Demographic aging and its implications for the Dutch welfare state

an Exploratory System Dynamics approach

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Master Thesis MSc. Engineering and Policy Analysis

Delft University of Technology, August 2011
For Joes
Preface

Before you lies the final part of my studies at TU Delft: my master thesis. It is the result of 6 months of hard work and a collection of all knowledge gathered during the 2 years I studied the Engineering and Policy Analysis-master.

This research is one of the first in its kind by combining System Dynamics and uncertainty exploration using Exploratory Modelling and Analysis with an interactive workshop setting for expert input, leading to a broad explorative study into the effects of demographic aging.

I would like to thank everyone who has contributed to this report in any way, but specifically:

Dr. Erik Pruyt, for his supervision and guidance during the project,

The persons at TNO and HCSS, and dr. Govert Gijsbers in particular, who gave me the opportunity to perform this research,

All experts and interviewees that have contributed to the research with providing support and knowledge,

Everyone else that has provided me with support during my studies at TU Delft,

And last, but certainly not the least, I would like to thank Lieske and Joes for their support and inspiration.

Thomas Logtens,

Delft, August 23, 2011
Summary

Demographic aging, i.e. the process of an increasing ratio of older persons in a population, is a widespread phenomenon. The majority of industrialized countries is facing this process caused by a decreasing birth rate and an increasing life expectancy. Decreasing fertility is generally caused by the rise of using contraceptives, secularization, individualism and emancipation of women. Increasing life expectancies are generally contributed to increased hygiene, housing and nutrition, and from World War II mainly due to vaccination programs, prevention and medical care.

The research aims at answering the following research question: “What are the main consequences involved with demographic aging in The Netherlands (in terms of labour supply, financing and societal costs in health care, social security, housing and the labour market) taking future uncertainties seriously into account, and what consequences should be focused on in order to achieve a sustainable welfare-state in The Netherlands in the coming 50 years?”

Answering the research question is done by the use of Exploratory Modelling and Analysis (EMA) with an Exploratory System Dynamics (ESD) model as input. EMA is a method that can be used for analysing urgent problems containing a lot of uncertain aspects. By performing EMA to a large number of uncertainties in a computational model (in this case the ESD model) a problem analysis can be performed taking into account uncertainty that exists in the system. Ultimately, these results can be used to analyse trends in the system, define problem areas and to construct and test the robustness of policies.

The first step of this research was to analyse the system under study. The system considered here is the Dutch welfare state comprised of a demographic sector, the health care supply and demand sector, the social security sector, the housing sector and the economy and labour market. Important trends and relations between these subsystems WERE defined and an ESD model was constructed. In this model, major uncertainties existing in and between the sub systems were identified.

In order to fill in the blanks in these uncertainties, a number of experts were consulted to sketch trend lines of what they would think might happen in the future. The trend lines were used as input in the uncertainty analysis and explored using the EMA method. For doing this, special software designed by the Policy Analysis section of the Technology, Policy and Management faculty of Delft University was used.

The main outcomes of this research are defined as challenges that can be used to determine the direction of future research. These challenges are:

1. **Increase labour participation of older workers**
   By increasing the labour participation of older workers, part of the shortages arising on the labour market can be solved. This can be done by increasing the retirement age, but not solely: labour participation is not only driven by the retirement age but also by willingness of persons to work and the willingness of hiring a person.

2. **Increase relative attractiveness of working in health care**
Attractiveness of working in health care is found to be an important determination of the number of persons working in health care. As a large part of the GDP will be spend on health care in the future, a large part of the employees will need to work in health care.

3. **Focus on the Dutch labour market**
   To be competitive to other nations having to deal with an aging population, an important aspect will be to remain an attractive labour market. By focusing on the right skills, to focus on productivity and to focus on quality, output increases. Additionally, an attractive settling environment can attract both skilled workers and companies.

4. **Focus on the Dutch housing market**
   The vast majority of simulations show a shortage of houses. Household size decreases and the number of newly build houses is stagnating. Housing supply should follow and anticipate on possible demographic changes in order to provide sufficient housing for all households.
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1. Introduction

A large problem of the majority of 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 older persons. This causes a smaller part of the population being able to work, and thus paying social security benefits for the ones in need and the health care expenses to rise because health care expenses currently increase exponentially with age.

When considering the current situation in The Netherlands, a large proportion of the current employees, the so called “baby-boom generation”, will retire within a 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 population inflow). Considering these figures, one can conclude that the age distribution in The Netherlands will drastically change in the coming decades.

The main questions asked in this respect concern 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 potential working population compared to the total population will become smaller, but the consequences of this change in age distribution are to a large extent unknown. The Dutch government is currently implementing particular policies for increasing the retirement age with one year (from 65 to 66 in 2020) but the effect of this policy is questionable.

This research described in this report is part of the Strategy and Change programme initiated by the Dutch research institutes TNO and HCSS. It investigates the effects of future demographic changes in The Netherlands, with special attention paid to the consequences in terms of health care, housing, social security; all basic aspects of the Dutch welfare state, and the labour market. The scope of this research will be to explore the effects of an aging population on the determined parts of the welfare state, and in a later stage the results might be used as a steppingstone towards further research into this topic.

This report is built up of 7 chapters, all describing a part of the research that is performed. Chapter 2 starts with a problem description on which the research is based. This chapter describes the scope of the research and the research questions that will be answered in this research. Chapter 3 describes the system that is researched, i.e. the Dutch welfare state and the demographics that are of influence. Chapter 4 describes the used methodology and how this methodology should be taken into account during the different parts of the research. Chapter 5 describes the different sections of the model built during this research and how the model input is gathered. Chapter 6 describes the model output and results and how these should be implemented for further use in future research. Finally, chapter 7 are conclusions drawn from and recommendations made to the research results.
2. Problem description

As mentioned before, demographic aging is a widespread phenomenon. The majority of countries will suffer from this demographic shift in the future, although not all at the same time. The question that rises is: what may happen in The Netherlands and how could the government deal with it?

2.1 Identifying consequences and challenges involved in an aging society

The rising life expectancy and the decreasing fertility rate are causing a shift in the age distribution of the Dutch population. When looking at the statistics of the Dutch population (Fig. 2.1), 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 small 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 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 ratio is expected to rise from 26% (2010) to 49% in 2040 (CBS, 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, which is a decrease of 5% compared to 2010 (CBS, 2010). Fig. 2.2 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. 2.2: fewer contributors (persons aged 25-65) and more benefiters (mainly elders) (CPB, 2010).

The causes of the declining fertility rates are rather unsure, but female participation in the labour market, the costs of raising children, better access to contraceptives and decreasing child mortality are generally considered reasons for women getting fewer children (Grant et al., 2004; De Graaf,

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1 Netherlands Bureau for Economic Policy Analysis
Improved hygiene and better health care (and availability of health care) are considered the main reasons for the increasing life expectancy, although current research already focuses on a health level decline due to unhealthy living\(^2\).

This research focuses on the consequences of demographic aging in four different fields: health care, labour market, housing and social security. These fields are considered being part of the ‘welfare-state’ in the Netherlands and are regarded among governmental responsibility. This means that, among others, the government is responsible in maintaining continuity in the welfare state and has to take measurements to make sure that everyone, current and future inhabitants contribute and benefit from the facilities provided by the welfare state. Due to the relatively slow dynamics within demographics, the Dutch government needs to anticipate on rising issues instantly, or at least as fast as possible. But what consequences (or challenges) involved with aging are currently identified by researchers?

Consequences of aging in terms of health care can be found in different areas. First, the larger proportion of older persons is expected to cause an increase in health care expenditures, as health care expenses per year increase exponentially with age (Fig. 2.2). Second, fewer workers may lead to labour problems in health care, causing quality loss or increased efficiency demand or automation.

Aging problems that might arise in the labour 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 overestimations 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

\(^2\) Indicated by A Chorus in interview on March 2, 2011
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 paid 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 CPB. This research generally takes into account the situation as is and projects it towards the future. But it does not thoroughly take into account uncertainties arising in the future, and perhaps more important: interrelations between different aspects of the macro-economy and welfare state, e.g. a decreasing working population will lead to decreased availability of personnel in health care and this might influence the quality of health care, which will obviously influence the number of healthy workers.

2.2 Research scope
The contribution of this research to the population aging debate will be to provide insights into these interrelations: not to show how government spending or debt might increase due to this demographic shift, but what its consequences will be for the mentioned aspects of the welfare state and the labour market, taking into account uncertainties in several parameters in this system, e.g. fertility and death rates, attitudes of individuals towards issues, economic growth rates etc. The aim is not to provide exact figures, but to show trends in the parts of the system using an uncertainty exploration with a very large number of scenario’s. In a later stage, the model and the results might be used for thorough policy testing and defining directions in future research. So, important aspects of this research will be to identify the main parts of the system influencing the research results. By doing this, a certain direction for future research will be defined in order to focus on the parts of the system that have the largest influence on this system and are best influenced by future policy measurements.

Due to the broad research scope, setting the right boundaries is very important. Besides that, gathering data and making substantiated assumptions solely based on literature will be quite difficult, especially when regarding the relatively short amount of time within which the research has to be performed. The relatively short time span of the research can be contributed to the necessity of acquiring the results to be able to take measurements and provide input for future research. This has lead to the research being more explorative, not providing exact results within a certain error range but more of an indication of a range of plausible results to indicate a certain direction towards which future research is suggested to be performed. In this respect, gathering data will be done as much as possible in collaboration with experts. These experts provide input for the relations and parameters in the system. A list of experts that have contributed to this research by giving interviews and assessing the model can be found in appendix I.
In general, this research aims on answering the following main research question:

“What are the main consequences involved with demographic aging in The Netherlands (in terms of labour supply, financing and societal costs in health care, social security, housing and the labour market) taking future uncertainties seriously into account, and what consequences should be focused on in order to achieve a sustainable welfare-state in The Netherlands in the coming 50 years?”

In order to come to an answering of the main question, the following sub-questions should be answered:

1. How is the welfare state in The Netherlands organised and what trends currently occur that might be problematic in the future?
2. How can the system of the Dutch welfare state be modelled in order to come to a simulation of the system taking into account the main uncertainties that do exist in the system?
3. What interrelations exist between the different sectors of the welfare state?
4. How can the output of the simulation be interpreted in order to come to a justification of the focus of future research?

The different steps that are followed to answer these sub-questions, and consequently, the main research questions, are described in the next sections. These steps include: i.) a research into the system of aging and the welfare state in The Netherlands (chapter 3), ii.) a research into the method used to model this system and the consequences this has for the research performed during modelling the system (chapter 4), iii.) modelling the system and defining the main uncertainties for input into the model (chapter 5) and iv.) an analysis into the output of the model and how this output should be interpreted (chapter 6).
3. Description of the welfare state system in The Netherlands

This chapter describes the functions of the welfare state in The Netherlands, with a special focus on the aspects of the welfare state that are mainly influenced by a growing fraction of older persons in the population. The system in this chapter is described as a combination of different subsystems as pointed out in the previous chapter, and the relations that exist between them.

3.1 The Dutch welfare state

After World War 2, the government focused increasingly on social responsibility and taking care of the weak in society. During several post-war administrations, laws had passed that ensured this new focus on social responsibility and to make sure the strong ones took care of the weak. The main areas that were focused on in this new approach were proper health care for everyone, accessible education, proper housing and social security for the ones unemployed or unable to work (WRR, 2006). In fact, the welfare state is designed as a system to which every inhabitant of the country contributes to his or her capacity and everyone in need can equally benefit from the funds available.

Concerning this research, the welfare state is considered a system in which health care supply and demand, social security and housing are related to the demographic build-up of the society (determination of demand of these aspects) and the labour market (provision of funds for these aspects). When considering an aging society, these aspects are directly influenced by it. In the next chapters, all 5 subsystems, i.e. health care, social security, housing and labour market, are described in more detail in terms of organisation, funding and changes over time.

Although education is an important aspect of a nations’ economy, it is left out of this research. Problems arising within education due to an aging population are mainly due to a decreasing workforce in education (Korver, 2007) and considered part of the shortages in labour supply on an aggregated level. Additionally, due to the scope of this research which focuses on the (financing of) problem areas within an aging society, education is not considered a problem area.

3.2 Demographic changes in The Netherlands

The main driver of aging is of course the demographic system. As previously stated, a decreasing fertility rate and an increasing life expectancy are the main causes of aging.

Fertility

When looking at the birth rate during the last 50 years, one can notice a significant decline in the number of children per woman in the fertile ages (generally considered 15 to 50 years) in the 1970’s (see fig. 3.1). As previously discussed, this is mainly subscribed to the rise of using contraceptives, secularization, individualism and emancipation of women. From the 1980’s until now, the fertility rate has been relatively constant but with some

\[\text{According to CBS (2011) [1]}\]
fluctuations. The lowest fertility was seen in 1983 with 45.7 children per 1000 women between 15 and 50. Since then, the highest value has been 52.4 in 2000.

Economic growth is considered to have a small contribution to the fertility rate: around 1.5 years after a year with economic prosperity, the number of births increases. The level of increase is rather uncertain, but between 1997 and 2000 an increase in willingness to buy (a rate for perception of prosperity) of 5% annually led to an increase of 2000 births per year, which was around 1% of the total number of births in these years. On the contrary, CBS (2010) expects the fertility rate to stay relatively constant in the future.

**Life expectancy**

Life expectancy, or rather life expectancy at birth, is commonly regarded as the expected years to live of a person at birth taking into account the probabilities of dying of all ages in the year of birth. It is thus a measurement of all death rates combined in a certain year and can also be calculated for persons at older ages. Therefore, life expectancy is not a measure for the average age a person might reach as it is a snapshot of all death rates at that point in time.

The life expectancy at birth in The Netherlands has been steadily increasing during the 20th century. The life expectancy for females was around 50 years in the beginning of the 20th century, and a little less for males. Due to increased hygiene, housing and nutrition, and from World War II mainly due to vaccination programs, prevention and medical care, this has lead to a life expectancy of 78.53 for males and 82.65 for females in 2009.

This life expectancy is expected to increase in the next decades. According to calculations by RIVM, the life expectancy for males in 2050 will be 83.8 and for females 88.1 years. CBS estimates the life expectancy in the same year to be 83.2 years for males and 85.5 years for females. The difference is mainly contributed to the different calculation methods of the two institutes, taking into account certain behaviour.

Behaviour and the prevalence of diseases caused by this behaviour is a very important aspect in life expectancy calculations. The main unhealthy behaviours causing declining life expectancy for individuals are smoking, alcohol abuse, obesities and physical inactivity. Table 3.1 shows a table of life expectancy increases (in years) on population level and on individual level for quitting unhealthy behaviours.

<table>
<thead>
<tr>
<th>Table 3.1: life expectancy increases for quitting unhealthy behaviours</th>
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<tbody>
<tr>
<td><strong>prevalence in society (%) in 2009</strong></td>
</tr>
<tr>
<td><strong>on population level</strong></td>
</tr>
<tr>
<td><strong>Smoking</strong></td>
</tr>
<tr>
<td><strong>Obesities</strong></td>
</tr>
<tr>
<td><strong>Physical inactivity</strong></td>
</tr>
<tr>
<td><strong>heavy drinking</strong></td>
</tr>
</tbody>
</table>

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4 According to Economic statistical Announcements (2001) [3]
6 Health care future exploration (RIVM, 2010) core report pp. 16
7 Health care future exploration (RIVM, 2010) core report pp. 16
8 Data from CBS 2009 [5]
9 Health care future exploration (RIVM, 2010) core report pp. 14, 15 and 20
10 Health care future exploration (RIVM, 2010) core report pp. 20
case everyone in the population would quit this unhealthy behaviour. The prevalence in society is the percentage of persons with this behaviour in 2009\textsuperscript{11}.

\textit{Migration}

The third factor influencing the population size is migration. Net migration is considered the immigration minus emigration and when positive, it is increasing the population. According to CBS, the contribution of net migration to population growth is relatively small when compared to other (European countries)\textsuperscript{12}: 22\% compared to an EU-27\textsuperscript{13} average of 81\% out of the total growth rate.

When looking at the net-migration in The Netherlands from 1995 to 2010, one can notice a large fluctuation. For several years (between 2003 and 2007), the net migration was negative but has been positive since 2008.

Net migration is very much dependent on regulation by government and thus might be relatively uncertain in the future. Additionally, 20\% of all immigration is considered labour migrant so economy and economic growth are considered contributing factors to migration\textsuperscript{14}. CBS (2010) expects a long term annual number of 144.000 immigrants and 128.000 emigrants. This leads to a net immigration of 16000 annually.

\subsection*{3.3 Health care in The Netherlands}

The Dutch health care system of the second half of the 20\textsuperscript{th} century is mainly one based on solidarity. The main goal of health care is to be accessible to everyone needing it and that everyone is contributing financially to his or her capacity.

