MASTER THESIS

THE SUSTAINABILITY OF THE DUTCH SOCIAL CARE SYSTEM

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Preface

Dear reader,

A couple of months ago, I started my research at the Financial Risk Department of KPMG Advisory N.V [1]. on the sustainability of the Dutch social care system. I have worked on this thesis with a lot of pleasure. I wanted to conduct a research with a social aspect and I think that this has been achieved by combining the AOW system and the health care system.

I have had a great time at the Financial Risk Department. I would like to thank my colleagues for the warm welcome and pleasant time in these months. I am very excited that I am becoming a part of this team starting January next year.

I want to thank my supervisor at KPMG in particular. Every two weeks, I had a meeting with Giel to review my progress. You have helped me structuring my research and have given me a lot of useful feedback. I also want to thank my other colleagues that helped in the process of this research, including Janinke, Patrick, Machiel, Helen, Peter, Bart and Egbert. And lastly, of course, I would like to thank the FRM interns. The daily table football matches were a welcome distraction.

I also want to thank my supervisors Reinoud and Wouter from the University of Twente. I enjoyed our meetings, both on an informal and formal level. The meetings were very productive, resulting in a higher level of academic research and better English writing.

Furthermore I want to thank my parents. They have always been a big support. I am very thankful for the delicious meals whenever I dropped by during my thesis period.

After eight years, my life as student comes to an end. I enjoyed this time with a lot of different people. I want to thank everyone that has been a part of it.

Last but not least, I want to thank my boyfriend, Koos. Thank you for being a great brainstorm partner, debugger of my programmed code, supplier of an unlimited amount of chocolate and, of course, for just being you.

I hope you enjoy reading my thesis.

Amy Dofferhoff
Utrecht, November 8th, 2019

[1] KPMG Adivisory N.V. cannot be held responsible for the content of this master thesis

Executive Summary

In this thesis, we address two social securities of the Dutch social care system, namely the AOW system and the health care system. The AOW is made for the elderly, where an individual has the right to receive a contribution of the government at the age of 66 years and 4 months. This contribution, also known as a pay-as-you-go system, is collected from the working part of the population. At the moment, the fraction of the working part of the population is decreasing and the fraction of the elderly part of the population is increasing. This results in an increasing problem, where too much expenditures are made to fulfil the elderly contribution payments. Since the government pays the shortage, the central government expenditures are rising, which causes problems with the central government budget. The health care expenditures are rising as well. More and more individuals are using health care facilities and the suspicion is that the elderly part of the population is responsible for the major part of them. This indicates that the government is also paying for the extra expenditures to cover the shortage.

Our goal is to investigate if the current AOW and health care system are sustainable in the future. We use an existing demography model to forecast the population for the next thirty years. We use this as input parameter for the forecast of the social security model. We test if the two models are sustainable by looking at the value of the temporal predictive liabilities (IPL). A value of zero indicates that the system is sustainable, since the tax revenues cover the expenditures. A positive value indicates that more expenditures are made than tax revenues received, a negative value shows less expenditures than tax revenues.

We notice from the demography forecast that the fraction of elderly in the population keeps increasing until the year 2037. From this moment on, the elderly part of the population is decreasing due to the fact that the baby-boom generation is passing away. This course of demography has an impact on the AOW system. We notice that with an entitlement age of 65 and 68 years old, the system is not sustainable, since more expenditures are made than revenues received. An entitlement age of 71 years old, shows that the system is sustainable for the next four years, but is not sustainable for the remaining years. This indicates that the life expectancy should be taken into account for the determination of the AOW entitlement age.

The health care system is also not sustainable, but we notice a decrease in total health care expenditures as percentage of GDP. This indicates that an ageing population is not responsible for an increase in expenditures, but other factors as improved technology, better medicines and increasing employee salaries do, which are not taken into account in this forecast model. The Wlz system is not sustainable either, but the influence of the ageing population is shown in the forecast model. We noticed difference in costs for individuals in their last year of living, they make much more expenditures than a person in a healthy year.

An optimal solution to the unstable situation of the Dutch social security system is not immediately known. A lot of factors should be taken into account, since for both financial aspects as ethical aspects, a lot need to be considered. We have to think about drastic changes to keep the social care system sustainable, in which every part of the population should take her responsibility.

