomes either highly problematic (below 1) or unproblematic (between 1 and 20)
- the *health care costs as a fraction of GDP* become either problematically high –even impossibly high (above 100%)– or unproblematic (close to the current 10.1%).

It should be clear that this ensemble requires further analysis.

4.4 Exploratory SD Modeling & Analysis: Further Analysis

ESDMA is particularly interesting for this issue because many aspects of the aging system/issue are uncertain. Any model would contain or consist of (experts) opinions/assumptions. All different points of view were separately introduced in the model and by using switches, the different sections can be turned on or off from the python meta-file. For example, the productivity of workers of different ages is disputed. Some research shows a decreasing productivity of older workers because the wages increase with age but productivity stagnates. Other research shows an increasing productivity of older workers due to experience and a stagnating (or possibly a decreasing) wage level from a certain age on. Figure 12 contrasts these two points of view (Gelderblom, 2005): The

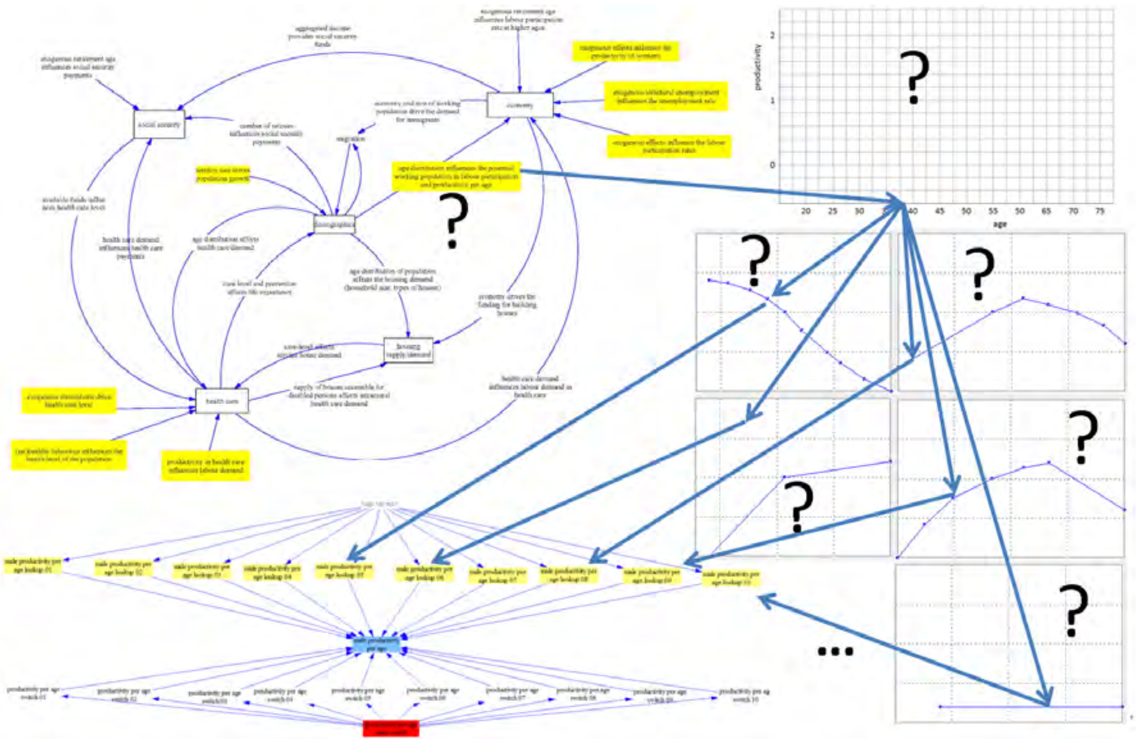


Figure 10: From uncertainties in the sector diagram to uncertainties in the simulation model

left hand graph shows the first point of view of a decreasing productivity with age, the right hand graph shows the opposite. Figure 13 shows the implementation of these views into the SD model. The switches are used to turn the sections on/off in the uncertainty analysis.

4.4.1 Multiplots wrt output variables

The multiplot in Figure 14 shows the correlations between output indicators for 2000 LH samples.

It could be used to select a useful set of output indicators (i.e. output indicators that are perfectly correlated with other output indicators do not need to be shown / described). It could also be used to verify whether particular (complex) relationships work out fine (i.e. higher male or female life expectancies generally lead to a higher total population).

From this multiplot, it seems as though the output indicators *government contribution to AOW*, *fraction care fte demand fulfilled*, and *health care costs as a fraction of GDP* are an appropriate set. The output indicator *total population* is added to the set because policies may actually change the strong link between the *total population* and the *government contribution to AOW*.