\subsubsection*{3.2.1 Sectors in health care}

Health care in The Netherlands is commonly \textit{horizontally} divided into 4 sectors (Boot, 2010): i.) care, which is considered long term health care focused on the long term health needs of a person, ii.) cure, which is considered acute health care, focusing on the improvement of a person’s health (e.g. hospital care, general practitioners, pharmaceutics etc.), iii.) mental health care, focused on mental or psychological problems and iv.) social care, focused on social well being of persons.

Additionally, sectors in health care are \textit{vertically} subdivided by rate of accessibility: i.) zero line care (i.e. care by persons in the direct environment, e.g. family and friends), ii.) primary care, i.e. the first step into the health care system (e.g. general practitioners, first aid in hospitals, primary psychological care or extramural nursing and personal care,), iii.) secondary care or specialist care, which is the second step into the health care system after referral by primary care (not necessarily

\begin{footnotesize}
\begin{itemize}
\item[\textsuperscript{11}] According to CBS 2009 [6]
\item[\textsuperscript{12}] According to CBS (2011) [7]
\item[\textsuperscript{13}] All 27 nations of the European Union
\item[\textsuperscript{14}] According to Economic statistical Announcements (2001) [3]
\end{itemize}
\end{footnotesize}
hospital care or surgery, but also psychiatric care) and iv.) tertiary care or institutional care, and is accessed when a patient is no longer able to live independently (either temporarily or permanent).

A third division in health care is made based on the type of funding. Health care is generally financed through five different funds: i.) ZVW (health insurance law) that consists of private health insurance companies that provide a governmental regulated costs coverage, ii.) AWBZ (general law for special health care costs) that is part of the social insurances to which every inhabitant of The Netherlands contributes, iii.) WMO (law for social support) which consists mainly of municipal contributions to care support (e.g. transport of disabled persons and domestic help), iv.) Governmental contributions to shortages in health care costs and v.) personal contributions to costs not covered by the general insurances. A more detailed description of health care funding can be found in chapter 3.2.2.

The four horizontally divided health care sections will be explained in more detail below.

**Care**

The care-sector is subdivided in nursing (i.e. taking care of a person’s long term medical problems) and personal care (e.g. helping with bathing, dressing etc.). These two areas mainly involve elders and an increase in the elderly population might increase the demand for these types of care. A third area in long term care is care for disabled persons (i.e. persons with mental or physical disabilities).

Care can be provided within institutions (so called “intramural”-care) or at home (so called “extramural”-care). Intramural care is again subdivided into two types: nursing homes, that provide long term medical care (medical care that is not acute but aimed on sustaining one’s health level) and personal care, and caring homes, that provide only personal care.

Extramural care is provided by (often private) organisations that supply either nursing or personal care. Up to 2007, domestic help (i.e. housekeeping) was part of the long term care funding but is now part of the municipal tasks of care providing (see section WMO). A person in need of care (extramural as well as intramural) can request this care at the CIZ that will judge the necessity, type and amount of care a person is entitled to.

**Cure**

The “cure-sector” is, as stated before, mainly focused on acute health care. In this respect, one can think of acute medical care as well as psychological care. Pharmaceuticals are generally regarded among the cure sector. The cure-sector is generally divided into primary cure and secondary cure.

General practitioners are regarded the gatekeepers of cure (Boot, 2010): they are often the first step into the medical system of a person needing medical aid. A large part of the patients are treated by this general practitioner, the patients that need additional medical aid are redirected to the proper secondary cure, e.g. specialist or hospital care and mental health care, but also to other sectors like care, mental health care or social care.

In principal, every Dutch inhabitant in need of medical aid, has access to the cure sector and in general, primary cure is available to everyone close by. Regarding hospital care (secondary cure), one

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15 According to CBS [9]
16 Centre for care indication
can divide three types of hospitals: general, categorical and academic hospitals. General hospitals are located in all relatively larger municipalities (a total of 220 locations) and 99.8 % of the inhabitants are able to get to a hospital within 30 minutes by car. Categorical hospitals are hospitals with a certain specialization (e.g. in physical rehabilitation, epilepsy or cancer treatment) and academic hospitals are hospitals that are affiliated to a university.

**Mental health care**

In general, persons needing mental health care can be divided into two groups of patients: persons with addictions and persons with psychiatric problems. The former will be treated in specific clinics, the latter will be hospitalized in psychiatric hospitals. In case these treatments are insufficient, a person can be institutionalized. Institutionalization can occur voluntarily or forced. For the latter, an authorization or court order is needed (Boot, 2010).

**Social care**

Social care is considered helping vulnerable persons in society to ensure their participation in society (Boot, 2010). In this respect, one can think of psychosocial care, administrative aid (e.g. helping with finances) or social help (e.g. helping solitary persons participate in society). The aim of social care is to make sure vulnerable persons are able to live on their own and are not forced to be institutionalized (Boot, 2010).

### 3.2.2 Funding of health care

As stated previously, health care in The Netherlands is financed from 5 different funds: i.) ZVW, ii.) AWBZ, iii.) WMO, iv.) government and v.) personal contributions. i., ii., and v. are (partly) funded by individuals, as direct payments or as part of their income (both either voluntary or involuntary). iii. and iv. are financed by general governmental funds.

All five different funds will be explained in the next sections.

**ZVW**

ZVW is considered the part of health care financing that mainly finances cure and a part of mental health care. The law has been active from 2006 and has been initiated to promote market competition in health in order to lower the prices of health care.

The ZVW-system is a system where persons are obliged to subscribe to a private insurance company. The contribution is paid in two ways: a monthly individual contribution that is paid directly to the insurance company and a part (7.75 %) over the first € 33,427 earned annually (this can either be income through salary or (unemployment) benefit). Employers are legally required to cover the expenses that are paid to ZVW, but income tax is calculated over this additional employers’ part. Income gathered from retirement benefit or profit by entrepreneurs pay a smaller contribution (5.65 %).

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17 According to Care Atlas (in Dutch: Zorgatlas) (RIVM) [10]
18 According to National Compass (in Dutch: Nationaal Kompas) (RIVM) [11]
19 Health Insurance Act (in Dutch: Zorgverzekeringswet)
20 Values for 2011 (source: Hop, 2011)
The insurance consists of a basic coverage, additional coverage might be added by the insurance-taker. The basic coverage is obligatory for every inhabitant of The Netherlands and the coverage is regulated by law and determined annually. The costs of the individual part of the insurance are not regulated. Persons with a low income are subsidized for the individual part of ZVW contribution by the government.

The ZVW-system is in principal a self supporting structure, regulated by the government. In the event of cure costs increases, the government has several options to ensure the affordability of the system. The most important ones are to either decrease the covered expenses, or to increase the personal contribution.

When looking at the annual expenditures from 2006 to 2010 one can notice an annual increase, from € 26.7 million (2006) to € 35.4 million (2010). These cost increases can be subscribed to a number of factors: volume growth, due to demographics (i.e. aging and population growth), increased health care use due to increased medical standards, policies (e.g. funding structures and costs coverage) and social-cultural changes and costs increases due to wage expenditure increases (possibly due to the Baumol-effect) and increased asset expenditures.

Labour demand in cure is determined by the volume of the demand and labour productivity. In 2009, 196260 fte were working in cure and this amount is expected to increase to 253000 by 2030 (an annual growth of 1.1 %). As of 2007, 12.4 % of all employees work in health care, of which 24.5 % in cure.

AWBZ

AWBZ is considered the part of health care funding that finances long term health care expenditures. AWBZ funding is part of the people’s insurances to which subscription and contributions are obliged for all inhabitants of The Netherlands. In principal, AWBZ covers the expenditures for all long term care costs and a part of mental health care costs (see chapter 3.2.1, section Care and Mental health care).

Contributions to AWBZ are paid as part of the people’s insurances which demand a fixed part of the income. As of 2011, 12.15 % of the first € 33.436 earned annually is paid to AWBZ. The insurance covers care expenses regarding: personal care and nursing, treatment aimed on recovery or sustaining one’s condition (physically and mentally) and institutionalization for persons unable to live independently (temporarily or permanent). The coverage is regulated by the government and can be supplied in kind or in funds. The latter gives the care demander the opportunity to buy care

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21 Indicated by Johan Polder (RIVM) in interview on May 31, 2011
22 Data from CBS, data of 2006-2010 [12]
23 Persons with non-Dutch social-cultural backgrounds might have a different (more specific and relatively higher) health care demand compared to persons with a Dutch background (Boot, 2010)
24 Health care future exploration (RIVM, 2010), sub report ‘Time and Future’ pp. 36
25 The Baumol-effect is the effect that productivity growth in health care stays behind on productivity growth in industry because of the labour intensity of the former. This means health care cannot profit from economies of scale (source: Health care future exploration (RIVM, 2010), core report pp. 91)
26 According to CBS, data of 2009 [13]
27 Health care future exploration (RIVM, 2010), sub report ‘Time and Future’ pp. 46
28 Exceptional Medical Expenses Act (In Dutch: Algemene Wet Bijzondere Ziektekosten)
personally (PGB\textsuperscript{29}). A person needing care can arrange the care-taking individually with the care-taker of his or her own choice.

Because a large part of care-demand can be contributed to persons at an older age, care demand is very much influenced by demographic changes (i.e. aging). The volume growth of care was 3.2 % annually from 2003 to 2007, of which 2.1 % can be accounted for by demographic effects\textsuperscript{30}. The annual expenditures for AWBZ have increased from € 22,966 million (2007) to € 24,443 million in 2010\textsuperscript{31}. Nursing and personal care amount up to 54 % of the total AWBZ expenditures, PGB amounts up to 9 %\textsuperscript{31} and 48 %\textsuperscript{32} of this value goes to extramural nursing, personal care and domestic help.

In 2010, the income dependent contributions to AWBZ amount up to an annual € 14,682 million. Additionally, personal contributions amount up € 1,638.4 million and contributions by the government of € 4,891.6 million. An easy calculation shows that the expenses are higher than the funds, and the government will contribute the difference out of general means (see section governmental contribution). As of 2007, the elderly care sector employs 212530 FTE\textsuperscript{33} and this is expected to rise to 409000\textsuperscript{34} as of 2030. The latter is very much dependent on productivity increase in this period.

\textit{WMO}\textsuperscript{35}

Executing WMO is done by municipalities. They receive a certain contribution by the national government in order to support individuals in participating in society. In this respect, one can think of social cohesion in neighbourhoods, information and advisory, promoting participation of disabled (mentally or physical) or care for drug-addicts.

An important part of WMO with regard to this research is domestic help. As of 2006, the domestic help was transferred from AWBZ to WMO. The main reason for doing so was the philosophy of municipalities being closer to the person needing care and therefore more capable of judging the needs of a person, and thus saving money on unnecessary care\textsuperscript{36}. Indicating the amount of necessary care is done by municipalities. The costs for domestic help in WMO are estimated on € 1,184 million as of 2011\textsuperscript{37}.

\textit{Governmental contributions}

Although the government promotes affordability of health care and a balanced budget for health care, often budget shortages need to be solved by the government. As of 2010, the governmental contribution to health care contributes € 12734 million (compared to € 10650 million in 2007)\textsuperscript{38}. In order to control these costs (increases), measurements are taken by the government, mainly with respect to coverage. An example is the substitution of domestic help from AWBZ to WMO.

\textsuperscript{29} Personal budget in care
\textsuperscript{30} Health care future exploration (RIVM, 2010), sub report ‘Time and Future’ pp. 39
\textsuperscript{31} According to CVZ (Council for health insurances) [14]
\textsuperscript{32} The rise of PGB (SCP, 2011) pp. 10.
\textsuperscript{33} According to CBS, data of 2009 [13]
\textsuperscript{34} Health care future exploration (RIVM, 2010), sub report ‘Time and Future’ pp. 46
\textsuperscript{35} Societal Support Act
\textsuperscript{36} Indicated by W Staalduinen (TNO) in interview on June 17, 2011
\textsuperscript{37} Meicirculaire gemeentefonds 2011 pp. 22
\textsuperscript{38} According to CBS, data of 2009 [12]
Personal contribution

Personal contributions are done in three areas: i.) additional (voluntary) insurances for cure costs, ii.) payments for cure that are not covered by insurances and iii.) (mandatory) personal contribution to care costs. Regarding i., the costs amount to € 3,625 million per year, which are not taken into account in this research as they are voluntary and personal. The costs for ii. consist of payments to health care expenditures of persons and are not measured separately, and since they are voluntary expenditures, not taken into account in this research. Regarding iii. the costs amount up to € 1,638.4 million (2010) which is 6.7 % of the total expenditures on AWBZ.

In the event of health care increases, raising the personal contribution might be a means to control the health care costs. When persons have to pay more, they are less likely to make use of health care. On the other hand, providing a decent health care available to all inhabitants of The Netherlands is one of the most important missions of health care and thus demanding a high personal contribution might lead to excluding certain groups in society from this health care.

3.2.2. Main trends in health care

When looking at specific trends in health care, the expected volume growth of health care demand is putting a lot of pressure on the system. Care demand is one of the main sectors in this respect because of a volume increase of an expected 2.5 % per year due to demographics.39

Specific trends that can be identified in health care:

- Increased extramuralization in care: as extramural care is less expensive government policies are aimed at living independently as long as possible.40
- Increased control on covered costs, especially in care.40
- Increased focus on social cohesion and zero-line care.40
- Increased labour demand in health care opposed by a declining working population.41
- Number of chronic diseases increases, as does life expectancy, due to higher medical standards.42

39 Health care future exploration (RIVM, 2010), sub report ‘From healthy to better’ pp. 43
40 Indicated by W Staaldruinen (TNO) in interview on June 17, 2011
41 Health care future exploration (RIVM, 2010), core report pp. 90
42 Health care future exploration (RIVM, 2010), core report pp. 20, 27-33
3.3 Social security in The Netherlands

The social security system in The Netherlands is built up on three pillars: i.) income dependent subsidies to support low income households, ii.) benefits for the unemployed or those unable to work and iii.) health care supply. The latter is already thoroughly discussed in the previous subchapter, this subchapter will focus on the structure of i. and ii.

**Subsidies for low income households**

The subsidies for low income households mainly exist to support household in having a decent living. Four different types of subsidies currently exist: i.) health care subsidy, ii.) children’s day care subsidy, iii.) rental subsidy and iv.) children’s subsidy.

Subsidies i., iii. and iv. support households in needs for housing, health care and to support expenses necessary for their children. These subsidies are dependent on income and are less for higher income levels, and decreasing to zero for higher incomes.

Although subsidy iv. is also income dependent and decreasing for higher incomes, this subsidy is mainly meant for increasing labour participation. Since day care is relatively expensive, it would not pay off for a large number of households for both parents to participate in the labour market. In order to increase female labour participation, this subsidy is created. One-third of the expenses are paid by tax services as employer’s part, two-third are paid as an income dependent subsidy (the higher the income, the lower the subsidy).

**Unemployment benefit and support for persons unable to work**

The Netherlands have a large number of different types of unemployment benefits and support for persons that are unable to work (fulltime). To discuss all of these benefits and supports would be rather unnecessary as they are not taken into account completely in this research. Therefore, this part of social security will only discuss the so called employer’s insurances and unemployment support.

Employee’s insurances are insurances for current employees. Every worker contributes to these insurances for a part of their income and their aim is to take care of the worker in the event of unemployment or sudden disability that prevents a worker performing his or her employment. One is only entitled to the benefit when this person has contributed through paid work. The contribution is in total 12.51 % of the total income and are paid by the employer. Benefit is only received for a fixed amount of time and the receiver is obliged to meet certain rules.

Persons unemployed for a longer period or not able to work at all, are also supported. For the persons able to work, this support is mainly aimed on getting them back into the labour market. They are obliged to apply for jobs and accept any job suitable. Support for persons not able to work is mainly aimed on having them cooperate in society, through social (subsidized) or voluntary labour.
Retirement benefit

The Dutch pension system is build upon 3 pillars: i.) AOW\(^{43}\), which is a so called pay-as-you-go system: the working population pay for the retired population, ii.) additional pension, a pension fund that is arranged between employers and employees collectively and iii.) individual pension savings, that are pension savings done by workers individually.

AOW

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). This contribution is fixed by the government (only the maximum income level of which a part goes to AOW is changed) but the maximum contribution is set at 18.25 % per year.\(^{44}\)

The part of the AOW-expenditures that cannot be paid from this system are paid from general funds, which was € 9.697 billion in 2009 (CBS data [35]). 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.\(^{45}\)

Individual pension funds

Pillar 2 and 3 are considered individual pensions. These pensions are savings of current workers and are paid after their retirement. The pension of pillar 2 is called the employers’ pension and is an arrangement between employers and employees. Employers are not obliged to arrange a collective pension for employees but if a pension fund is part of the labour contract the employee is obliged to take part in the pension. Usually, the employer contributes to a large part of the pension premium. The rules pension funds have to comply with are set up and regulated in the Pension Law. The rules in the pension law are the means for the government to make changes in the pension system. An employee receives tax benefits on the contributions to the pension system and the taxes are paid by the pensioners that receive the benefit (e.g. contributions to ZVW and AWBZ).