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Introduction

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1.1 Chapter Summary

The Netherlands has a very robust social care system with several social insurances and services. One social insurance is specifically made for the elderly. Currently, an individual has the right to receive a contribution from the government at the age of 66 years and 4 months, known as the Algemene Ouderdomswet (AOW). This contribution, called a pay-as-you-go system, is collected from the working part of the population. At the moment, fraction of the elderly part of the population is increasing. This results in an increasing problem, as too much expenditures are made to fulfil the elderly contribution payments. Since the government pays the shortage, the central government expenditures are rising, which causes problems with the central government budget and tax system.

Other increasing expenditures, are the health care expenditures. More and more individuals are using health care facilities and the question arises whether the elderly part of the population is responsible for the major part of these expenditures. Since the elderly part of the population is larger than the working part of the population, this implies that the current demographic distribution pressures the social care system of the Netherlands.

Currently, a national debate is going on about the AOW entitlement age, whether it is too high according to the individuals that are almost entitled to receive AOW (especially if they have a physically demanding job) and whether it is too low according to the government. Our overall research question is therefore as follows:

To what extent is the current AOW entitlement age sustainable relating to future AOW expenditures and health care expenditures, in the Dutch pay-as-you-go system?

In this research, not only the AOW expenditures have an impact on the AOW entitlement age, but also the health care expenditures, since parts of the social insurances and services are dedicated to health care. Therefore, a connection between these expenditures is made to make a better ruling about the current AOW entitlement age.

Further on in this chapter, we will give a more comprehensive description of the social care system of the Netherlands as well as the additional research questions.

1.2 Introduction to AOW

The Netherlands is a country with a very robust social care system. There are different social insurances and services, such as child benefits and provisions in case of long-term illness, all to ensure that the whole Dutch population is able to live on a certain base level. In general, the richer part of the population pays more taxes for this social care system. In addition, the Netherlands has a pension system, of which a government organised payment is one of the pillars. The Dutch pension system has three pillars in total. The first pillar is the general elderly contribution, or in Dutch known as AOW. The idea of this pillar is that the working part of the population pays for the part of the population that is entitled to receive AOW. The second pillar of the Dutch pension system is money saved during the time people have a job. This money is collected by pension funds that invest the money. The saved amount of money during their working life is used as an extra income for the remaining years during their pension, since the amount of AOW is just enough to live on a very basic level. In 90% of the cases, this second pillar is governed by the employer. The third and last pillar is individual pillar, where each individual is free to create a supplementary pension. This can be achieved e.g. by life insurances, since an extra amount of money is released at a certain point in time.

Over the last years, a national debate is going on about the current AOW entitlement age. As already mentioned, the first pillar of the Dutch pension system is a social security. Every individual at the right age is able to receive this provision. The Dutch system for AOW is called the 'omslagstelsel', also known in English as pay-as-you-go system. This has to do with the fact that the working part of the population pays the AOW for the part of the population that is entitled to receive AOW. This is the very heart of the matter. When the AOW was introduced in 1957, the main assumption for the pay-as-you-go system was that the demography of a population remain about the same during the upcoming years. Unfortunately, this was not the case for the Dutch, as is shown in Figure 1.1. After World War II, a lot of babies were born and more recently, fewer babies were born. Nevertheless, this change in demographics resulted in a rising problem. The babies born closely after World War II, also known as the baby-boom generation, have reached the AOW entitlement age. More AOW expenses are made in comparison with the received premiums, since the ratio of working population and AOW entitlement population is out of balance. The sustainability of the AOW system is under pressure by this rising problem. Besides, the life expectancy has increased. In 1957, the average life expectancy for both males and females was 15.14 years. In 2017, this had increased to 20.30 years, which results in an increase of more than five years.

The Dutch government already made some adjustments by increasing the AOW entitlement age since 2013. In Table 1.1, the different new AOW entitlement ages are given by different birth years. This gradual increase is done to ensure a transitional agreement. It should be noted that there is a difference in the AOW entitlement age and the pension entitlement age. The AOW entitlement age, is the moment where you receive AOW from the government, so a basic income for the elderly. The pension entitlement age, is the moment where you receive your accrued pension from pillar 2. This might be seen as the age you should continue to work, but it is possible to get an early retirement, which result in a lower pension payment. The pension entitlement ages for different years are shown in Table 1.2 and, at the moment, they appear to be higher than the AOW entitlement ages for different years.