4.4.2 Classification with regression trees on end states

Here it is assumed that *health care costs as fraction of GDP* above 25% are unacceptable. The same is true for a *fraction care FTE demand fulfilled* below 100% (i.e. inability to fill in the required number of care workers).

The regression tree in Figure 15 exploits these assumptions: each of the runs of the ensemble was classified into one of four classes before application of the C4.5 regression tree algorithm (Quinlan 1993) with following settings: maxMajority= 0.6, minimum number of cases per subset = 20, minExamples = 40.

Class 0 consists of cases with a *health care costs as fraction of GDP* end state above 25% and a *fraction care FTE demand fulfilled* below 100%, in other words, financially unsustainable cases

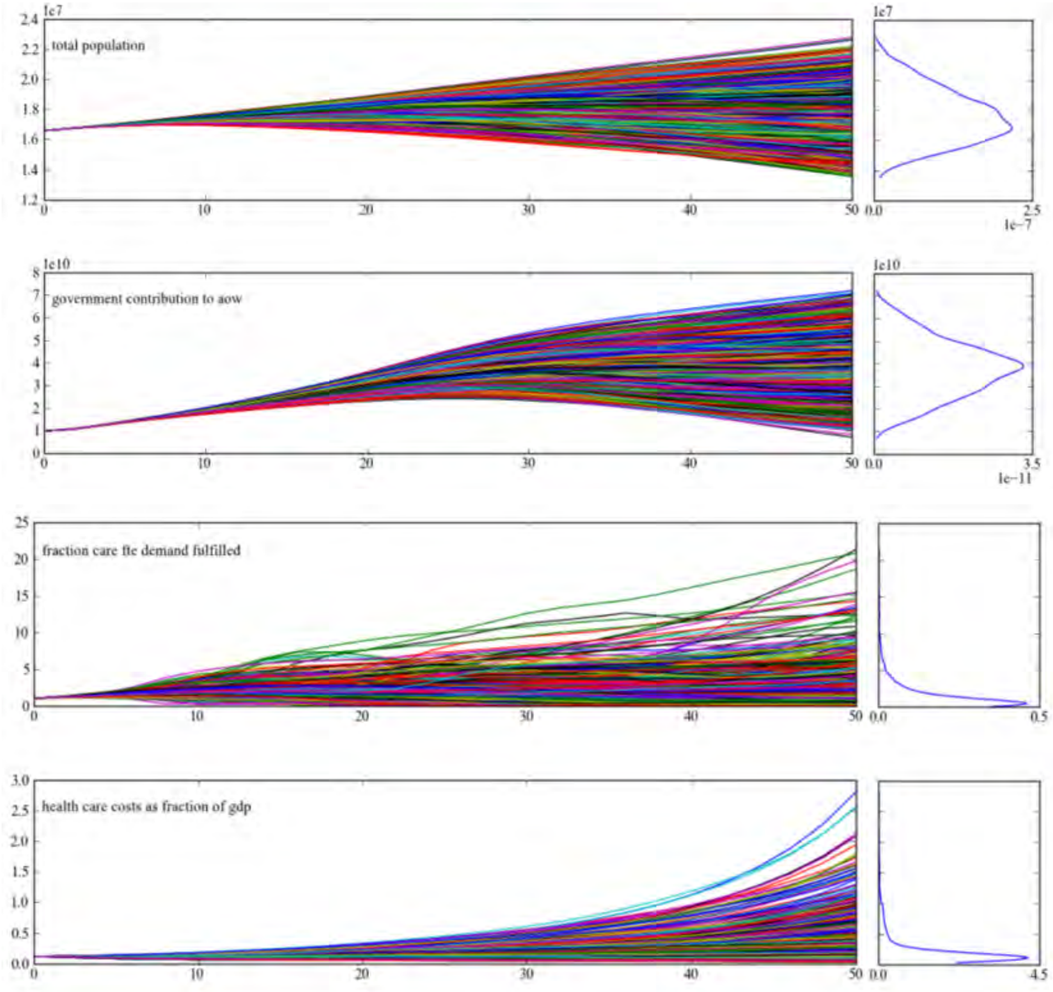


Figure 11: 2000 LH samples for four key performance indicators of the national aging model

with a shortage of care workers. Class 1 consists of cases with a *health care costs as fraction of GDP* end state above 25% and a *fraction care FTE demand fulfilled* above 100%, in other words, financially unsustainable situations without a shortage of care workers. Class 2 consists of cases with a *health care costs as fraction of GDP* end state below 25% and a *fraction care FTE demand fulfilled* above 100%, in other words, financially sustainable situations with a shortage of care workers. Class 3 consists of cases with a *health care costs as fraction of GDP* end state below 25% and a *fraction care FTE demand fulfilled* above 100%, in other words, financially sustainable situations without a shortage of care workers.