The pensions of pillar 3 are not regulated and an employee can choose to make savings in this pillar or not. The pension can then be used as an addition to the pensions that will be received in pillar 1 and 2. Savings can for example also be made by buying real estate or stocks.

Pension savings (and then specifically the ones in pillar 2 and 3) are considered additions to the income received after retirement and an indication of the necessity for persons to work until and after reaching their retirement age. Lately, some problems with the Dutch pension funds have come to the surface. Due to too small contributions, low interest rates and increasing life expectancies\(^{46}\) the coverage (or ability to pay all pensions that contributors are entitled to) of the pension funds is decreasing. As soon as this coverage gets below 100%, retirees receive less pension than they are entitled to in the pension agreement.

\(^{43}\) General law for the elderly (in Dutch: Algemene Ouderdoms Wet)
\(^{44}\) ESB Economic statistical reports, 2002[15]
\(^{45}\) Based on “The Dutch pensionsystem” by Ministry of Social Affairs (2009) [16]
\(^{46}\) NOS.nl, “Ook grote pensioenfondsen in de problemen” [17]
Making sure that the pension funds are healthy and able to pay all agreements is one of the main concerns and tasks of the current administration. Ultimately, unhealthy pension funds may lead in the end to lower income for retirees, and that might lead to bad living circumstances for this group of elders and to extra governmental expenditures to support this group.

3.4 Housing system in The Netherlands

The Netherlands are a country with a large population density and subsequently, a relatively small amount of available area per capita. This leads to a tight housing market, where demand often exceeds supply of houses.

In general, the Dutch housing system is made up of two different markets: the rental market and the private market. These markets have a large interrelation and influence each other to a large extent, as the products from these two markets can—to some extent—be considered substitutes. This sub-chapter explains the Dutch housing system and the difficulties that might come across in the next decades, partly driven by aging.

The rental market

The rental market in the Dutch housing system can be subdivided into two sectors: social rent and private rent. The social rental market mainly consists of a number of large corporations that own a large number of houses in relatively cheap price ranges. Because of the latter, social rental houses are usually meant for and occupied by lower income households. Due to the low prices and the relatively high level of maintenance of these houses, the demand is high, leading to waiting lists amounting up to 13.1 years for social rental houses in Amsterdam in 2009. Prices for social rental houses are regulated by the government, based on a grading-system that grades the facilities provided in the house. The maximum price level of a social rental house is € 652.52 per month in 2011, houses exceeding this price are considered private rental houses and do not have to conform to the grading system.

Private rental houses are owned by either large real estate companies or small real estate investors. Waiting lists for these types of houses are relatively short, but prices are on average higher than social rent. Rental prices are not regulated in this sector.

The rental subsidy, as described in the previous section (under Subsidies for low income households) is only meant for household in social rent and does not apply for persons in private rental markets.

The private market

The private housing market mainly consists of households that have used a mortgage to buy a house. This indicates a certain level of trustworthy income (e.g. salary) and is thus a market occupied by higher income households.

Prices for houses in The Netherlands are relatively expensive when compared to neighbouring countries like Belgium or Germany. This is due to the relative small supply of land per inhabitant but more importantly, to tax advantages for house owners. Households that have a mortgage are

47 According to figures of 2009, Amsterdam Figures and Statistics Service [18]
48 See Ministry of Housing website [19]
49 According to the Ministry of Housing website [20]
allowed to subtract the interest paid from their income before taxes. This leads to a lower income on which taxes are paid (and thus lower taxes to pay). This tax advantage was initially meant for to give households the opportunity to buy a house, but has ultimately lead to households being able to spend more money on houses, which lead to general housing price increases. Abolishing the tax advantages would in the worst case lead to price drops of houses and thus to households getting into problems as they will lose their capital. This leads to a lock-in into the housing market where access is difficult (e.g. for starters on the housing market) and large losses would be suffered by households in the event of tax increases.

House owners having built up a certain capital of real estate, have increased their savings rate and have less incentive to work until or after the official retirement age. On the contrary, persons that do not have sufficient savings, are more likely to work until and after the official retirement age. Implications of aging for the housing system

In the event of demographic changes, the housing market will usually be affected as well. When considering the implications of an aging population, we can determine a number of effects that might occur in the (near) future.

One the most significant effects is that older persons (or households) have other needs than younger persons (or households). Due to an aging population, the demand for accessible houses might increase as elders are commonly physical less able compared to younger persons. Accessible houses are houses that preferably do not require walking stairs (but e.g. elevators or stair lifts) and, preferably, common facilities close by (e.g. grocery stores, medical services, social network i.e. friends and family). Additionally, because of an aging population, the average household size decreases: older households often do not have any children still living with their parents. A decreasing average household size combined with an increasing population size will lead to a larger demand of houses but according to CBS the population size will decrease from 2040 on, which will consequently lead to a decrease in housing demand.

The previous implies a well considered housing policy in the coming years. Although the demand increase will probably still last for a few decades, houses are usually built for the next 50 to 100 years. This means that changes expected in the future should be certainly taken into account immediately and the housing market is therefore an important factor in this research.

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51 Indicated by W Staalduinen (TNO) in interview on June 17, 2011
52 According to CBS, April 2011 [21]
3.5 Labour market and economy in The Netherlands

An important factor in a country’s economy is of course the labour market. The income of a state due to taxes and the GDP is to a large extent driven by the income of the population and thus the level of employment in a country.

In a country’s labour market one could simplistically define a number of important factors that influence the level of employment of the population and the output generated by this employment. When taking into account an aging population, these factors are: employment and (structural) unemployment, productivity and labour participation. These factors are described in more detail in the next sections.

*Employment and (structural) unemployment*

The number of employed persons in a country is mainly determined by the availability of employment, of persons willing to work and the level to which this labour supply and demand correspond.

The number of available jobs is to a large extent defined by the economy. Basic Keynesian or Neoclassical economic theory (see appendix V for a more thorough explanation of Keynesian and Neoclassical labour market theory) tells us that companies having more opportunities of selling their products (i.e. output growth) will increase their demand for labour (Galbraith and Garity, 2005; Sachs and Larrain, 1993) and the other way around: decreasing their demand for labour in the event of less opportunities for selling their products. This will also apply on an aggregated (national) level.

The availability of labour is dependent on a number of factors. First, there is the number of persons participating in the labour market. This will be looked at in section *labour participation*. Second, there is the availability of skilled labour (or in fact, the level to which the skills of the available workforce corresponds to demands in the market). This match, or mismatch in the labour market, is regarded as the qualitative structural unemployment.

Defining the level of qualitative structural unemployment is relatively difficult (no recent values could be found in this research). Together with frictional unemployment these types of unemployment define the minimum level of unemployment (Himmelweit et al., 2001). When looking into unemployment rates between 1996 and 2010, we find the minimum level of unemployment in The Netherlands to be 3.5 % in 2001. Note that this is not a measure of qualitative structural unemployment but only the smallest level achieved during the last 15 years.

*Labour productivity*

Labour productivity can be defined by certain aspects. According to OECD, driving forces behind labour productivity are “the accumulation of machinery and equipment, improvements in

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54 “Qualitative structural unemployment (...) occurs where demand does exist but is of a different nature from the supply of available labour”, Eurofound (2009) [22]
55 Eurofound (2009). *Structural unemployment* [22]
56 Unemployment of persons due to a job-switch (Himmelweit et al., 2001)
57 Based on CBS data 1996-2010 [23]
organisation as well as physical and institutional infrastructures, improved health and skills of workers ("human capital") and the generation of new technology. Thus, labour productivity growth can be defined as all output growth that cannot be explained from increase in the number of workers or the average amount of worked hours per worker. It can be regarded as a combination of capital, human capital and TFP.

Labour productivity in The Netherlands is among the highest in the world (see fig. 3.3).

But when regarding labour productivity growth, The Netherlands lags behind on other countries (see fig. 3.3). The main factors that are thought to cause the decrease in labour productivity growth is a lack of dynamics and innovation in the Dutch industry.

Labour participation

The part of a population taking part in the labour market is considered the rate of labour participation. In this research, labour participation is defined in two ways that both influence the total amount of worked hours in a country. First, labour participation is defined as the fraction of persons willing to be employed (so employed, but also unemployed). Second, the average amount of worked hours per worker is defined as a fraction of a fulltime-equivalent (FTE). One FTE is considered 40 working hours per week.

When looking at labour participation rates in The Netherlands per age and per gender, a number of striking characteristics come forward. When looking at participation rates for both males and females, these are relatively high for age cohorts between 25 and 55, but outside these cohorts the participation is relatively low. This is easily explained for age cohorts up to 25, as a large part of the population between 15 and 25 is still in school and this participation is relatively constant. But for cohort age 55 to 65, this is more difficult to explain: when looking at the data, the values are increasing.

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59 Total Factor Productivity, according to Solow (1957) the residu of economic growth that cannot be explained by capital or labour accumulation. TFP is considered the rate for technological change (Himmelweit et al., 2001).
61 Based on CBS data of 1996-2010 [26]
annually, from 40.8 % in 1996 to 64.3 % in 2010. The main reasons for this relatively low participation are early retirement, the average retirement age from 2000 to 2010 has increased from 60.7 to 62.7. This is mainly due to the fact that early retirement has been made more difficult due to 2006 regulations (CBS, 2011 [27]). Labour participation from 55 to 65 is expected to increase in the future.

Another difference, one that exists primarily between men and women, is the fact that labour participation and the amount of worked hours per week for women is smaller than for men. This is mainly due to a historical task-division between men and women: men working and women taking care of children and housekeeping. Although the difference has become smaller, women still work more frequently part-time: female labour participation in The Netherlands is among the highest in Europe\textsuperscript{62}, but the amount of worked hours per week lags behind in this respect. In order to increase the labour participation among women, the government makes policy based on encouraging women to work more, mainly by increasing opportunities for children’s day care\textsuperscript{61}.

\textsuperscript{62} Ministries of Education, Social Affairs and Health Care (2010). \textit{Government aims for higher female labour participation}. [28]
4. Methodology

In order to perform a thorough research into the consequences of aging on the Dutch welfare state and to be able to answer the research questions, the system of aging and the welfare state is researched using Exploratory System Dynamics Modelling and Analysis (ESDMA). This method is first described by Pruyt (2010) and is mainly based on a system dynamics study in which a large part of the variables, parameters and other input are uncertain. The main reason for choosing this modelling technique is based on the size of the system under research and the relative short amount of time in which the results should be generated. Different from traditional system dynamics, ESDMA is a method that can be used for researching deep uncertainty in a system and to be able to come up with an uncertainty analysis using a large number of scenario’s.

This chapter describes the different parts of the modelling method that together form ESDMA. These parts are Modelling and Analysis (EMA) and System Dynamics (SD) and Exploratory System Dynamics (ESD) models. Additionally, the used method for performing the uncertainty analysis is described and the chapter ends with a detailed substantiation of the choice for this modelling technique in this research.

4.1 Exploratory Modelling and Analysis

According to Bankes et al. (2010), EMA is a method for researching complex and uncertain systems using computational models. The method is founded on the fact that there is no model fully explaining all behaviour of a system correctly and uses uncertainty exploration for making sure that all possibilities are taken into account when researching a particular problem. Uncertainty exploration and scenario analysis can be done through several sampling methods, e.g. Monte Carlo analysis, Latin Hypercube sampling or factorial design (Bankes et al., 2010).

Agusdinata (2008) provides a framework for performing EMA on a policy problem. He divides seven steps that can be performed to come to a thorough analysis. These seven steps include:

1. Conceptualize the policy problem
2. Specify the uncertainties relevant for policy analysis
3. Develop a computer model
4. Perform computational experiments
5. Specify criteria for choosing policies
6. Explore and display the outcomes of computational experiments to reveal useful patterns of system behaviour
7. Make policy recommendations.

Considering this research, the computer models that are used are SD-models that are specifically designed to be able to perform the designated computational experiments needed for performing EMA. The demands to the model that Agusdinata defines are “automated input sampling”, in order to add (uncertain) variation ranges to the model input and “analytical agility”, which is defined the ability to run a large amount of scenario analyses in a relatively short amount of time. This can be reached by creating small and simple models, suited to the needs for obtaining usable results.
According to Agusdinata (2008), the researcher is free to choose and to use (and modify) an existing model or to create a model from scratch. Using an existing model will save time in the research but might sometimes be difficult when source codes are unavailable. Building a model from scratch is usually more time consuming, but the researcher will have the freedom to build a model which suits the needs of the research.

As previously stated, the EMA performed in this research is based on a System Dynamics model. The choice of constructing an SD-model instead of using other modelling techniques like agent-based models or econometric models is made on the basis of the fast to build and relatively fast to run SD models and modelling technique compared to agent based models. Additionally, SD is a method which provides models including feedback within the system, which is less possible in econometric models. Design of the SD model is explained in the next section.

4.2 System Dynamics

The Systems Dynamics (SD) modelling method is developed by J.W. Forrester during the second half of the 1950’s. It consists of a number of stocks and flows that are related and influenced by other variables. Appendix VI provides a more detailed overview of the system dynamics method.

To be able to use an SD-model as input for EMA, the modeller should be aware of the advantages and disadvantages of traditional system dynamics involving analysing uncertainties. Traditional system dynamics is suitable for systems simulation in which the real world is “caught” in stock-flow structures and feedback loops driving these stock-flow structures. It aims on gaining better understanding of the real world system from a historical perspective into the future in order to show outcomes and test the effects of certain policies. The variables in traditional SD models are rather rigid and aimed on gaining consensus on the best possible value, mathematical function or lookup graph. This leaves no room for exploring different possibilities and is not suitable “for detailed operational analysis nor for trajectory forecasting/prediction” (Pruyt, 2010 pp. 5).

In order to create system dynamics models that are more suitable for EMA, the inputs should be chosen in a way that these are not rigid to changes when exploring different plausible values. Pruyt (2010) mentions SD-models of such nature to be Exploratory System Dynamics (ESD) models. In order to do so, different uncertainties (or uncertainty structures) can be added to the model. The different types of uncertainties are: i.) parametrical uncertainties (i.e. uncertain values of a parameter), ii.) functional uncertainties (i.e. different plausible functions, iii.) uncertainties in lookups (i.e. different plausible lookups) and iv.) structural uncertainties. Each of these uncertainties will be described in the next sections.

Parametrical uncertainties

Parametrical uncertainties are parameters in the model of which the value is uncertain. This value should be defined as a range of plausible values between an upper and lower bound. During an uncertainty analysis, a random value is chosen for this parameter, possibly according to a probability distribution for the different values in the range of plausible ones.

The parametrical uncertainty provides a lot of opportunities during an uncertainty exploration. This type of uncertainty can be added as a ratio, real value or integer. Examples are:
- Explore different values of coefficients in a mathematical function to change the shape of this mathematical function (e.g. the changing the coefficients of a polynomial function can provide a large number of differently shaped functions)
- Create graphs with values that change over time on order to create a number of plausible graphs. This can be done in order to create conjuncture cycles in economics, by picking a value for economic growth per time period and smoothing the function.
- Create switches to explore different possible inputs or structures (see next sections)

Defining parametrical uncertainties can be done by using expert opinions or literature.

*Functional uncertainties*

Functional uncertainties can be used in case experts or literature show no consensus to the kind of mathematical function which should be used in a system. As different functions provide different behaviour, implementing different plausible functions into the model would provide a larger number of plausible behaviours. A functional uncertainty can be implemented in the model as different variables in which a switch chooses between these variables. The uncertainty exploration then drives the value of the switch, which can also be according to a certain probability function.

*Uncertainties in lookups*

When no consensus is available on certain graphs that are used as input, all possible graphs can be implemented in the model, using a switch to determine which graph is used. An example might be the different opinions that exist on the average productivity of workers of different ages. Certain 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 wage level from a certain age. Figure 4.1 and 4.2 provides an overview of these two points of view (Gelderblom, 2005): The left hand graph shows the first point of view of a decreasing productivity with age, the right hand graph shows the opposite.

![Fig. 4.1 and 4.2: graphs of two points of view regarding human capital and age (source: Gelderblom, 2005)](image-url)
Structural uncertainties

This type of uncertainty exists when no consensus can be reached by experts on which structure is best or most suitable. In order to generate all plausible outcomes, all different structures will be implemented into the model and a switch is used to choose between structures in the uncertainty exploration.