Before we explain the different social security systems, we already want to outline some of the steps that need to be taken in this research. We want to test the sustainability of the AOW system. Therefore, we need a forecast of the demography as input parameter for the forecast of the AOW system. We are not looking for a improvement of every system, but we want to make a connection between different forecast models. Therefore, we work with existing models, for both the demography as the social securities. We want to make a forecast for the next 30 years. A more detailed explanation is given in Section 1.4.

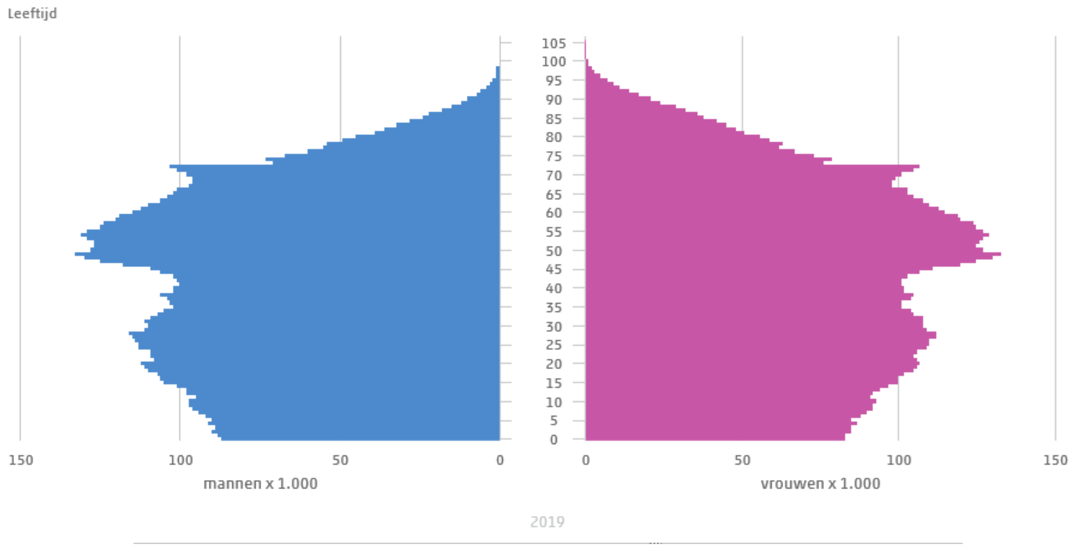


Figure 1.1: Demographics of the Netherlands in 2019, CBS (2019a). The left x-axis is the number of males in the Dutch population. The rights x-axis is the number of females in the Dutch population. The y-axis is the age.

Year	AOW entitlement age	Born between:
2016	65 year + 6 months	30th of September 1950 - 1st of July 1951
2017	65 year + 9 months	30th of June 1951 - 1st of April 1952
2018	66 year	31th of March 1952 - 1st of January 1953
2019	66 year + 4 months	30th of December 1952 - 1st of September 1953
2020	66 year + 8 months	31th of August 1953 - 1st of May 1954
2021	67 year	30th of April 1954 - 1st of January 1955
2022	67 year + 3 months	31th of December 1954 - 1st of October 1955
2023	67 year + 3 months	30th of September 1955 - 1st of October 1956

Table 1.1: AOW Entitlement Age for Different Years (Pillar 1).

Year	Pension entitlement age
present time - 2032	68
2033 - 2040	69
2041 - 2049	70
2050	71

Table 1.2: Pension Entitlement Age for Different Time Periods (Pillar 2).

1.2.1 Social Security Contributions

Before going into more detail in the AOW system, the different social security contributions should be explained. The premiums for the AOW are collected by taxes as a component of the social securities. The social securities consist of four different elements:

- General elderly benefit (abbreviation in Dutch: AOW).
- Benefit for surviving relatives (in Dutch: Algemene nabestaanden wet (Anw))
  A benefit to ensure a basic income for surviving relatives in case of the death of a spouse.
- Benefit in case of long illness (in Dutch: Wet langdurig zorg (Wlz))
  A benefit in case of 24 hour care for elderly, people with disabilities or mental illness. This subject is discussed in more detail in Section 1.3.
- Benefit for children (in Dutch: Algemene kinderbijslag wet (Akw))
  A benefit for everybody that has children.