Class 0 does not appear explicitly in the regression tree in spite of the fact that 161 runs out of 2000 end up in this least desirable class. Hence, they are not simply caused by one uncertainty or a set of uncertainties. Class 1 consists of 240 out of 2000 runs, class 2 of 1022 runs, and class 3 of 577 runs. Most cases have health care costs as a fraction of GDP below 25%. But most cases are critical in terms of the fraction of *fte care jobs being fulfilled*.

Productivity growth and *productivity growth in care* are the most discriminating uncertainties, followed by *economic growth* and *relative attractiveness of working in health care*. Less important overall but still discriminating between branches of the tree are the *relative attractiveness of working until retirement age* and the *building houses delay time*.

But classifying on end states may not be enough. Figure 16 shows the evolution of runs classified in terms of their end state values (*health care costs as fraction of GDP*><0.25 and

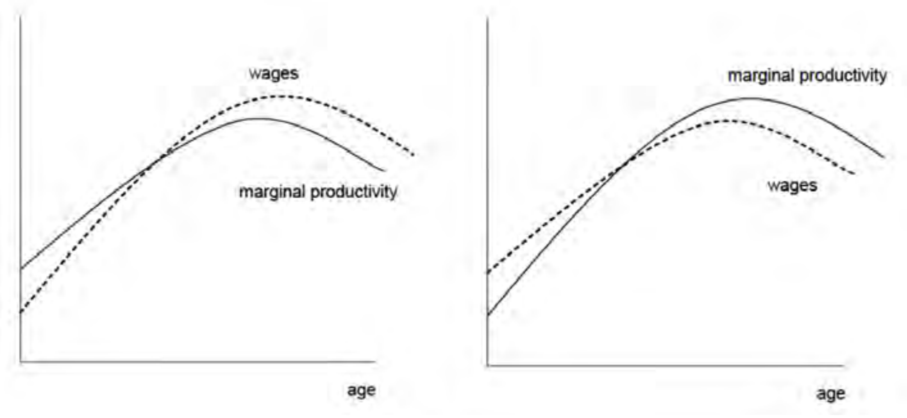


Figure 12: graphs of two points of view regarding productivity (Gelderblom, 2005)

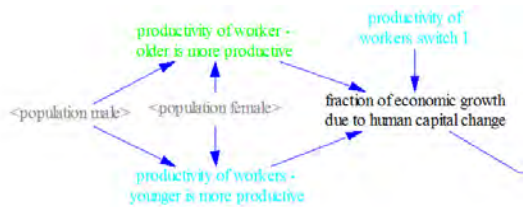


Figure 13: SF structure to vary the point of view

fraction care FTE demand fulfilled><1). Figure 16 shows that end state classification is indeed insufficient –and that the evolution over time should be considered– for the *fraction care FTE demand fulfilled*. [This and more advanced analysis are currently performed.]

4.4.3 Time series clustering

Clustering these 2000 artificial time series according to the concatenation of atomic behavior patterns for *health care costs as fraction of GDP* with the most basic algorithm (ABPv0) leads to 64 classes. Figure 17 shows 6 of these classes.

4.4.4 Policy analysis and regret analysis

Policy analyses and regret analyses are currently performed: results will be communicated in a follow-up paper.

5 Preliminary Conclusions

The global model: Although developing the global model was rather quick and easy, using and explaining the global model proved to be a challenge. Studying the dynamic complexity under deep uncertainty of and between 8 different regions is fairly complicated and time consuming. It nevertheless proved to be useful: although predicting the dynamics of and especially between these different regions is impossible, exploration is possible. A better understanding of the inter-relatedness of the regional developments and the envelopes of the ensembles of future worlds are useful for lower-level modeling and policy analysis.