4.3 Performing the uncertainty analysis

The main demands which an uncertainty exploration method should meet are: i.) speed of performing the uncertainty exploration and ii.) the completeness of taking into account all plausible values that are specified. Using the available methods, in order to achieve ii., a large number of scenario’s (or runs) need to be performed, and this will obviously affect i. Agusdinata (2008) describes two suitable methods to perform the uncertainty exploration: Full Factorial analysis and Latin Hypercube Sampling.

**Full Factorial Analysis**

Full Factorial Analysis (FFA) is an analysis method that explores all possibilities for the specified uncertainty. In terms of uncertainty space coverage, this would be the most suitable method, as it covers all plausible uncertainty values. This is also the downside of the method, as it requires a relatively large amount of exploration runs to cover a relatively small amount of uncertainties. For example, when 10 uncertainties are defined and each uncertainty has 2 plausible values, the number of runs would be 1024. But, when the model contains 20 uncertainties which have 2 plausible values each, the number of runs would be 1,048,576. In this perspective, using FFA would only be useful in case of a relative small amount of uncertainties and plausible values.

**Latin Hypercube Sampling**

Latin Hypercube Sampling is first described by McKay et al. in 1979 and is a technique for sampling without replacement and for a number of experiments each segment is sampled only once (Agusdinata, 2008). Because of the latter, LHS will provide a better coverage of the uncertainty space compared to random sampling (e.g. Monte Carlo analysis) and will need a relatively smaller amount of runs to cover a relatively large uncertainty space compared to FFA.

Fig. 4.3, 4.4 and 4.5 show the uncertainty space that is covered using thee different techniques: Monte Carlo Sampling (MCS), FFA and LHS. Note that the samples of MCS are located relatively close to each other compared to LHS.

Fig. 4.3, 4.4 and 4.5: coverage of uncertainty space by three different (sampling) techniques: Monte Carlo Sampling (1), Full Factorial Analysis (2) and Latin Hypercube Sampling (3) (source: Agusdinata, 2008).
Regarding this research, the uncertainty exploration will be performed using LHS. The main reason for this is runtime and the relatively large amount of uncertainties implemented in the model.

4.4 Reasons for using ESD in combination with EMA in demographic aging research
Using ESD-models for EMA, or as it is mentioned by Pruyn (2010) as ESDMA, is very useful for chronic crises that develop slowly in time but have a large impact and taking actions is required on short notice, since processes develop slowly, adaptations and measurements might also take relatively long to take place. The latter often contain many uncertainties in terms of structure and behaviour and future dynamics.

The problem of aging in The Netherlands can be considered among iii.: population dynamics often develop relatively slow and implementing policies is rather difficult as these often affect a large number of persons and to make sure no undesirable side effects occur, policy makers should be cautious with taking actions.

Using ESDMA in this research will help in finding underlying structures, defining problem areas that might occur in the future and, in a later stage, to develop robust policies that have a desirable effect on all plausible scenario’s.
5. Model structure

Using the system description, literature and expert opinions, an Exploratory System Dynamics model is created based on this data. In traditional System Dynamics modelling, a predefined model building process is commonly used. This process consists of the following steps (Sterman, 2000; Vennix, 1996; Roberts et al., 1994):

1. Problem identification and model purpose
2. System conceptualization
3. Model formulation and parameter estimation
4. Analysis of model behaviour: testing and sensitivity analysis
5. Model evaluation: model validity
6. Policy analysis
7. Model use or implementation

Regarding this structure, steps 1, 2 and 3 are followed in this order, although step 2 and 3 were performed together: due to the large system and the large amount of knowledge and data needed in the modelling process, the system conceptualization and model formulation were performed together with experts during interviews and based on literature proposed by these experts. A list of interviewees, their expertise and the date the interview was taken can be found in appendix I.

Because the model set up in this research is used in a deep uncertainty exploration, validation and verification in a traditional way is rather difficult. Although a sensitivity analysis is already performed in the uncertainty exploration (by taking a wide range of values for the different parameters), validation using model behaviour is impossible because of the large amount of runs and because all runs are defined as plausible behaviour. In this sense, it will be possible to try and explain behaviour by model parameters.

Validation on the model structure is possible, and is basically the only suitable model validation option available. In this research, validation was done during a ‘validation’-workshop, in which different experts from the research fields are invited to discuss the model structure, to give comments and to get acknowledged with the model itself.

During the second workshop, organised as part of this research, a parameter estimation is performed. A number of model parameters with a large influence and high level of uncertainty were selected during the validation workshop and were filled in by the attendees during the second workshop: A description of this ‘Exploratory Group model Specification and Simulation’ workshop can be found in chapter 5.8.

This chapter will first describe the ESD-model used in this research and the choices and payoffs made during the modelling process, as well as data and relation definition. The second part of this chapter will focus on the validation of the model and the third part will discuss the uncertainties and uncertainty determination.
5.1 Setting up the aggregated model

As can be found in chapter 2, this research will focus on demographic aging in the Dutch welfare state. A number of sectors part of the Dutch welfare state were defined and in order to design a suitable model for this research, the first activity would be to define the relations between the different sectors and to do so, a sector diagram is set up.

A sector diagram is an aggregated view of a large system that cannot be represented by showing all structures and relations. In a sector diagram, only the relations between the different sectors are shown in order to provide a simple overview of all relations existing between the different sectors of the model. After defining the relations on an aggregated level, the focus will be moved to a detailed overview of the structures and relations within the sectors. The sector diagram of this research is shown in fig. 5.1, a larger view can be found in appendix VII.

As already discussed in chapter 2 and 3, the Exploratory System Dynamics model used for the Exploratory System Dynamics Modelling and Analysis (ESDMA) is built up of 5 subsystems. The main subsystem is demographics, in which population dynamics are simulated. The other 4 subsystems are the economy (in this research mainly implemented as labour market dynamics), health care, social security and housing. The consequences of aging in the Netherlands are mainly focused on these
subsystems and their interrelations and therefore researched and modelled in the SD-model. The main interrelations between the subsystems are shown in the sector diagram of fig 5.1 and from the next page these relations are described. Defining and validation of these relations is done during the expert interviews (see appendix I for an overview of interviewees) and during workshop I (see chapter 5.8).

Demographics <-> Economy

- Population size, age distribution and health level influence the size of the potential working population by labour participation per age (see Chapter 5, “Subsystem II: economy”).
- Economy influences the need for migration or the willingness of persons to migrate. Migration influences the population size and age distribution.

Demographics <-> Social security

- Population size and age distribution (e.g. the number of retirees) influence the supply and demand of pension payments.
- Population size and age distribution influence the number of persons contributing to social security funds.

Demographics <-> Health care

- Population size and age distribution drive the demand for health care (see section “Subsystem III: health care”).
- Health care level influences life expectancies and thus the population size and distribution (see chapter 3, “Demographic changes in The Netherlands”).

Demographics <-> Housing

- Population size and age distribution determine household size and thus demand for housing (See Chapter 3 “Housing in The Netherlands”).
- Population size, age distribution and health level drive the demand for accessible houses (see Chapter 5 “Subsystem IV: Housing”)

Demographics <-> Exogenous

- Fertility rate drives the number of new born babies and population inflow

Economy <-> Social security

- Aggregated output (or income) on a national level provides the funds for social security, because the majority of social security contributions (including health care) are depending on income (See Chapter 3 sections “Health care in The Netherlands” and “Social security in The Netherlands”).
- The economy drives labour demand and determines the number of unemployed persons

Economy <-> Health care

- Economy drives the labour market, and thus labour supply in health care
Economy <> Housing
- Economy drives the funding for houses

Economy <> Exogenous
- Retirement age influences the labour supply in the economy

Health care <> Social security
- Social security provides funds for health care. If funds are insufficient, additional funds need to be supplied or budget cuts will take place in health care

Health care <> housing
- Supply of accessible houses determines the demand for intramural care

Social security <> Exogenous
- Retirement age determines the number of pension payments

These values of these relations is explained in the next sections. These sections will focus on each of the subsystems in detail and explain the way the model is performing and what data is used to get to the model.

5.2 Subsystem I: Demographics and population dynamics
As stated above, demographics is considered the main structure 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 sub model corresponding in a proper way to the real life situation is vital.

In order to do so, the model is subdivided in two populations: female and male. This subdivision is made for reasons of difference in these populations on certain aspects. For example death rates (and thus life expectancy) and labour participation differ in such a way that averaging these properties will cause major irregularities (see appendix II for a list of population data used).

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 (Sterman, 2000) 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 (see appendix II) 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.

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 labour (Berkhout and Van de Berg, 2010; CPB, 2007). In this respect, 3 plausible scenarios are determined during expert interviews and workshop I (see section Workshop):

1. The Netherlands is able to attract the necessary number of workers to provide the necessary labour.
2. The Netherlands are not able (or not willing) to import the required labour from elsewhere, but is able to keep the available labour stock.
3. The Netherlands are not able (or not willing) to import the required labour from elsewhere and emigration of the current labour 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.

Fertility as a modelling input is made uncertain over time and implanted as such in the model. For a description of this, see chapter 5.8.
Fig. 5.3: Model structure for male demographics (a large view can be found in appendix X)

Fig. 5.4: Model structure for female demographics (a large view can be found in appendix X)
5.3 Subsystem II: economy

Labour demand

In subsystem II, the economy is explored. For this research, the economy is built up of labour supply and demand, where a certain exogenous economic growth drives the demand of labour. In this respect, the simplest form of labour defined output is taken\(^63\): \( Y = L \cdot \frac{Q}{L} \). This function calculates aggregate output \((Y)\), labour \((L)\) and output per unit of labour \(\frac{Q}{L}\). This function is chosen in order to easily define the relation between labour and output and thus define labour demand growth \((dL)\) at a certain economic growth \((dY)\): \( dL = dY - d\left(\frac{Q}{L}\right) \). So, economic growth and change in output per unit of labour define the amount of labour necessary to fulfil the defined economic growth. The output per unit of labour is defined by OECD as labour productivity (see Chapter 3).

Aggregate output growth is regarded as the exogenous economic growth and determined as the potential growth that might occur and is simulated in the model as a random function, taken from Pruyt et al. (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 as a main factor of output growth in The Netherlands.\(^64\)

Labour productivity can be defined by certain aspects. As stated previously and according to OECD, driving forces behind labour 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” (see Chapter 3). When regarding the problem of aging, labour 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 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 wage level from a certain age. General labour productivity growth and age defined human capital are implemented as uncertain inputs (see chapter 5.7) and explored in the uncertainty analysis. Productivity in health care is regarded a special case because of the “Baumol- effect” (see Chapter 3) which shows that productivity in health care will always lag behind on productivity in industry, mainly because of the labour

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\(^63\) Indicated by R. Vergeer (TNO) in interview on June 7, 2011

\(^64\) Indicated to by R. Vergeer (TNO) in interview on June 7, 2011
intensive processes taking place. Economies of scale in health care will not pay off in the same way as industry. Therefore, labour productivity in health care are taken as separate inputs (see Chapter 5.8).

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 workshop I, see chapter 5.8). In the model, at a certain point in time, this preference will change to a more evenly distributed preference (see fig. 5.5). The time this switch takes place is uncertain as well, and explored in the uncertainty analysis.

**Labour supply**

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

A striking observation is the labour participation of workers between 55 and 65, which is relatively low compared to labour participation at younger ages. During workshop I, this effect is contributed to labour market effects induced by early retirement of persons. This effect is currently fading out and expectations are that the labour participation at higher ages will increase slowly in the coming years. This is implemented in the model as well. Therefore, the increase in labour participation for males and females in higher age cohorts is simulated as an uncertainty, increasing between 0 and 0.03, as the largest increase during the last 4 years has been 3%\(^{66}\). The maximum the participation can reach is dependent on labour participation rates in younger age cohorts.

Changes in the average labour participation are implemented as an uncertain input over time and explored in the uncertainty analysis (see Chapter 5.8).

**Labour supply and demand in Health Care**

As stated previously, labour supply and demand in health care is different from general labour demand and thus regarded separately. According to RIVM\(^{67}\), 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).

![Fig. 5.6: different S-shaped curves with different values for the coefficients (y-axis is particular value increase, x-axis is time in years)](image)

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\(^{65}\) Indicated by Pauline Bongers (TNO) in her presentation on February 3, 2011

\(^{66}\) Based on CBS data [26]

\(^{67}\) Health care future exploration (RIVM, 2010) core report
To be able to research the potential labour 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:

\[ f(t) = \frac{A}{B + e^{C+C_Dt}}. \]

By exploring the coefficients A, B, C and D, the curve can show a lot of different behaviour (see fig. 5.6) and thus provide a wide range of different plausible results.

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 Chapter 5.8).

**5.4 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 (see Chapter 3). As stated in chapter 3, 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 pharmaceuticals. 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) (for data, see appendix II).
Data of RIVM for age dependent costs of diseases (KVZ, 2008) are used as initial input for costs of cure\textsuperscript{68} and used for defining the age-specific cure-costs increase. Additionally, according to RIVM (2010)\textsuperscript{69} 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 labour 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 “uncertainty exploration”).

Behaviour of persons is considered another important aspect of cure demand (and life expectancy). In this respect, the four main unhealthy behaviours are implemented in the model, i.e. smoking, alcohol abuse, obesity 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\textsuperscript{70}. 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\textsuperscript{71}. 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\textsuperscript{72}. The uncertain variable determining the unhealthy expectancy increase is simulated between 0.25 and 0.75 years per increased year of life expectancy.

As can be argued, the effect of starting unhealthy behaviour has a delayed effect on the unhealthy expectancy. Several research is performed on this matter and in order to implement all plausible results, the delay time of starting or ceasing unhealthy behaviour is set between 5 and 20 years. These figures are taken from smoking cessation research in which several sources determine a decrease in health hazards to the same level of a non smoker will take 5 to 15 years for a smoker after quitting. Doll et al. (2004) state that for a person quitting before age 30 the health hazards are similar to a non smoker 50 % for quitting at the age of 50. Because the statements of the former (5 to 15 years delay time) cannot found to be scientifically proven the delay time is chosen to be uncertain between 5 and 20 years in order to take into account certain level of uncertainty. The order of delay is also uncertain and therefore chosen to be 1, 3, 10 or 1000 in order to take into account different ranges of orders.

\textsuperscript{68} Indicated by Johan Polder (RIVM) in interview on May 31, 2011
\textsuperscript{69} Health care future exploration (RIVM, 2010) core report
\textsuperscript{70} Health care future exploration (RIVM, 2010) core report
\textsuperscript{71} Indicated by R Perenboom in interview on March 9, 2011
\textsuperscript{72} As discussed in workshop I, indicated by R Perenboom (interviewed March 9, 2011), A Chorus (interviewed March 2, 2011) and J Polder (interviewed May 31, 2011)
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 (see appendix II for an overview of the used data).

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 and 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 labour input. As care is relatively labour intensive, an increase in care demand means a similar increase in labour. 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 labour supply in health care. Additionally, the government currently stimulate elders to stay at home
instead of going to nursing homes.73 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: the allowed access to intramural care is decreased with an uncertain value between 0 and 1 % annually, meaning that the rules for admission are more strict. A decrease of 1 % annually means an effective decrease of 40 % in 50 years if the number of complaints stays equal.

Increasing health care costs are to a large extent caused by increasing costs due to an increase in wages in health care, availability of cure techniques and, to a lesser extent, aging. 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 funded74 and this will lead to shortages in care.

Looking back at the system description for health care in The Netherlands in chapter 3, one will notice the model only simulates care and cure and leaving out mental health care and social care. This is done because the input data covers a large part of the expenses done in this respect because ZVW and AWBZ funds pay health care costs made in these sectors.

5.5 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 accessible75. 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

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73 Indicated by W Staalduinen (TNO) in interview on June 17, 2011
74 Indicated by W Staalduinen (TNO) in interview on June 17, 2011
75 Kenniscentrum Wonen en Zorg (Knowledge centre Living and Care) based on WoON (2007) [29]
their house when becoming physically less able (and these houses will be modified). An uncertain part of the persons living in a house that is difficultly modified are assumed to be moving away to an accessible house.\textsuperscript{76}

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.\textsuperscript{77} 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 values of 1990 and 2000.\textsuperscript{78}

The demand for accessible houses is based on the health data by CBS of persons encountering physical problems in their daily life.\textsuperscript{79} Dividing these values by the average household size per age will determine the demand of accessible houses. The number of persons encountering physical problems in their daily life is influenced by the unhealthy expectancy of the cure subsystem.

The housing demand (for regular houses) is determined by the household size and the amount of persons demanding a particular house. Changes in the household size is made uncertain over time and might thus change the demand for houses.