Every working individual is obliged to pay a certain amount of premium. A working individual is not only a paid employee, but also people that have their own company or receive unemployment benefit. The amount of paid premium is determined by the income level of an individual. The percentages for every contribution are given in Table 1.3. The premium for the contribution for children is 0% and therefore not added to the table. So for example, if an individual earns €28000 per year, a premium of €28000*(17.90%+0.10%+9.65%) = €7742 is paid over that year. Different premium levels apply for individuals that have the AOW entitlement age, since they do not pay for the AOW anymore, this premium is set to 0%. The situation for the ageing population is given in Table 1.4.

Year	AOW premium rate	Anw premium rate	Wlz premium rate	Maximum chargeable amount	Maximum premium payment:
2019	17.90%	0.10%	9.65%	€34300	€9483
2018	17.90%	0.10%	9.65%	€33994	€9399
2017	17.90%	0.10%	9.65%	€33791	€9343

Table 1.3: Premium Levels for Working Population, Belastingdienst (nda).

Year	Anw premium rate	Wlz premium rate	Maximum chargeable amount	Maximum premium payment:
2019	0.10%	9.65%	€34300	€3344
2018	0.10%	9.65%	€33994	€3314
2017	0.10%	9.65%	€33791	€3295

Table 1.4: Premium Levels for Ageing Population, Belastingdienst (nda).

We can conclude from Table 1.3 that the AOW premiums differ per working individual, depending on level of income. This means that it is necessary to know the different incomes per individual. Another important element in the calculation of the overall premium income is the demography of the Netherlands, since the AOW entitlement population does not pay anymore for the AOW premium. Another assumption that should be taken into account is the fact that each working individual pays 2% per year, so in total 50 years, for the AOW premium (SVB (nda)). So, in the original system, an individual started paying at the age of 15 years, since the AOW entitlement age was 65 years. The difference is exactly 50 years. In the current system, the start date for paying AOW is increasing, since the AOW entitlement age is increasing.

1.2.2 AOW Expenditures

Besides the income side of the AOW system, a lot of expenditures are made. In the Dutch system, some exceptions are made for different living situations or levels of income. First of all, at the moment there are different AOW entitlement ages, due to the transitional agreement (see Table 1.1). This scenario already an impact on the total AOW expenditures. The demography of the ageing population is also needed to calculate the overall costs. Another distinction that is made, is the status of the relationship. If two people share their life and are living together, the amount of AOW that each individual receives, is €787.45 with tax benefit. For singles, the amount of AOW is €1146.51. Then, there are different arrangements for different cohabitation scenarios. For example, before 2015 it was possible to get a higher AOW benefit if your spouse had not even reached the AOW entitlement age. This arrangement has been abolished, but the people that were already using this arrangement, still get different amounts of AOW. An overview is given in Table 1.5.

Relationship status	**Arrangement**	**AOW with tax benefit**	**AOW without tax benefit:**
Single	-	€1146.51	€918.76
Cohabitants	Both are entitled to AOW	€787.45	€631.37
Cohabitants	One is entitled to AOW	€787.45	€631.37
Cohabitants	One is entitled to AOW, entitled before 2015	€1481.85	€1243.18
Cohabitants	One is entitled to AOW, entitled before 2015 with a high income	€1420.65	€1181.98

Table 1.5: AOW Contributions for Different Scenarios and Arrangements, SVB (ndb).

Another distinction that should be considered is that not only Dutch inhabitants receive AOW. If a person from another nationality lived here for more than 50 years and paid the social care contributions, he is also entitled to receive AOW. If an individual did not pay the full amount of social care contribution, he will receive less AOW. For example, if an individual only lived here for 30 years, he will only receive 30*2% = 60% of AOW. This is independent of the nationality of the person. The last distinction in the AOW system, is the transitional payment. In the past, it was possible to stop working before the AOW entitlement age without tax consequences. This arrangement is not very popular anymore, since nowadays it has a lot of negative financial consequences. However, the part of the population that already accepted this arrangement, could encounter financial problems by an increasing AOW entitlement age. Therefore, it is possible to get an extra amount of money with a maximum of €1195.54 for a single person and €767.56 for a cohabitant person (SVB (ndc)).

In the ideal situation, the amount of tax revenues covers the AOW expenditures. However, this is not the current situation since the balance between the ageing population and the working population is disturbed. In the past years, the AOW expenditures were a lot higher than the premium income, see Figure 1.2. In 2017, almost one-third of AOW expenditures has been paid by the central government. An overview of the Dutch AOW system is given in Figure 1.3.