The national model: The national model merges many expert assumptions. The combination of these assumptions provides a much broader view on the issue than other studies. If health care

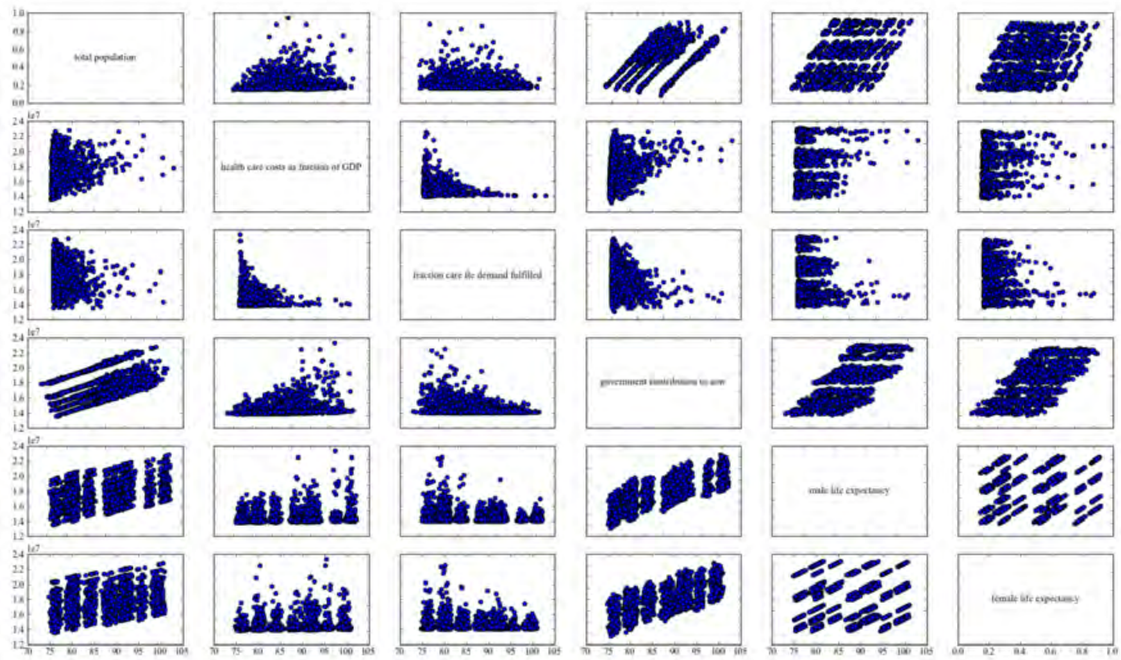


Figure 14: Multiplot showing the correlations between output indicators for 2000 LH samples

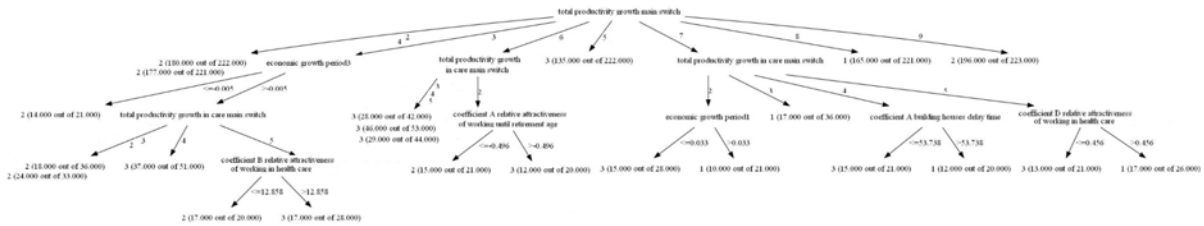


Figure 15: C4.5 regression tree algorithm applied to 2000 runs pre-classified according to their end states

costs as a fraction of GDP of 25% (currently 10.1%) are considered sustainable, then most cases are sustainable. Many cases are nevertheless critical in terms of care costs as a fraction of GDP. However, most cases are critical in terms of the *fraction of fte care jobs being fulfilled*. Policy analysis is currently performed in order to find robust policies that deal with these critical cases. The global model is used to see whether policies to migrate out of the aging issue are feasible given the global fight for employees in care.

The ESDMA methodology: The models in this paper are different from other ESDMA models in that they are subscripted. Subscripting models is interesting when using a Python shell and Vensim simulation package: although subscripted models still require an enormous amount of data/uncertainties to be specified, they also allow structural uncertainty space exploration beyond the exploration possible with unsubscripted models about the same issue. Combining subscripts and lookup switches allows for example to (randomly) turn co-evolution of similar regions on/off, to select a subset of plausible evolutions for a particular region, etc.