Housing supply is determined based on demand and building and demolishing rates of the type of houses. The building rate is made uncertain but based on the economic growth. In time of economic growth, income increases and house prices might increase as well and thus developers are more eager to build new houses (based on the demand). The relation between building time and economic growth is rather unsure and therefore has been made uncertain in the model using different kinds of S-shaped functions (see fig. 5.4 for an example of s shaped functions) with economic growth as input. This leads to an input dependent value but with uncertain behaviour over time. The values of the coefficients are chosen in a way that the delay time for building houses will always be between 1 year and 5 years, depending on the economic growth. The minimum value of 1 is chosen as an estimation of the minimum building time of a house, the maximum value of 5 is chosen as an estimation of the maximum time within which demand for housing should be fulfilled. No data is available to substantiate the latter and therefore the value has been estimated.

Demolishing rates are also made uncertain. When looking at the number of demolished houses compared to the total number of houses, the last 15 years show a minimum value of 0.18 % and a maximum of 0.34 %.\textsuperscript{80} Therefore, in order to take into account a decent level of uncertainty, the value is chosen between 0 and 1 %.

Regarding accessible houses, available data show that the number of accessible houses are not all occupied by persons needing an accessible house. Therefore, an uncertainty has been implemented in the model, simulating the number of persons willing to move away from an accessible house. This factor has been set between 0 and 0.03. Additionally, there is a possibility of modifying regular

\textsuperscript{76} Indicated by W Staalduinen (TNO) in interview on June 17, 2011
\textsuperscript{77} Based on official announcement by Dutch government (1997) [30]
\textsuperscript{78} Based on CBS data for 2009 [31]
\textsuperscript{79} Based on CBS data for 2009 [32]
\textsuperscript{80} Based on CBS data 1995–2010 [33]
houses in order to make them suitable for older persons. The fraction of houses that are adapted as part of the demand for accessible houses is made uncertain. In principal, modifications to a house for medical reasons are paid by municipalities as part of WMO. No data is available in this context either, but regarding statements\textsuperscript{81} that persons will rather stay in their current house than moving to an accessible one, estimations are that somewhere between 60 and 100 % of all houses that are easily modifiable are transformed to accessible houses. Based on the same statements, an estimated 0 to 40 % of the houses that are difficultly modifiable are transformed to accessible houses.

As stated in chapter 3, the average household size and the population size determines the demand for housing. Although the data show a possible decrease in household size, taking into account a plausible uncertainty range, the annual change in household size has been set at −0.01 and 0.01.

Fig. 5.10: Model structure for housing supply and demand (a large view can be found in appendix X)

\textbf{5.6 Subsystem V: social security}

The social security subsystem is made up of three funds of certain aspects of the social security. As discussed previously, several sources (CPB, CBS, SCP) determine the parts of the social security system suffering from the consequences of aging as 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.

\textit{Retirement benefit}

\textsuperscript{81} Statements made by W Staalduinen (TNO) in interview on June 17, 2011 and H Luiten in interview on March 11, 2011
As stated in chapter 3, the Dutch pension system is built up on 3 pillars: AOW, additional pension and individual pension savings, that are pension savings done by workers individually.

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 labour participation increases or decreases in a certain way that a wide range of possibilities are explored.

*Cure fund*

Every person contributes to this fund by a percentage of their income. This is modelled similar to the AOW fund: changes in the amount of persons of 15 and older change the total contribution to ZWV, 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.

*Care (AWBZ) fund*

Care is, similar to ZWV, also funded by an insurance system (see Chapter 3). 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

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82 Indicated by S d’Hondt in interview on March 30, 2011 and C Wevers in interview on March 9, 2011
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\(^83\), 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\(^84\), the value is taken as a random trend (Pruyt et al., 2011) 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. The AOW benefit increase per person is made dependent on the wage level increase, but the rate is made uncertain as AOW benefit increases are not necessary equal to wage level increases. Therefore the AOW benefit increase is made uncertain as a fraction of wage increase with a rate between 0 and 1 times the wage increase.

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\(^{83}\) Indicated by C Wevers in interview on March 9, 2011  
\(^{84}\) Indicated by R Vergeer in interview on June 7, 2011

Fig. 5.11: Model structure for social security (a large view can be found in appendix X)
5.7 Uncertainties

The uncertainties earlier described in this chapter have been identified in this part of the report. Basically, a list is made of all gathered uncertainties together with the range (upper and lower bound) in which they might differ.

Different types of uncertainties can be identified: i.) parametrical uncertainties (i.e. uncertain values of a parameter), ii.) functional uncertainties (i.e. different plausible functions, iii.) uncertainties in lookups (i.e. different plausible lookups) and iv.) structural uncertainties.

The table in appendix VIII provides an overview in the basic uncertainties and their values. Parametrically uncertainties are uncertainties that are randomly chosen between an upper and lower bound. Categorical uncertainties can only reach certain values that are determined in advance, 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. The values are chosen as specified in the previous sections.

5.8 Model validation and parameter determination: workshops

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. Organisation of these workshops is described below.

5.8.1 Workshop I: Validation

Workshop I is primarily 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.

Ultimately, the comments made during workshop I were used to define a number of different uncertainties that were found to have very unpredictable behaviour over time or uncertain to determine in the initial state of the system (and model) but were found to have a large influence on model behaviour. The uncertainties defined based on workshop I are:

1. Average productivity per age
2. Relative average labour productivity
3. Relative average labour productivity in care
4. Relative average labour productivity in cure
5. Fraction smokers in population
6. Fraction meeting standards of physical activity in population

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85 See appendix III for a list of attendees in workshop I
7. Fraction heavy drinkers in population
8. Fraction obese in population
9. Female life expectancy
10. Male life expectancy
11. Fertility rate
12. Average labour participation male
13. Average worked hours per week male
14. Average labour participation female
15. Average worked hours per week female

All variables except for number 1 are time dependent and can thus be seen as trend lines. These uncertainties are implemented in the model according to fig. 5.12. A larger view can be found in appendix IX.

The uncertainties added to the model are treated as exogenous inputs. This goes against the philosophy of Forrester and his foundation of system dynamic as treating a problem as a closed system where decisions are part of the system and influenced by the side effects caused by the decision (see appendix VI for a description of the system dynamics method). So choosing to do so is a deliberate choice, made to implement a large number of different views into the model in an easy and unbiased way. The method will be explained in more detail in the next section (workshop II).
5.8.2 Workshop II: Exploratory Group model Specification and Simulation

The second workshop is organized in order to bring together different experts from different fields of research and with general knowledge on the issues involved with aging. The purpose is to generate trends in uncertainties that have a potentially large influence on the aging system and to implement these trends simultaneously into the model and show results during the workshop.

In order to do so, and in order to provide the attendees of workshop II the necessary freedom in describing their trends, the attendees were given a number of graphs on which they were asked to draw (trend) graphs. Additionally, to make sure some difference would be available in the drawn graphs, the attendees were asked to draw an upper and lower bound of the trends they thought would be possible. In case no difference can be found in the contribution of the middle line, the upper and lower bounds can be used to make sure a certain uncertainty range would be applied 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 into the model lookups.

Fig. 5.13: structure for implementing different graphs in the model: lookups (yellow) for inserting the graphs, variable for input in particular subsystems (blue) and switch driven by the ESDMA-software (red)

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86 A list of attendees can be found in appendix IV
Fig. 5.13 shows the structure used in the model to implement all different graphs. The different lookups are shown in yellow and are input for the variable (shown in blue) used for driving the model parameters in the designated subsystem. The red variables is used as a switch that is driven by the uncertainty analysis to choose between the different options. The number of options is dependent on the graphs filled in by the workshop participants. The prepared software is then randomly picking one lookup per variable per simulation and by performing a large amount of simulations, all provided plausible uncertainties are explored. The values for the different graphs implemented in the model can be found in appendix XI.
6. Results and model output

In order to generate output from the model, the model should be made ready for the uncertainty exploration. To do so, the selected uncertainties are implemented in a software shell that can be modified in order to generate the desired behaviour.

The software that is used for this research is constructed as software shell that allows to control programs such as Vensim. Vensim is a conventional computer program that is commonly used for constructing and simulating system dynamics models. The software shell is specifically constructed for use in an EMA-environment. As stated in chapter 4, EMA is an approach for performing a large uncertainty exploration based on computer models (not solely system dynamics), and the software is used for two functions. First, the shell generates uncertainty values based on the specified uncertainty ranges (taking into account values that should be integer) according to the specified sampling method, the number of uncertainties and the number of runs. Second, the shell is used for interpreting and visualizing the acquired data produced by the different simulation runs. This can be done by creating graphs, but also by researching end states of simulation or by performing regression analyses. In a later stage, policy performances can be researched and compared to each other or the base ensemble.

The shell used in this research is still under construction, but very usable in the context of this research. It is constructed by researchers of the policy analysis section from Delft University and is already very useful in performing uncertainty explorations, but is even more promising for future use in various fields of research.

6.1 Types of output

This research uses three different kinds of output visualization. Mainly for reasons of calculation capacity, the outputs of interest for drawing conclusion to this research should be specified specifically. In general, the higher the amount of outputs of interest, the more time the calculations take and the larger the size of the file in which all data is saved. This is because all data generated by the analysis is saved per outcome per time step and when the number of simulated runs is high (multiple thousands of simulation runs is not an exception) the amount of data that should be saved can become enormous. Therefore, one should be aware of choosing a small number of outputs that provide a clear overview of the system results.

In this research, three different kinds of visualization techniques are used: i.) graphs describing all performed simulation runs per output variable, ii.) envelopes, i.e. uncertainty ranges with a distribution showing the location of all end states of the simulation runs per output variable and iii.) correlations between end states of two particular output variables. These three different techniques are described in the next sections. Interpretation of the data in the figures used in sections 6.1.1, 6.1.2 and 6.1.3 and additional data will be provided in section 6.2.

6.1.1. Graphs

As stated in the previous section, graphs as an EMA visualization technique is a representation of all graphs of a particular output combined in an (x,y)-space. Commonly, the x-axis shows simulation
time (for continuous models like system dynamics simulations) and the y-axis the value of the output variable. Fig. 6.1 shows an example of this technique.

![Graph showing the evolution of total population](image1)

This graph shows the evolution of the total population in a large number of simulation runs. Each coloured line is one simulation run. This method is applicable in determination of the maximum and minimum levels of the uncertainty ranges. But, in the event of specifying the value of these different runs, it is not very useful, especially for a large number of runs or a large number of different graphs in a small range of uncertainty: the density of the different graphs becomes too high and determining single model runs or even location of end states of the graphs becomes almost impossible. Therefore, this method is not very useful for drawing conclusions from a large number of simulation runs.

### 6.1.2. Envelopes

The second visualization technique used in this research is an *envelope* with KDE on the endstate. This technique uses the data similarly to the *graphs* technique but then calculates the value of the end states of all graphs (i.e. the last value calculated in each simulation run) which are visualized in a histogram or distribution. Fig. 6.2 shows an example of an *envelope*.

![Graph showing the end states of total population](image2)

Fig. 6.2 shows the graph similar to the data of fig. 6.1 but then used in envelopes. Because the data that is located between the minimum and maximum value is not visible or easy to interpret, these graphs have been left out of the visualization. Additionally, this helps in speeding up the calculation processes (i.e. not every value of every simulation run needs to be visualized but only those of the minimum, maximum and the final values). The main purpose of using envelopes is for providing additional explanation to the graphs function. One can see the end states of all simulations and interpret where the majority of simulations end. This is done by using a ‘Kernel Density Estimation’ (KDE), which is a method to calculate the density of outcomes at a certain point and provides a distribution based on this. This method might be important in judging policies.
6.1.3. Multiplot

A third visualization technique used in this research is a *multiplot*. With this technique, different correlations between output variables can be visualized in a graph. Similar to the envelopes technique, correlations uses simulation run end states to calculate correlations. This is, again, done for optimizing visualization of the output, because in the event of multiple thousands of simulations being able to interpret results that are visualized over three dimensions (i.e. the two output variables and time) is almost impossible. Therefore, the technique shown in fig. 6.3 is used.

In this correlations-diagram, each ‘dot’ represents one simulation run. The end states of two output variables are set out in a graph, the y-axis representing the value that is horizontally determined (i.e. the value to the left or right of the particular graph), and the x-axis representing the value that is vertically determined (i.e. the value above or below the particular graph).

The purpose of finding correlations between outputs of interest is mainly to determine which values are correlated and this might help in choosing output indicators and policy design and testing.

6.1.4. Policies

A fourth visualization technique for EMA is to perform an uncertainty analysis using equally sampled values for the uncertainties in different models. This can be done to test the performance of different policies compared to the base case, but also to test different structures or assumptions to the same uncertainty values. This technique can also be performed by just simulating the models separately and comparing the results, but the advantage of using the policy-technique is that the sampling plan is equal for each model/policy. By doing this, the models are tested in the same uncertainties and can thus easily be compared. In the event of just performing three uncertainty analyses, the whole uncertainty range should be explored in order to draw plausible conclusions to comparing the results and to do so, a relatively large number of runs should be performed compared to the technique of using the same values.
The visualization is performed together with one of the previous techniques and the outcomes per model are visualized by using different colours. In general, the base case is given in blue, policy 1 in green and, if applicable, policy 2 in red.

6.2 Output variables used as performance indicators

Performing EMA to the model constructed for this research is done through the use of a small number of different simulation assumptions. First, these simulations include a base ensemble of the model, using all uncertainties previously specified and running it for a particular number of runs. This base ensemble does not include migration scenarios. Second, the base ensemble is used with implementation of the migration scenarios with different models simulated according to the policies-technique, so with the same uncertainty values for each model and colours specifying the model used. The third analysis concerns a policy option currently implemented by the government, also using the policies-technique. The output of each simulation set is discussed in the next sections.

Additionally, as indicated previously, before starting the simulation one has to choose a small number of output indicators that provide a certain overview of the total model performance. In the context of this research, the used output variables are:

**Elderly dependency ratio**

Elderly dependency ratio is defined as the retired population divided by the of potential workforce. It is seen is a measurement of demographic pressure in the economy as it compares the major contributors to the main benefitters.

**Total population**

Total population is a measurement of the population density. The Netherlands are already a relatively densely populated country and a large increase of the population will surely cause pressure on some parts of the system, e.g. housing.

**Health care costs as fraction of GDP**

Health care costs in general are not a very good measurement for the affordability of health care. Therefore, the health care costs as part of Gross Domestic Product is calculated. This provides a rate of health care costs as part of the total country’s income and when this rate is high, it is not very affordable. The model does not contain a limit to health care costs as fraction of GDP so in the event of simulation runs that show this value higher than 1, the system can be considered to collapse. The value for 2009 is 10.1%\(^{87}\). Setting boundaries to a certain level of health care costs compared to GDP is not feasible, as it is generally a matter of choice: when persons choose to have access to the latest medical technologies or suitable care, they basically have to pay for it\(^{88}\).

**Gross Domestic Product**

\(^{87}\) Based on data by CBS 2009 [12] and [34]

\(^{88}\) Indicated by J Polder in interview on May 31, 2011
GDP is a measure for the output of the economy. Historically spoken, economies tend to grow gradually over time, but the question is whether this is still feasible in case the employment or productivity stagnates. Therefore this output is considered in the analysis.

Fraction of FTE demand in health care fulfilled

One of the most severe problems expected by experts is a shortage of personnel in health care. Therefore, the fraction of fulfilment of workers in health care is measured. Cases that show a value of 1 or higher do not provide any problems, but in cases the value is below 1, problems are ahead and not everyone can receive the necessary health care.

The governmental contribution to AOW as fraction of GDP

One of the aspects of aging causing a lot of discussion is the affordability of AOW. As already stated in chapter 3, the government provides the part of the payments that exceeds the employees’ contribution. It is given, again, as fraction of GDP to be able to put the value in the right context. The governmental contribution to AOW was in 2009 almost € 10 billion, which was 1.7 % of GDP

Fraction of housing demand fulfilled

The housing demand that is fulfilled can be seen as a rate for pressure on the housing market. An additional conclusion that can be drawn from this figure is whether it is necessary to build a large number of houses of which you might forecast that these houses are not needed in the future.

6.3 Model results

As stated in the previous section, the model is explored in three different analyses. These analyses are explained in this section and the output is reviewed in the context of the analysis. First, the base ensemble is generated, second the base ensemble is generated using different scenarios for migration and third, the ensemble is generated using the policy option of increasing the retirement age.

6.3.1. Results from the base ensemble

For this analysis, the model is explored using 10000 simulation runs. This number is relatively small compared to the number of uncertainties, but the uncertainties used are predominantly used in small ranges and therefore simulating more than 10000 runs is not very applicable as it will only increase runtime but not provide that many new insights. In this ensemble, the model does not include scenarios on migration, it only uses the prevailing current migration determined in chapter 3 and 5.

Total population and elderly dependency ratio

One of the important determinants of a population growth model is the population size: the population size together with age distribution provide an overview of the difficulties that might arise as a consequence of demographic aging.