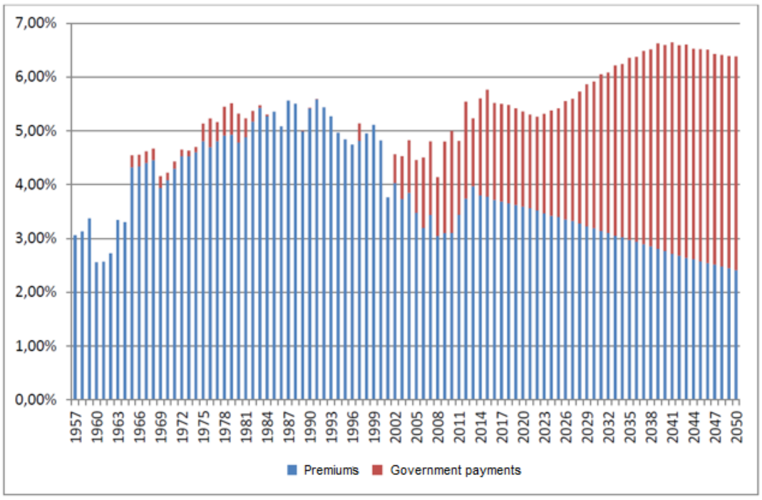


Figure 1.2: Distribution of Premium Payments and Central Government Payments as Percentage of GPD, SVB (2015).