The EGMSS process: The main methodological innovation described in this paper is the use of exploratory SD simulation models in an Exploratory Group Model Specification and Simulation

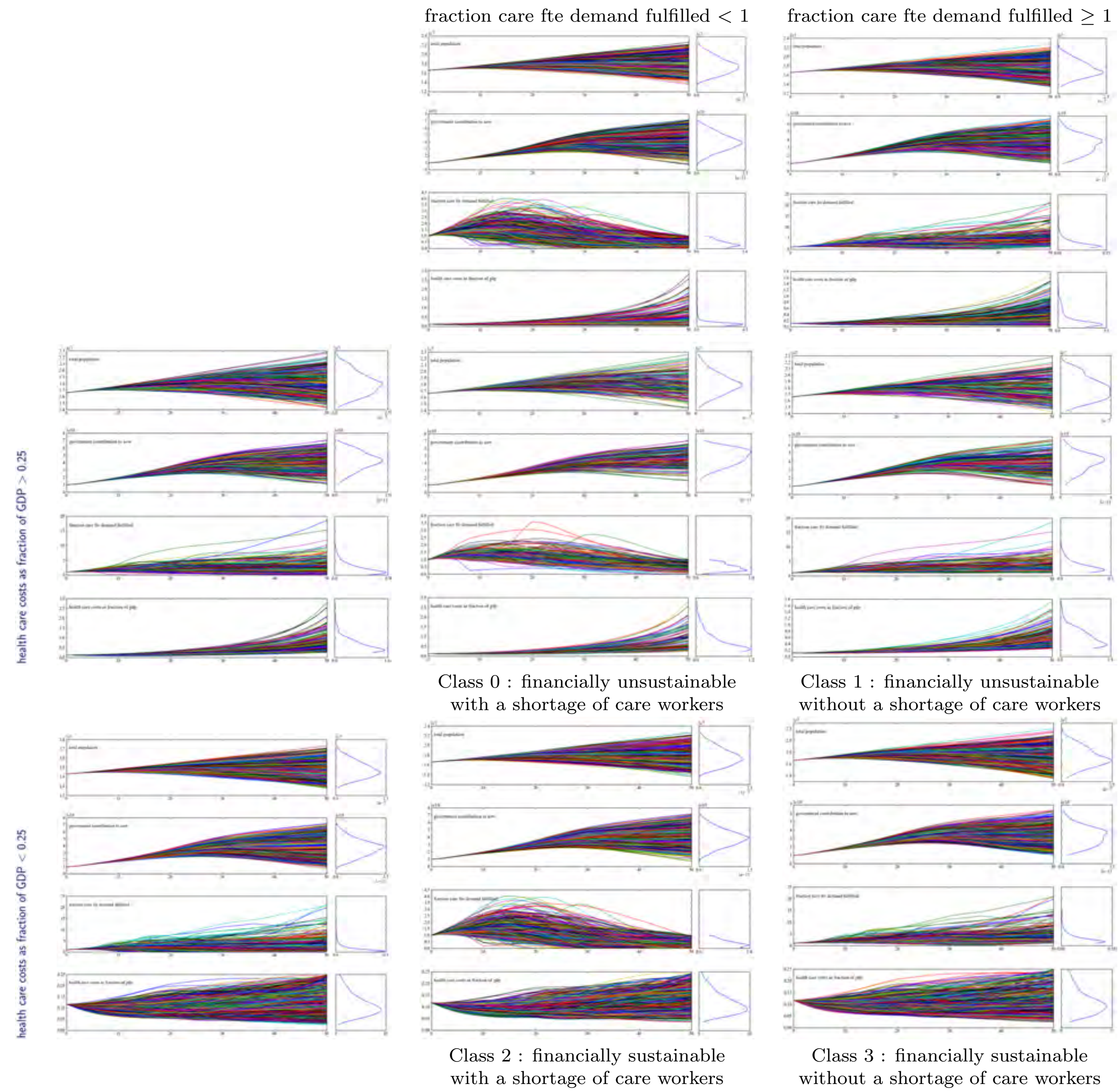


Figure 16: Lines and end state distributions for the total population of four classes (determined on the end states of two key output indicators)

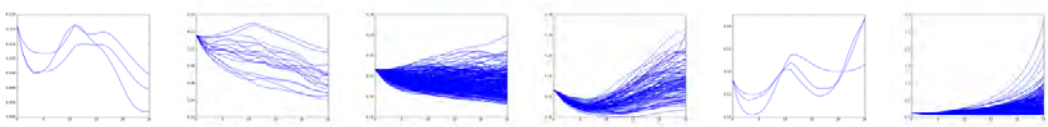


Figure 17: Some of the 64 classes generated with the ABPv0 time series classification algorithm

workshop. Characteristic about this type of workshop is that the main uncertainties still need to be specified, that diversity of opinion is sought after and included in the models, and thousands of simulations are generated on the spot to provide direct feedback about the influence of the diversity of opinions included in the model.

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