To be able to provide realistic and approachable determinants of the model output, a number of analyses are performed to define the plausible behaviours and consequences of these behaviours.

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89 Based on CBS data 2009 [34] & [35]
The overall output of 10000 runs exploring all defined uncertainties can be found in fig. 6.4 and 6.5. Analysing these figures, one may notice a wide range of plausible outcomes between 13.5 and 23.5 million inhabitants.

When dividing these runs into clusters showing similar behaviour, one can find 18 clusters (see appendix XII). From these clusters, one can conclude all simulations show similar behaviour in terms of an increase in the first ten years. After this time span, the behaviour of the different runs starts to deviate, ranging from a rather linear increase up to 23.5 million to a decline after 10 years up to 13.5 million. A large number of 3317 runs show behaviour predicted by the CBS\textsuperscript{90}: first an increase followed by a decline. For the latter, the tipping point from increase to decrease differs in time per simulation between approximately 2035 and 2050, where CBS predicts the tipping point to be reached in 2040.

Regarding the end states of the population size in the different runs, the mode (i.e. the value at which the majority of runs end) is approximately 17.2 million. The median (i.e. the middle value of all outcomes) is approximately 17.8 million.

*Elderly dependency ratio* can be considered a determinant for the age distribution of a population. It is calculated as the number of retired persons divided by the potential working population\textsuperscript{91}. CBS estimates the elderly dependency ratio to be 49 % in 2040. Although current state of the art of EMA software does not provide tools to elaborate on intermediate values, dividing values based on a minimum or maximum value is possible. When dividing the different simulation steps between maximum 0.49 (i.e. 49 %) the graphs in fig. 6.6 and 6.7 are generated.

\textsuperscript{90} Based on graph 12, pp. 12 (CBS, 2010)
\textsuperscript{91} In this research all persons between age 15 and the retirement age (i.e. 65)
Figures 6.6 and 6.7 show the graphs of the elderly dependency ratio with a maximum equal to or below 0.49 (fig. 6.6) and with a maximum above 0.49 (fig. 6.7). 4968 out of 10000 simulations show a maximum that is above 0.49 and thus 5032 out of 10000 simulations show behaviour that is equal to or below 0.49.

When comparing elderly dependency ratio to total population, one can find a correlation between them (see fig. 6.8). Although the variance is relatively large, the correlations are structured in a linear way, showing a correlation between a large population causing and a high elderly dependency ratio. But, because of the large variance, this correlation can be considered relatively weak, concluding that a large population is not a strong determinant for a high elderly dependency ratio or vice versa.

The figure also shows a number of linearly distributed values with space in between. This indicates a driver which is simulated as a discrete value. In this case, this is assumed to be caused by the generated input for life expectancies. These values are defined discrete and have a large influence on both population size and elderly dependency ratio.

Health care costs

One of the main issues concerned with aging are health care increases (see chapter 2). As previously stated, to put this indicator in the right context, the health care costs are considered as part of GDP. This is done to see the expenditures to health care as part of aggregated income. In general, one can state that health care expenditures can amount to a maximum of 100 % of GDP, because in this ensemble all income will be spend on health care. But, a nation spending its total GDP on health care will not be sustainable, so the maximum needs to be set at a lower value. This value is disputed, as the expenditures to health care in a population is a matter of choice: a population might value their

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92 Indicated by J. Polder (RIVM) in interview on May 31, 2011
health and the access to health care high and are consequently willing to spend a large part of their income to health care. The opposite is also possible: a population not willing to spend a large part of their income to health care and consequently have less access to health care.

For this research to remain objective, the model does not contain a constraint for health care expenditures and that is why the value in the model output may exceed 100 % of GDP. A particular constraint to the expenditures will mean that runs reaching a value higher than the constraint can be considered a system collapse.

Regarding this research and result discussion, the constraint to health care expenditures is set at 40 % (or 0.4) of GDP. The output graphs for health care cost as fraction of GDP can be found in fig. 6.9 and 6.10.

![Graphs showing health care costs as fraction of GDP](image)

Fig. 6.9 and 6.10: base ensemble, 10000 simulations for ‘health care costs as fraction of GDP’

When dividing all output between runs that reach a maximum below and equal to or above 0.4, the simulations show a number of 8596 runs that do not reach a maximum above this constraint and consequently 1404 runs that do reach a value equal to or above 0.4. The output graphs of this division can be found in fig. 6.11 and 6.12. Comparison of these graphs can be done by reviewing the density of the KDE-function: for a maximum below 0.4 the maximum KDE is approximately 9, where

![Graphs showing health care costs as fraction of GDP with max below and equal to (left) and above (right)](image)

Fig. 6.11 and 6.12: base ensemble, 10000 simulations for ‘health care costs as fraction of GDP’ with a maximum below 0.4 (left) and a maximum equal to or above 0.4 (right). Note the different scales for the KDE graph.
the maximum KDE is 1.2 for the maximum above 0.4. This means that the number of runs ending at the particular maximum KDE is much larger for the graphs below 0.4.

Using these results, one can subdivide the graphs further. When looking into the results of the runs with a maximum below 0.4, a new division can be made between the runs with a maximum equal to or above 0.20 (or 20 % of GDP) and with a maximum below this value. The simulation shows a result of 7374 out of 8596 runs having a maximum below 0.2 and 1222 out of 8596 having a maximum above 0.2.

Labour demand in health care

Another aspect of health care that is expected to cause large problems is the supply of labour. As previously stated in chapter 3, due to an increasing demand of health care, the labour demand is expected to increase and because of the decreasing potential working population, this might lead to a mismatch between supply and demand. The model simulates this as a fraction of fulfilment of labour demand. This is a ratio of the number of persons (in FTE) working or willing to work in health care divided by the total number of demanded FTE in health care. The optimal outcome would be a value equal to or higher than 1 and consequently, runs having a minimum that is below 1 are expected to cause problems.

The general output of fulfilment of FTE demand in health care is shown in fig. 6.13 and 6.14.

From these results, one can notice a wide range between plausible outcome values. In order to value these outcomes, a subdivision can be made between runs that will not provide any problems, i.e. runs with a minimum equal to or above 1, and runs that might provide problems, i.e. with a minimum below 1. The results are show in fig. 6.15 and 6.16. The simulation shows a number of 6603 out of 10000 runs having a minimum below 1 and consequently, 3397 out of 10000 that have a minimum value equal to or above 1. Additionally, looking into the runs with a minimum below 1, the simulation shows a number of 3949 out of 6603 runs with a minimum below 0.5.
Comparing the fulfilment of FTE demand in health care to aggregate scarcity of labour in the total labour market\footnote{Here defined as the number of working persons (in FTE) divided by the labour demand. When this value is 1, enough labour is available for fulfilling the demand. Labour scarcity is present in cases where this value is below 1.}, one can find a correlation between them. Fig. 6.17 shows the correlations between these two outputs. The runs used here are the runs with a minimum fulfilment of FTE demand health care below 1. From this figure one can conclude the fulfilment of FTE demand in health care to be low in the event of labour scarcity. But there are also a large number of runs that show unfulfilled labour in health care in ensembles without labour scarcity or very low labour scarcity. These low values cannot be explained by aggregate labour scarcity. When looking at the model structure, these values can only be explained by a low attractiveness of working in health care as this is the only other value defining the number of persons working in health care (see chapter 5).
Aggregate labour demand and supply

The previous section discussed the fulfilment of labour demand in health care in relation to the fulfilment of aggregate labour demand (in this research defined as labour scarcity). When looking into the model results of labour scarcity we find the graphs of fig. 6.18 and 6.19.

The model output for labour scarcity will remain 1 in ensembles with sufficient supply of labour. Therefore, to value the model output, the runs are divided in groups with a minimum labour scarcity of 0.95. This value is chosen to rule out the effect of changes in labour supply due to delays in labour market outflow (e.g. retiring, mortality or migration) and hiring of workers. The simulation shows a number of 6435 out of 10000 runs with a labour scarcity minimum below 0.95. These values might cause problems in the labour market due to scarcity in the supply of labour which might hamper the economic growth. Fig. 6.20 shows the end state correlations of GDP and labour scarcity.

The figure shows low values for GDP for small values of labour scarcity (i.e. low labour supply compared to labour demand) and high values for GDP for high values of labour scarcity does not explain all values in the correlations graph, as the values are not distributed linearly. One other factor which is expected to influence these values is the potential economic growth. This can be concluded from the model structure, as the potential economic growth defines the labour demand. Concluding from this, in the event of sufficient labour supply, the potential economic growth defines the annual GDP. In the event of insufficient labour supply, the supply of labour is the constraint for economic growth.
Additionally, an important potential source of labour in the future would be the workers between age 55 and 64. As of 2009, the labour participation rates of these groups are 69% for men and 45% for women. The labour participation rates for these groups in the simulation are given in fig. 6.21 and 6.22.

One can notice these graphs have a constraint at approximately 0.82 for men and 0.8 for women. This constraint is mainly due to the assumption that cohorts of age 55 and older do not have a higher labour participation rate than the previous cohort. Therefore, a constraint exists at a certain point.

The results show an increasing labour participation for males for the majority of runs, with 8699 out of 10000 runs ending at a participation above 0.75. Female labour participation lags behind in this respect, with 4378 out of 10000 runs ending below 0.7 and 5797 out of 10000 runs ending below 0.75.

**Housing supply and demand**

Sufficient and suitable housing will become more and more important in the upcoming 50 years. Due to an aging population and a decreasing average household size, the demand for houses in general and in particular accessible houses is expected to increase. Since housing is considered one of the primary needs, sustainable supply of houses is vital. Fig. 6.23 and 6.24 show the simulation results for fraction aggregate housing demand fulfilled.

The results show a range of outcomes between approximately 0.7 and 1.2. The current value at start time is approximately 0.92.
When evaluating the values of the different runs, a large number of runs show values below a sustainable rate. The optimal outcome would be 1, because in that ensemble demand and supply of houses is equal. But as can be concluded from the runs and the value at the start time of the simulation, a sustainable value for housing demand fulfilment might be set at a lower rate. In order to divide between sustainable runs and unsustainable ones, the constraint is set at 0.85. Using this minimum value for dividing the runs, the simulation shows a number of 5072 out of 10000 runs that have a minimum value below 0.85 (see fig. 6.25 and 6.26). These runs are considered unsustainable since in these ensembles at a certain point, more than 15 % of all potential households do not have suitable houses.

Looking into these results, a number of 72 runs out of 10000 runs have a minimum value below 0.75, which is a relatively small number of runs. On the contrary, the simulation shows a number of 9945 runs that at a certain point in time, have a minimum value below 0.9 (i.e. 10 % of all households does not have appropriate housing). This number is relatively large.
One might expect the fulfilment of housing demand to be influenced by the population size. Looking into the correlation between housing demand with the population size and distribution (elderly dependency ratio), the correlations graph of fig. 6.27 is generated.

From this correlations graph, one can conclude the fulfilment of housing demand to have a relatively strong relation to elderly dependency ratio and total population. If either one the latter two values is high, the fulfilment of housing demand is low. This can be explained by the statement that older persons more often live in small (1 or 2 person) households and a larger population means more households in general, both leading to a higher demand for housing.

**Retirement benefit**

Sustainability in the costs for retirement benefit is another important factor concerned with aging. Due to an increasing ratio of older persons in the population, the costs for retirement benefit might increase over the next decades. Important factors in this respect are the number of retirees and the size of the potential working population, defined in the elderly dependency ratio, because every person having reached the retirement age is entitled to this benefit, which is paid by a fraction of the income of the potential working population. Because the government contributes the expenses that cannot be paid by the aggregate payments by the potential working population, this governmental contribution to AOW is taken as a parameter for the affordability of AOW payments. The fraction of income going to retirement benefit funds per person in the potential working population is constant due to governmental agreements so this aspect is not evaluated here. The output values of the runs in the simulation are shown in fig. 6.28 and 6.29. In order to put the output in the right context for comparing the results, the governmental contribution to AOW is taken as a fraction of GDP.
The values range from approximately 0 to 0.71. As previously stated, the value at the starting time for this output is 1.7%. In order to evaluate the simulation output, the runs are divided between runs which have a minimum value below 10% and runs with a minimum value equal to or above 10%. The 10% value is taken as a measure of unsustainable values for the governmental contribution to AOW. Although this constraint is not very strict, a country paying 10% of its GDP to AOW is expected to encounter problems in the affordability of government pensions. Fig. 6.30 and 6.31 show the simulation output for runs with a maximum value equal to or above 10% and consists of 1184 out of 10000 runs.
6.3.2. Conclusions from the base ensemble

From the results generated by the base ensemble, a number of conclusions can be drawn. These conclusions focus on potential problem areas and on areas which are not expected to cause potential problems.

First, when looking into the results for health care, the majority of runs show no problematic values in terms of costs and affordability. But, as setting a maximum on the affordability of health care costs is difficult and a matter of valuing by the population and ones paying the bill, drawing strong conclusions based on this output is rather difficult. The result shows a number of 14.04 % of the runs reaching a value that is above 40 % of GDP, which might be considered a value beyond sustainable country finances. But the probability of one of these runs taking place is relatively low.

Concerning the fulfilment of labour demand in health care, the model output shows a large number of plausible outcomes that reach a value that is below the optimum: 66.03 % of all runs reaches a value below fulfilment of labour demand and 39.49 % reach a value below 50 % fulfilment of labour demand. The main reasons for these low values can be found in aggregate labour scarcity and attractiveness of working in health care.

The aggregate fulfilment of labour demand can be considered problematic, as 64.35 % of all runs show a value which is not sustainable and where the supply of labour cannot fulfil the demand. This leads to stagnating economic growth. Labour participation of older persons in the labour market (from 55 to 64) is increasing significantly in the majority of runs.

Another factor which is expected to be negatively influenced by the aging population problems is the aggregate fulfilment of housing supply. 50.72 % of the runs is considered problematic, where only 0.0055% of the runs show an outcome which is comparable to or higher than the current value.

An aspect which was thought to be negatively influenced by the aging and aging process in advance of the research, is the governmental contribution to retirement benefit (AOW). But looking at the simulation results, one can conclude it does not cause large sized problems. When looking at the ensembles which are considered unsustainable, only 11.84 % of the runs reach an unsustainable value, which is rather low compared to the large discussion that exists in this respect.

An addition that has to be made in this respect is the existence of growing and shrinking regions in The Netherlands. For example, regions like the ‘Randstad’ attract a lot of workers from elsewhere in the country, leading to a number of regions where the population size decreases (e.g. in the north and south of The Netherlands) and the effects of aging might by worse compared to the Randstad. The model only considers the values on an aggregate, national, level and does not include the differences between the regions of the Netherlands.
6.3.3. Results from the base ensemble using migration scenarios

The migration scenarios used in this simulation are specified in chapter 5. These scenarios involve immigration of workers in the event of aggregate labour shortages and emigration of workers in the event of foreign labour markets being more attractive than the Dutch labour market. For the latter, the amount of persons emigrating is made uncertain in the range between 0.5 and 3% annually. Regarding the outcomes, the different models are specified in the colours blue (base ensemble), red (immigration) and green (emigration).

Total population and GDP

The results of the uncertainty analysis using the emigration and immigration for population size are shown in fig. 6.32. 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 fig. 6.33. A larger view of the KDE end state distribution is shown in fig. 6.34. From these outputs, one can notice a small difference between the base ensemble and the immigration scenario, with the number of runs ending at a higher value (from approximately 1.5 billion) being slightly larger for the immigration scenario and the number of runs ending at a lower value (up to 1.5 billion). The end state values for the emigration scenario are in general small compared to the values for base ensemble and immigration policy. This can be explained by looking at the model structure and the previous section discussing the aggregate labour demand: the supply of labour is a constraint for economic growth. In ensembles where this constraint is taken out (by emigration of workers), the economic growth will be equal to the exogenous economic growth. When the economic growth is high for several years, labour immigration will also be high, leading again to population growth in the short and long term due to increased number of births. The latter does not happen in many ensembles and therefore, the exogenous economic growth has a large influence on the effective economic growth and GDP.
In ensembles where the supply of labour is decreased, labour will become the main constraint for economic growth. Therefore, the end state values for the emigration scenario are lower than the other ensembles.

![Fig. 6.34: migration ensemble, KDE of end states of ‘annual GDP’ for different scenarios: base case (blue), immigration (red) and emigration (green)](image)

**Elderly dependency ratio**

Another important problem which might be solved by labour migration is the age distribution of the population. For valuing the effect of the different scenarios, the elderly dependency ratio is used. Fig. 6.35 shows the results for this output for the different scenarios. One can conclude from this result that the ranges of plausible outcomes of the elderly dependency ratio in the different scenarios is wider than the base ensemble, with a highest KDE at a higher point compared to the base ensemble. This is easily explained for the emigration scenario, since in this scenario younger workers leave and thus lead to a smaller potential working population compared to the size of the elderly population. For the immigration scenario, this effect is not that easily explained. One plausible explanation would be the effect of a large number of immigrants retiring at a certain point, leading to an increased elderly dependency ratio.