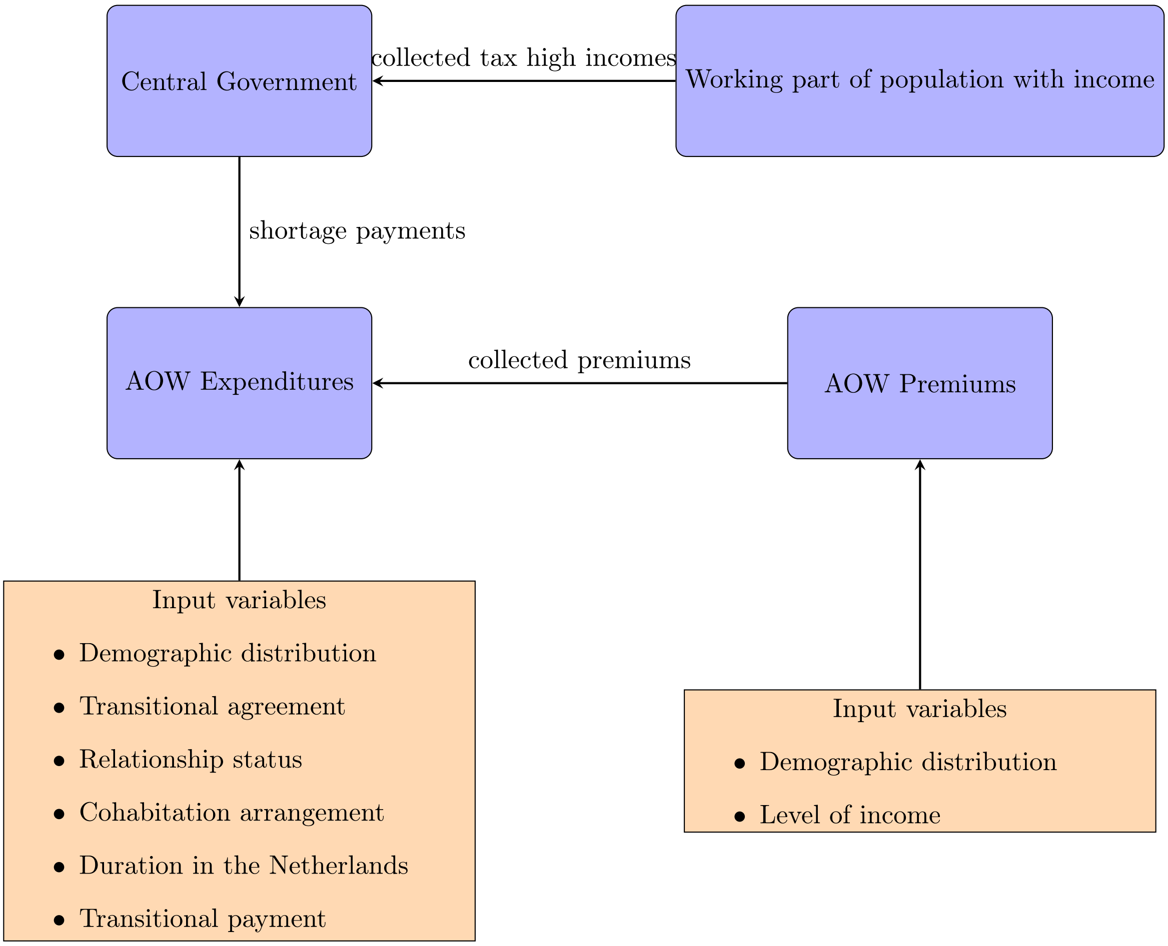


Figure 1.3: Overview of AOW System.

1.3 Introduction to Health Care

Another subject that might be seen as a problem is the increase in health care expenditures. The health care expenditures are the highest budget post of the government. Over the last years, the total health care expenditures increased every year, as shown in Figure 1.4. A possible explanation is the change in demographics and a more ageing population. Not only medical care is considered as health care expenditures, but it also includes nursing homes and lot of other health care institutions. The question might arises whether there is a connection between an ageing population and the increase in advanced medical support. Just as in the case of AOW expenditures, a part of the health care expenditures is financed by the government. The government covers the health care expenditures by collecting taxes. This means that an increase in health care expenditures pressures the sustainability social care system. Especially since the ageing part of the population is likely to use more health care provisions. We should not only question the current AOW system, but the social care system in general.

For the health care system, we use the same forecast model as for the AOW system. So, we need to forecast the demography before we could forecast the health care system in general. We forecast the health care system for the next 30 years. A more detailed explanation is given in Section 1.4.

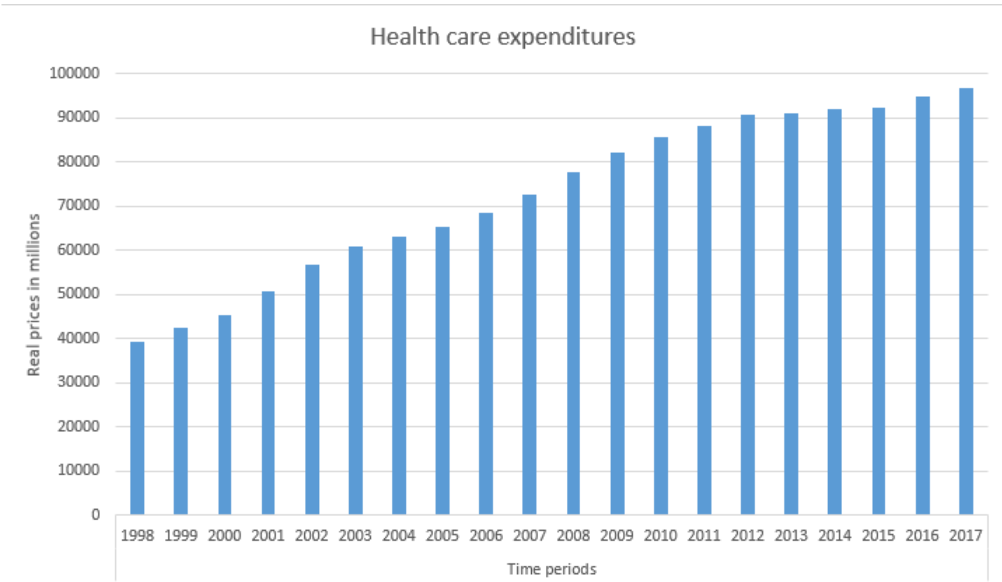


Figure 1.4: Total Health Care Expenditures, CBS (2019c).

1.3.1 Legislation

Before it is possible to make some statements about the expenditures and the demographic distribution, the legislation of the health care system should be explained in more detail. The health care system in the Netherlands has gone through some major changes during the last decade. First of all, in 2006, it became compulsory for every individual to have a health insurance. This was established by introducing the health insurance law (in Dutch: Zorgverzekeringswet (Zvw)). Among 60% of the total health care expenditures is covered by the Zvw and it consist mainly of curative care (Ministerie VWS (2016)). Not only the government is involved, but also private insurance companies. Every individual is free to choose an insurance company and can switch between insurance companies every year. This is done to create competition between the latter and therefore to lower the health care premiums paid by the insurees. A more detailed description of the Zvw is given further on in this section.