**Labour demand in health care**

One of the important findings from the evaluation of the base ensemble simulation was an expected mismatch between labour supply and demand in health care. interesting would be to know whether migration can solve this mismatch or not.

The results of the simulation can be found in fig.
6.36. Striking in the simulation results is the low amount of difference between the scenarios. A larger view of the KDE output graph can be found in fig. 6.37. For this visualization, the outliers are left out of the analysis in order to have a better indication of the results of the majority of the runs.

![Fig. 6.37: migration ensemble, KDE graph for ‘fulfilment of fte demand in health care’](image)

Although some difference is visible, it is not as large as one would expect when discussing the migration scenarios. As came forward from the evaluation of the base ensemble, the willingness to work in health care has a strong influence on the number of persons working in health care. This is evident, because if persons are not willing to work in health care, they will probably not choose it as a job. But in ensemble of labour immigration, this factor should not be of influence, as migrants do not necessary have the same preferences as Dutch labourers. Therefore, further research will be necessary to look into this effect.

6.3.4. Conclusions from the migration ensemble

The migration scenarios are in general not a matter of choice and good or bad results. The reason for implementing and researching the different scenarios using the model constructed during this research is done in order to find effects of the different possibilities in labour emigration and immigration.

As said, migration is too a large extent not a matter of choice and should not be reviewed like that. Governments can exert some influence on decisions of persons concerning migration, but in general, the attractiveness of The Netherlands compared to other countries is expected to be an important aspect in the migration issue. If The Netherlands is a relative attractive country for (skilled) labour, the likeliness of being able to attract necessary labour from elsewhere and keeping (skilled) labour inside the country will increase. But the question whether The Netherlands is able to become or stay attractive 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 set accept large workforce immigration. The model used in this research does not have an addition that defines the likeliness of each of the scenarios to happen. Therefore, further research is recommended to include a model structure which defines the demographic flows between nations and global regions, e.g. based on the research by Pruyt et al. (2011).

When looking at the results of the different scenarios, an important conclusion that can be drawn from the emigration scenario is that it will cause a number of problems regarding economic growth (due to labour scarcity), elderly dependency ratio and population size.
An important conclusion that can be drawn from the immigration scenario is that it might be a solution to certain problems regarding labour scarcity, but other issues might be caused, for example a considerable population growth.

Another conclusion that can be drawn from the migration scenario concerns the influence of willingness to work in certain types of jobs (e.g. health care). The model attaches similar preferences to migrants as to Dutch workers. But this is not necessarily true, and therefore the results are preliminary and need further focus to be able to draw conclusions based on the labour supply in health care.

### 6.3.5. Results from the model with retirement age policy

As previously stated, the current administration has the intention to raise the retirement age to 66 as of 2020\textsuperscript{94}. By doing this, the administration is trying to reduce the costs for AOW pensions and this is expected to save annually 0.4 % of GDP. Critics of this bill are mainly focusing on the expectation 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 are made: first, a model in which the retirement age is increased to 66 in 2020 and after that stays at that age. Second, a model in which the retirement age is gradually increased to 66 in 2020 and to 67 in 2025 (similar to the first proposition by the administration\textsuperscript{95}). The third model is similar to the second one, but with the addition that after 2025 the retirement increases with the life expectancy increase.

The retirement age policies are expected to have an effect on a number of factors: first, on the costs for AOW. Second, on the fte demand in health care and third, on the GDP due to a larger potential workforce and lower elderly dependency ratio. The results of the policies on these factors are discussed here.

#### Retirement benefit costs

Fig. 6.38 shows the simulation output for the governmental contribution to AOW. The output graph shows few differences between the different policies. To be able to draw conclusions from this figure, the results need to be split up and zoomed in in more detail. As previously stated, a division can be made between sustainable and non sustainable runs at 0.1 or 10 % of GDP.

The KDE-graphs of the results for this division are given in fig. 6.39 and 6.40. From the graphs of fig. 6.39, one can conclude policies 2 and 3 are to a large extent equal. The highest densities are located at the lowest point for policy 2 and 3 and the highest density for policy 1 is located at a

\textsuperscript{94} Proposition letter from Minister of Social Affairs, Mr. H.G.J. Kamp to the House of Representatives on May 2, 2011 concerning the retirement age increase [36]

\textsuperscript{95} From CPB, Analysis proposition retirement age increase pp. 3 [37]
slightly lower point than the base case situation. From graph 6.40, one can conclude the policies 2 and 3 having higher densities in the lower parts and lower densities in the higher parts compared to policy 1 and the basecase. Similar conclusions can be drawn when comparing policy 1 to the base case.

In general, when considering the graphs for the end state densities, one can conclude the output with policies having relatively small differences with the base case regarding costs for AOW.

**Gross domestic product and elderly dependency ratio**

One of the reasons for retirement age increases is, besides lowering the number of persons receiving retirement benefit, increasing the labour participation of older persons. If this is the case, this effect should be visible in the output for GDP. Additionally, the elderly dependency ratio should increase due to the retirement age increase. Both outputs are shown in fig. 6.41 and 6.42.
Although the graph for elderly dependency ratio shows considerable amount of difference between the different policies and the base case, this difference does not come forward in the GDP. This can be explained by a not increasing real labour participation\(^{96}\) of older persons. The reasons for this not increasing real labour participation can be found in either unemployment of older persons (i.e. employers not willing to hire older workers) or older persons not willing or needing to participate in the labour market. Further research might be necessary into these effects.

Labour in health care

As came forward from the previous analyses of the labour supply and demand in health care, the labour market in this research is expected to suffer from shortages in labour supply. Increasing the retirement age might help in the supply of labour in health care, but questions might rise whether this is suitable for a sufficient supply of employees. Looking at the simulation output using the retirement age policies (see fig. 6.43), one can conclude very few differences between the output of the different policies. In order to try and see whether differences are visible on a smaller scale, the

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\(^{96}\) ‘Real labour participation’ is defined here as the rate of persons being employed, rather than just be willing to work in ‘labour participation’
output runs are divided in runs having a minimum value below 1 (i.e. potential problematic runs) and runs with a minimum value equal to or above 1. This output is visualized in fig. 6.44.

Even after zooming in, no differences are visible in the KDE-graphs for the fulfilment of FTE demand in health care. This is an unexpected outcome, and can be explained by referring to the previous conclusions drawn from the analyses of labour in health care in this chapter and the analysis of GDP in the different retirement age policies. The GDP is not increasing considerably due to the increased retirement age which lead to the conclusion of low labour participation of older workers. This will also apply here and so do the plausible explanations given in the previous sections. But looking at the model structure, a third reason comes up, which is the attractiveness of working in health care. The latter is already discussed in the previous analyses for labour supply in health care.

6.3.6. Conclusions from the retirement age policies

Although differences are visible, particularly in the elderly dependency ratio, the model shows only small differences between the base case and the different policies for increasing the retirement age. The main explanation for these small differences that can be found from the model output is a low real labour participation rate of older persons. For the policies to be effective, first the labour participation of older persons should be researched and improved.

The reasons for the low real labour participation rates cannot be concluded from the particular model result generated in this research but in general, two plausible causes can be identified (based on the findings in chapter 3): first, employers are not willing to hire older employers for numerous reasons. Second, a certain part of older persons do not have an incentive to keep working until their retirement age.

Besides the few difference between the base case and the policies involved in this policy analysis, one could argue that the different policies do not go far enough in getting older persons to participate in the labour market. When calculating the number of persons adding to the labour market in the event of a retirement age increase of 1 year, one could mean an increase in potential workers of approximately 2 % in the most optimal situation (80 % labour participation, 200000 persons). In order to increase the number of employees by raising the retirement age, this retirement age should probably be raised even more than with 1 or 2 years.
6.4 Result comparison

When trying to validate the correctness of a research like this one, the most convenient way to do so is to compare the result to equal research by other researchers. When comparing the data to data calculated and provided by CBS, the two results can be plot in one graph. In fig. 6.22, both the result of this research (in the most narrow way, without immigration policies) for total population and the population forecasts by CBS are provided in a 95 % confidence interval (green, blue and yellow).

Although the two analyses show similar behaviour, the range of uncertainty for the CBS data is wider for lower time intervals (until 2030) and more narrow for higher time intervals (from 2030).

When comparing the calculated life expectancies to the values calculated by CBS (see fig. 6.23 and 6.24) the range of uncertainty of this research is wider than the CBS data, specifically for male life expectancy. This mainly due to the data provided during the workshop, as this input is to a large extent determining the value for this variable.

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97 Based on CBS data 2011-2060 [38]
Although comparing the results of different analyses is possible, doing so for this research is quite difficult as the majority of results are not very much comparable due to differences of scale. Forecasts by CBS are usually accompanied by an uncertainty range (see previous) but this not common. For example, the health care costs as part of the GDP as calculated by CPB (Fig. 6.25) is difficult to compare to the result generated during this research (see fig. 6.6).

The result generated by this research is predominantly focused on uncertainty ranges, where the research of CPB is usually not accompanied by uncertainty ranges or not in the sense this research does.

Taking this into account, one can wonder what the added value of this research is. One of the main purposes of this research is to promote thinking in uncertainty ranges instead of point prediction. The advantage of thinking in ‘plausible’ scenarios is the low probability of surprises that might arise in the future. As long as the uncertainty ranges are taken into account as wide as necessary, all plausible results are taken into account and thus, the future behaviour that might occur will, in a thorough analysis, always be part of the plausible results and therefore very useful for policy creation and analysis.

The other purpose of this research is to answer the research question and to determine a number of challenges that might be used in future research to provide a certain focus or direction. This will be discussed in conclusion and recommendation in the next chapter.
7. Conclusions and recommendations

7.1 Research findings

This research aims at answering the following research question:

“What are the main consequences involved with demographic aging in The Netherlands (in terms of labour supply, financing and societal costs in health care, social security, housing and the labour market) taking future uncertainties seriously into account, and what consequences should be focused on in order to achieve a sustainable welfare-state in The Netherlands in the coming 50 years?”

To structure the answering of this main question a number of sub questions have been determined. Answering each of the sub questions led to a logical structuring of the research in order to come to an answering of the main question.

Sub question 1: “How is the welfare state in The Netherlands organised and what trends currently occur that might be problematic in the future?”

This question has been answered by performing a research into the system elements. By determining these elements, a global overview of the system was generated that was later used for determining the modelling structure.

The main trends that came forward during the literature research and the interviews were:

- Decreased fertility
- Increased life expectancy for both male and female
- Stagnating positive net migration
- Increasing health care demand due to demographic aging but also due to increased medical possibilities
- Increasing health care costs due to increasing demand and wage increases
- Increased extramuralization in care.
- Increased labour demand in health care opposed by a declining working population
- Number of chronic diseases increases due to higher medical standards
- Increasing AOW expenses.
- Controlling AOW expenses by increasing retirement age.
- Possible decreasing benefits from pension funds and real estate.
- Increased demand for accessible houses for (partially) disabled persons.
- Increasing labour participation for persons older than age 55.

Sub question 2: “How can the system of the Dutch welfare state be modelled in order to come to a simulation of the system taking into account the main uncertainties that do exist in the system?”

The modelling of the system is performed by combining Exploratory Modelling and Analysis and System Dynamics modelling and simulation. This method is suitable for various problems with different levels of urgency and therefore also for a chronic crisis situation with slow dynamics like the problem of demographic aging. By determining a number of uncertain factors that exist in the system and by exploring these factors using an uncertainty analysis, the problem can be explored taking into account the main uncertainties in the system.
Sub question 3: “What interrelations exist between the different sectors of the welfare state?”

This question is answered by performing a system dynamics study to the system as described for sub question 1, taking into account the most important trends that exist in the system. The system is designed according to the sector diagram in fig. 7.1. The system consist of 5 subsystems, which are demographics, economy, housing, social security and health care.

The main relations are captured in the diagram and the model, and by zooming in on each subsystem, the System Dynamics model is constructed. Some of the relations and variables are uncertain and therefore these variables are specified as an uncertainty range. The model is validated during a validation workshop and based on this workshop, a number of variables has been specified having a large uncertainty and a large influence on the system.

The values for these specific uncertainties are generated during the Exploratory Group model Specification and Simulation-workshop. This workshop has provided to be a very useful addition to this research and research method. The interactive set up of this research provides a number of advantages over performing one-on-one interviews for determining values:

- By organising an interactive workshop, a large number of experts provide their opinion on the matter.
- Even experts that have no experience in system dynamics modelling can participate in a relatively easy way.
- Values are generated relatively easily and discussions between attendees add value to the input specified by experts during the workshop.
- Having a number of experts attending a workshop gathers their attention to the research.
- Providing research results during the workshop will provide useful inputs on the value of the generated results and might be an indication of the model being valid or not.
- Simulation ‘on the spot’ with the experts’ assumptions is a starting point for policy generating and making

One disadvantage of the workshop and the generated variables is the exogenous nature of these variables. In order to keep the input generation as simple as possible, the variables had been made exogenous. This provides some disadvantages for variables of which it is certain they are causally influenced by other variables in the system (e.g. labour productivity). This had been solved by emphasizing the necessity of taking into account future influences on the variable.

Sub question 4: “How can the output of the simulation be interpreted in order to come to a justification of the focus of future research?”

The difficult part of performing a large uncertainty analysis is visualizing the results in a way the value of the results is obvious. The main output variables in this research have been visualized in a number of different graphs: by showing all separate lines, by showing end state location density, by showing correlations between variables and by grouping runs of similar behaviour.
Important in valuing the results and to interpret the outcomes, different techniques are used to make divisions between runs. These techniques make changes based on the end state values, in order to zoom in on certain end state behaviour, but, as applied more general in this research, make divisions based on minimum and maximum values in runs. The latter provides the opportunity to define whether a run is reaching an unwanted value in the total runtime rather than based on the end state.

7.2 Answering the main research question

When looking at the model results specified in chapter 6, a number of conclusions can be drawn. These conclusions are based on the three different analyses made in chapter 6: base case results, results taking into account migration scenarios and results to different retirement age policies.

7.2.1. Conclusions resulting from the base ensemble

From the analysis of the base case simulation and the defined output, one can draw the following conclusions:

- Health care costs are not expected to form a major threat to the financial system. The likelihood of the system collapsing and the health care costs being unaffordable is relatively small, but nonetheless still possible. An addition to this is the fact that choice is a very important aspect here: whether persons are willing to pay a large part of their income to health care.

- The fulfilment of labour demand in health care has been found to be relatively low in a considerable amount of runs in the simulation. This will probably become a problem in the future, as the majority of persons working in healthcare are educated to perform this job and shortages are expected to cause problems in sufficient healthcare supply. Shortages in labour supply in care are expected not to have an equally large effect, as a large proportion of the tasks performed in this sector can be taken over by other persons (e.g. relatives or friends). More research is necessary into this effect.

- Supply of housing can be considered under a lot of pressure, since shortages are already present and in terms of likelihood, are expected to remain in the short and long run. Note that this is a statement done on the aggregate supply and demand of housing in The Netherlands. As mentioned before, a number of shrinking regions exist in The Netherlands, where housing supply exceeds housing demands. In order to look into these effects, further research is necessary.

- The aggregate fulfilment of labour in The Netherlands is, in terms of likelihood, expected to become problematic. The majority of runs show values of labour shortages below a sustainable level. Considering the labour participation, as it 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 should come from productivity increases or labour immigration.

- Affordability of retirement benefit is, in terms of probability, not very likely to cause major problems, as the majority of runs do not reach problematic values, although problems could still arise.
In general, all values that, even though only in a small number of cases, cause problems should be taken into account in future research as the likelihood of a system collapse might not be large, it is still possible.

7.2.2. Conclusions resulting from the base ensemble with migration scenarios

As previously stated, migration and the likeliness of each of the scenarios to happen is not a matter of choice. As came forward in the previous, The Netherlands is expected to need labour migrants to fill the gap between labour demand and supply and the question in this respect concern whether The Netherlands are willing and able to attract workers from abroad. This will only be the case when The Netherlands stay an attractive country for foreign workers. But what if the country loses its attractiveness and is not able to attract any foreign workers? Or worse: that Dutch workers leave for other countries because prospects are better there? In order to answer these questions, research has to be performed into the effects of future changes and demographic shifts on the labour market in The Netherlands.

In order to take a preliminary look into the consequences of these scenarios on the welfare state in The Netherlands, the model is explored using these scenarios. The main conclusions drawn from this analysis were:

- Emigration of workers will cause a number of problems regarding population size, affordability of retirement benefit and elderly dependency ratio.
- Immigration of workers will increase the likeliness of GDP growth, in terms of probability. This is caused by an increased number of workers and growing output.
- The effect of the migration is lacking in the fulfilment of labour demand in health care. This can be explained by the model attributing similar preferences to labour migrants as to Dutch workers, which might not be true in the real world since labour migrants are attracted to perform certain types of jobs. Therefore, additional research is necessary to look into the effects of migration on fulfilment of labour demand in health care.

7.2.3. Conclusions resulting from the retirement age policies

- By increasing the retirement age, the elderly dependency ratio decreases, but only to a small extent, as can be seen from the output for governmental contribution to AOW.
- Minor differences between outputs for different policies concerning GDP and fulfilment of labour demand in health care. This is contributed to a not increasing real labour participation rate of older persons, which can be either for voluntary (not willing to work) or involuntary I willing to work but not being hired). Further research should take place into this effect.
- Minor differences between the policies increasing the retirement age to 67 in 2025 and increasing the retirement age to 67 and after that increase the retirement age with increasing life expectancy.

As mentioned before, increasing the retirement age with 1 or 2 years will not exert a lot of effect on the labour market, as a 1 year retirement age increase will lead to a maximum of 2 % increase in total labour supply. Therefore, research is recommended into the results of retirement age increases of more than 2 years and into increasing the real participation rates, which might lead to considerable effects on the labour market.
7.2.4. Challenges

From the previous, a number of challenges can be defined into which further research is recommended to be focused:

5. *Increase labour participation of older workers*
   By increasing the labour participation of older workers, part of the shortages arising on the labour market can be solved. This can be done by increasing the retirement age, but not solely: labour participation is not only driven by the retirement age but also by willingness of persons to work and the willingness of hiring a person.

6. *Increase relative attractiveness of working in health care*
   Attractiveness of working in health care is found to be an important determination of the number of persons working in health care. As a large part of the GDP will be spend on health care in the future, a large part of the employees will need to work in health care.

7. *Focus on the Dutch labour market*
   To be competitive to other nations having to deal with an aging population, an important aspect will be to remain an attractive labour market. By focusing on the right skills, to focus on productivity and to focus on quality, output increases. Additionally, an attractive settling environment can attract both skilled workers and companies.

8. *Focus on the Dutch housing market*
   The vast majority of simulations show a shortage of aggregate housing supply. Household size decreases and the number of newly build houses is not increasing equally to the demand increase. Housing supply should follow and anticipate on possible demographic changes in order to provide sufficient housing for all households.
7.3 Recommendations

Based on the findings emerged during this research, a number of recommendations can be made for further research. These recommendation concern either the research and the model used, and the method used to perform this research, as this method and the available software is still under construction and modifications are welcome for improving the software.

7.3.1. Recommendations for the research

For this research, a number of boundaries were set and assumptions were made in order to speed up the research process. These boundaries and assumptions were not specifically vital for the outcomes of this research as the focus was on defining problem areas on a national level.

But, in order to make clear assumptions and to base policy analysis on a more regional scale, the model is too aggregated. The Netherlands is, although a relatively small country in size, encountering shrinking population in some areas and the problems involved with this are not taken into account in this research. Future research might focus on the consequences of aging on a more regional scale, because problems arising there might be different from the problems arising on a national level.

Additionally, in order to make the model more solid, more research could be performed on a number of factors that have been considered with a relatively large uncertainty space: e.g. economic growth is considered solely as an exogenous variable, where this is of course not the case in the real world. Therefore, a sub model might be added simulating the economy and economic growth on a world scale and the influence of The Netherlands on this sub model and the influence of the sub model on the Dutch economy. The same problem arises with pension savings: the model is using very aggregated assumptions on the pension savings of persons leading either to increasing or decreasing labour participation. Therefore, a more elaborated second and third pillar pension system would increase the usefulness of the model.

A last recommendation for further research would be to include the effects of education. In the constructed model, education is included as the rate of matching labour supply to labour demand. But education is possibly adding more to society than only this. One can think of the observation that persons with higher education live healthier and have a higher life expectancies. This has been implemented in the model as different trends for unhealthy behaviours and thus taken into account, but in order to create a more closed loop system, these factors might be included as variables with causal relations.

7.3.2. Recommendations to the method used

When considering the method and more specifically, the software used in this research, a small number of recommendation can be made:

First, the software is at this point not very user friendly. It takes some time to find out the workings of the simulation and how to visualize the generated results in a proper way, especially when the researcher does not have any programming experience. Creating a proper interface would really help in the accessibility of the software for persons having experience with System Dynamic modelling but without programming knowledge.

Second, the visualization of the results is rather difficult and consequently, interpreting these results. This is not the case for end state analysis as the available techniques are very much suitable for...
analyzing the end state locations and the relations between the different output variables. But, the software was during this research lacking proper techniques for analyzing the behaviour of the different simulation runs, especially when the number of uncertainty runs is high. The development team is currently developing a number of techniques that can be used for analyzing behaviour.

The application of Exploratory System Dynamics, Exploratory Modelling and Analysis and the group workshops are unique in its kind and the first time an implementation of these methods has taken place. Although the attendees of the Exploratory Group model Specification and Simulation-workshop were satisfied with the setup and results, a number of comments were made for improving the setup of the workshop to reach a better result:

- The possibility to introduce ‘shocks’ in the system, so certain effects that might evoke crises or upswings
- Filling in the trend lines on a long time scale was found rather difficult by a number of attendees and they suggested to make graphs larger or more easy to fill in.
- The attendees would have liked to make use of the occasion of having brought together a large number of experts to implement and test policies to the system in order to see how these policy alternatives would work out.

Additionally, during the workshop some computational problems were encountered. The model used in this research had a rather long runtime and therefore performing the analyses took a relatively long time. Having the ability to perform a large number of runs in a short time span would improve the usefulness of ESDMA in an interactive setting.
8. Literature

8.1 Books, publications and presentations


Graaf, A. de (2007). Fertility of women in the 20th century (Vruchtbaarheid van vrouwen in de twintigste eeuw)


8.2 Websites

Websites are given in order of appearance in the report.


Demographic aging and its implications for the Dutch welfare state – Thomas Logtens


[33] CBS Statistics Netherlands Database. Changes in housing Stock 1995-2010. Last retrieved July 29, 2011: http://statline.cbs.nl/StatWeb/publication/default.aspx?DM=SLNL&PA=37263&D1=0%2c10&D2=0&D3=4%2c9%2c14%2c19%2c24%2c29%2c34%2c39%2c44%2c49%2c54%2c59%2c64%2c69%2c74%2c79&HDR=G1&STB=T%2cG2&VW=T


## Appendix I: list of interviewees

<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
<th>Company</th>
<th>Expertise</th>
</tr>
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<tbody>
<tr>
<td>March 2, 2011</td>
<td>Chorus, A.</td>
<td>TNO</td>
<td>Health care</td>
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<tr>
<td>March 9, 2011</td>
<td>Wevers, C.</td>
<td>TNO</td>
<td>Labour productivity</td>
</tr>
<tr>
<td>March 9, 2011</td>
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<td>TNO</td>
<td>Health care</td>
</tr>
<tr>
<td>March 11, 2011</td>
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<td>TNO</td>
<td>Built Environment</td>
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<tr>
<td>March 30, 2011</td>
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<td>TNO</td>
<td>Labour productivity</td>
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<td>RIVM</td>
<td>Health Care Economics</td>
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<tr>
<td>June 7, 2011</td>
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<td>TNO</td>
<td>Labour Market Economics</td>
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<tr>
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<td>TNO</td>
<td>Health care organisation</td>
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# Appendix II: All population data

## Male population

<table>
<thead>
<tr>
<th>Year</th>
<th>Population size</th>
<th>Remaining life expectancy</th>
<th>Net migration per person/year</th>
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Source: CBS, Central Bureau for Statistics.
## Appendix III: List of Attendees Workshop I

**June 8, 2011 at TNO Hoofddorp**

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### Appendix IV: List of Attendees Workshop II

**June 23, 2011 at HCSS Den Haag**

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Appendix V: Keynesian and Neoclassical labour market theory

Macro-economics, and considering this ageing model, in particular the macroeconomic labour supply and demand, can be regarded from two viewpoints: (i) the (neo)classical approach and (ii) the Keynesian approach. Although both approaches have their pro’s and con’s and neither can be found fully explaining macroeconomics in terms of labour supply and demand, both are implemented in and researched with the Exploratory SD-model for different reasons. First, economists can be generally divided into these two “camps”, so taking into account both views is necessary to be able to explain labour supply and demand in general. Second, although no economic theory can be found fully explaining supply and demand, neoclassical and Keynesian theory are complementary in the way that some economic behaviour can be explained from one view, and some can be explained from the other view. [needs addition]

Neoclassical economics

Neoclassical economics focuses on the self-regulating behaviour of markets. For the labour market, this means that supply and demand determine a certain real wage (money wage adapted for the price level). It also means that according to the neo-classicist view, unemployment can never be involuntary, although unemployment exists in the labour market. Classicists divide three possible types of unemployment: (i) frictional unemployment, which is considered unemployment due to change of jobs; (ii) unemployment due to wage demands of workers that are higher than market prices and (iii) unemployment due to minimum wages set by the government or trade unions.

Labour demand

Neoclassical labour demand is determined by the production function of the relation between employment and output. Given a certain capital size, adding additional employment will give diminishing returns. This means that firms will hire workers up to the point where the wage of an additional worker does not exceed the price of additional output due to this additional worker (i.e. the marginal product of labour is less than the real wage). The labour demand curve is downward sloping (see example of fig. 1).

Labour supply

The neoclassical approach relates the labour supply and leisure of workers. Working is considered unpleasant and leisure pleasant (although working can also be seen as satisfactory because it provides income). Workers will only work when the disutility of working is outweighed by the real wage that is earned. In most cases, the labour supply curve is upwards sloping (see fig. 1), although at (very) high real wage levels the utility for additional payment is lower than utility for leisure and this might lead to declining labour supply (see fig. 1).
Labour market equilibrium

Comparing labour demand to labour supply will lead to an equilibrium outcome at a certain real wage and employment. This employment can be inserted in the production function to calculate the labour output.

When the real wage is sufficiently flexible, according to the neoclassical view the labour market will settle at full employment (i.e. all unemployment is voluntarily) which means that only long term factors can influence (un)employment and output. Examples of these factors are: technical change that shifts the output curve upwards, leading to a higher labour demand.
Appendix VI: System Dynamics

The Systems Dynamics (SD) modelling method is developed by J.W. Forrester during the second half of the 1950’s in an answer to the Operations Research method, which was, according to Forrester, too much focusing on open loops in decision making (Vennix, 1996). The problem with open loops was, according to Forrester, that the decisions in a system were not influenced by the decisions themselves, where in real life, this will happen (Vennix, 1996). Therefore, he proposes a closed loop system in which the decisions provoke system changes and these system changes affect the decisions.

The system structure proposed by Forrester is built up of four hierarchical levels (Vennix, 1996 pp. 45):

1. The closed boundary
2. The feedback loop as basic system component
3. Levels and rates
4. Goals, observed conditions, discrepancy between goals and observed conditions and desired action

The closed boundary is stated as a system which affects and only is affected by this system. This means that all relations and elements influencing the system should be included (Vennix, 1996 based on Richardson, 1991).

The basic elements in a system dynamics model are feedback loops and stock-flow structures. Feedback loops are built up of the latter, combined with rates. These components will be discussed in more detail in the next sections.

Feedback loops

A common method to solve problems is by using an event oriented approach (Sterman, 2000). This approach is shown in Fig. 4.1. A goal and situation cause a problem, which leads to a decision to be taken which lead to a certain result (or results). If everything goes according to plan, the goals lead to a positive result. Sterman (2000) uses the example of the goal of sales increases of a company. If all goes well, the company takes the right decision and sales increase. When considering the event oriented approach, this would mean that the problem is solved. But, decisions taken might not only have effect on the company’s result, but also on the result of competitors. In order to compensate sales losses, the competitors might lower their prices and increase their sales, which would again mean sales losses for the company. Concluding, one should not only focus on his or her goals and situation and the resulting best decisions and result, but should focus on the whole system which is influenced by the decisions, the side effects, or effects of a decision. The system of decisions and effects is called a feedback loop.

Fig. 4.1: Event oriented problem solving (from: Sterman, 2000)
Fig. 4.2 shows a feedback loop of the system of fig. 4.1. This figure provides an overview of effects of actions taken in the system and actions that are provoked by these effects: goals drive a decision, which influences the environment directly and indirectly, by certain side effects. Changes in the environment drive actions of others, directly or through changes in the goals of other agents. These actions of others change the environment, which changes the goals of the first agent. Then, the cycle might start again, and feedback loops are created.

Two types of feedback loops can be distinguished (Sterman, 2000): positive and negative feedback loops. Positive feedback loops are systems where a positive action is followed by a feedback action which positive feedback on the first action. Fig. 4.3 shows a positive feedback: more chickens means more eggs, more eggs means more chickens.

Negative feedback loops are systems where a positive action is followed by a feedback that has a negative influence on the action. Fig. 4.4 shows a negative feedback loop: more chicken mean more road crossings by these chickens, and consequently, less chickens.

The system dynamics model is built up of several feedback loops that form the entire system.
**Stocks and flows**

A second component of a system dynamics model are stock-flow structures. A stock is a level containing resources and the flows can be either an inflow or outflow. Fig. 4.5 shows the stock-flow structure of a population: births increase the number of persons, deaths decrease the number of persons and net migration might increase (when positive) or decrease (when negative). The flows change over time and when simulating the model for a certain period, the population size changes over time as well.

By influencing the different flows, using variables or constant factors, or again by the system itself (as population size influences the number of births and deaths, a system can be built up, eventually by using a number of stocks and flows. When looking at the mathematics behind these processes, we can define the change of a level or stock by using differential equations.

Concluding, an SD model can be used for simulating a system in which a stock changes over time. The variables that determine these changes are either a constant value or an auxiliary variable. Constants do not change over time, but auxiliaries might. The latter can be either in the form of a mathematical equation (either with input variables that are constant or other auxiliaries, or time), a lookup graph which is a predefined graph, a delay where an input is delayed over a certain time period or a more discrete function like an “if then else” function.

Delays can occur either as a material or information delay, in different orders. Material delays are usually delays of a resource flowing from one stock to another. A material delay can occur as a pipeline delay, where all input in a stock is equal to output, delayed with a certain time period. First order material delays are stocks where the outflow is averaged over a certain time period and higher order delays are considered the output of a first order delay flowing into another level, of which the
output is averaged over a certain time period and so on.

Information delays are delays in information flows. Generally, delays are either 1st, 3rd and 10th order and a fixed delay, which is a delay with a fixed time period. Fig. 4.6 shows the shapes of different orders of information delays.

References:


### Appendix VIII: uncertainty ranges

<table>
<thead>
<tr>
<th>Variable</th>
<th>Lower bound</th>
<th>Upper bound</th>
<th>Type</th>
<th>Distribution</th>
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<tr>
<td>Initial Regular Houses Easily Modified</td>
<td>485571</td>
<td>1318459</td>
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<td>Random uniform</td>
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<td>0.01</td>
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<td>Random uniform</td>
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<td>annual fraction service houses demolished</td>
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<td>change in preference of employers for hiring workers</td>
<td>10</td>
<td>50</td>
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</table>
Demographic aging and its implications for the Dutch welfare state

Appendix IX: Sector diagram with basic uncertainties
Appendix X: Model overview

Female demographics
Economy and labour market
Demographic aging and its implications for the Dutch welfare state – Thomas Logtens
Care (health care subsystem)
Housing

Demographic aging and its implications for the Dutch welfare state – Thomas Logtens
Appendix XI: Trend lines specified during the workshop

Average marginal productivity per age (productivity at age 40 is set at 1, 2 is twice as productive):
Average labour productivity (1=value of 2010, 2 is twice as productive as 1)

Average labour productivity in care (1=value of 2010, 2 is twice as productive as 1)

Average labour productivity in cure (1=value of 2010, 2 is twice as productive as 1)

Fraction smokers is population (t1= 0.271)
Fraction meeting standards for physical activity (t1=0.56)

Fraction heavy drinkers (t1= 0.104)
Fraction obese (t1= 0.118)

Female life expectancy (t1= 82.71 Year)

Male life expectancy (t1= 78.82 Years)
Fertility rate (t1=0.048 per woman in fertile ages)

Average male labour participation (t1=0.783)

Average male worked hours per week (t1=36.9 hours)
Average female labour participation (t1=0.63)

Average female worked hours per week (t1=24.1 hours)
Appendix XII: Types of behaviour of ‘total population’ in base case run

In these figures, the time axis runs from 0 to 25 but which is in fact from 0 to 50 years due to software constraints.

345 runs

484 runs

1189 runs

1969 runs

2029 runs

3517 runs
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