Another change in the overall health care system was introduced in 2015. Before 2015, every type was centrally organised by the government. Most of the curative care was organised by the

Zvw, but other forms of care, such as care services, were organised in different systems. Since 2015, the Wlz has been centrally organised and meant for individuals needing long-term care, such as the elderly in nursing homes. As shown in Section 1.2, this is also a social security. The two remaining systems of health care consist of the systems for social support (in Dutch: Wet maatschappelijke ondersteuning (Wmo)) and the care for children (in Dutch: Jeugdwet). The responsibility of the last two systems has been organised by the municipalities since 2015. The idea by decentralising the systems is to provide a higher quality of care and a closer relationship with the patients (Ministerie VWS (2016)). The other systems will be explained in more detail further on in this section. An overview of the four different systems of the Dutch health care system, is given in Figure 1.5.

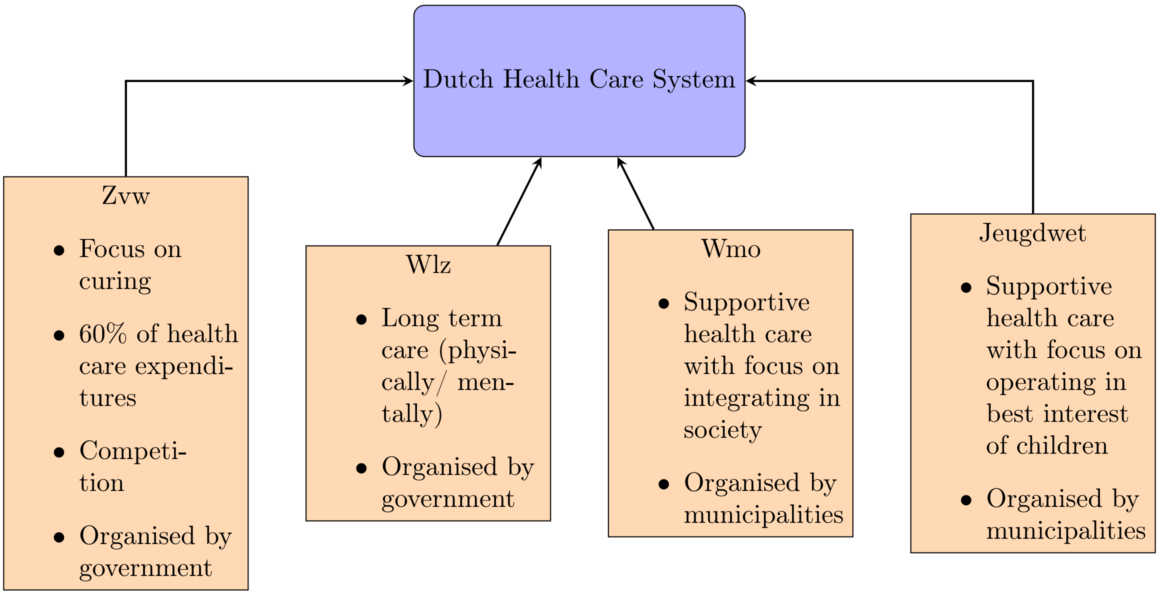


Figure 1.5: Overview of the Dutch Health Care System.

Zorgverzekeringswet (Zvw)

Even though there is lot of competition between health insurance companies, the government has set some basic conditions to ensure the social aspect of the Zvw (Ministerie VWS (2016)):

- Civilians are obligated to have a health insurance. It is possible to have a basic health insurance or to get an extended health insurance. The government decide what forms of health care should be included in the basic health insurance and this should be available for every civilian.
- Every individual is free to choose an insurance at the insurance company they like. An insurance company is not in the position to reject an individual, even if the health status of a person is bad.
- The premium that an individual has to pay is the same for every other individual at the same insurance company. Even if a person has a bad health condition.
- Insurance companies have a so called 'duty of care'. They have the responsibility to guarantee that every insured individual can receive the care that is provided in the basic health insurance. The extended health insurance is a choice that each individual might take. They will receive extra insured treatments, but the amount of premium to be paid is higher.

Since every individual should be accepted by an insurance company, it might be possible that some insurance companies have higher percentages of individuals with a bad health status than other insurance companies. To resolve this problem, a risk equalisation is made.

The introduction of a health insurance fund ensures that every insurance company get the right amount of money to compensate for individuals with an inferior health status. The health insurance fund is supplemented with money from the government and with taxes from civilians. The amount of tax that an individual must pay, is different for several scenarios, as shown in Appendix A. Besides the contribution from the health insurance fund, insurance companies receive a contribution from every insured individual. This depends on the type of insurance, namely a basic health insurance or a supplementary insurance, and is seen as the nominal premium. There is also a risk element for each premium holder over 18 years old. Every individual is free to choose the level of risk, but there is a compulsory part since 2008, as shown in Figure 1.6. Besides the compulsory element, a person is entitled to increase his own risk in return for a reduction on the premium. An increase of €100, €200, €300, €400 or €500 (Rijksoverheid (ndb)) is possible and the higher the increase of risk, the higher the amount of reduction on the premium. So, at the moment, the highest risk that an individual might have is €885 per year. In the end, the insurance companies pay the healthcare providers. An overview of the Zvw system is given in Figure 1.7. Two parameters might need some extra explanation:

- Care allowance:
  This is a benefit from the government to civilians that have a lower income to compensate for the healthcare expenditures or nominal premium.

- Accessibility contribution:
  This is a contribution for the expenditures that cannot be attributed to an individual. An example might be the training expenses for doctors.

Figure 1.6: Course of Compulsory Risk, Independer (nd).

Wet langdurige zorg (Wlz)

The Wlz is a fixed social security based on the level of income, which means that every civilian that pays income tax is obliged to pay 9.65% premium. The Wlz is for people that need long-term care, not only physically, but also mentally. The government is responsible for the specification of the different healthcare services that define the Wlz. The main functions are described as follows (Ministerie VWS (2016)):

- Residence in an institution. This might be a permanent stay in a nursing home or long-term admission in a psychiatric clinic.

- Personal care, for example, assistance with dressing or showering.

- Guidance in becoming more independent.

- Nursing.

- A medical, paramedical or behaviour treatment for the recovery or improvement of an illness.

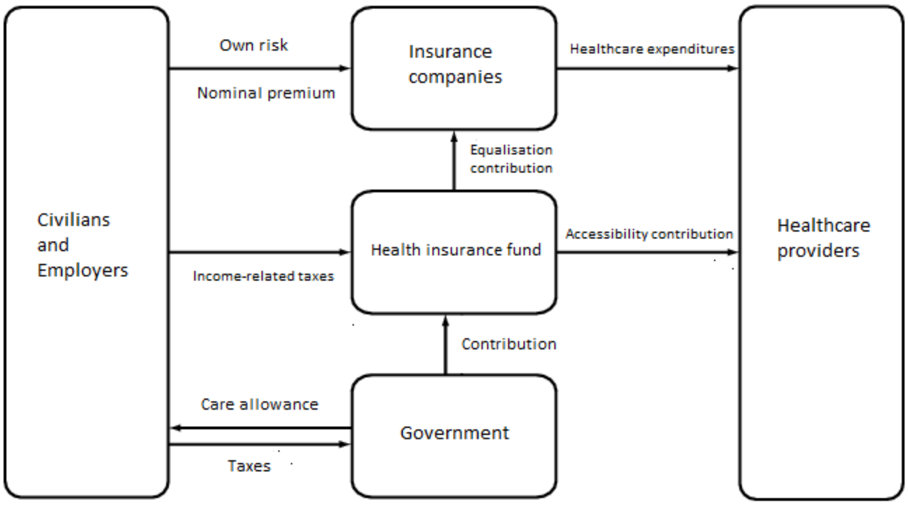


Figure 1.7: Overview of Zvw System, Rijksoverheid (nda).

- Transport to daytime activities or a daytime treatment.

An individual that feels entitled to receive Wlz, should make a request at the care assessment center (in Dutch known as: Centrum Indicatiestelling Zorg (CIZ)). CIZ provides an indication of the amount of care that is needed and the corresponding budget. The individual that filled the request can now choose to organise the entitled healthcare himself or to outsource this process. In case of outsourcing, a 'healthcare office' will take the responsibility and in case of self-organisation, an individual receives a personal budget (in Dutch known as: persoonsgebonden budget (PGB)). The PGB is provided from the Social Security Organisation (in Dutch known as: Sociale Verzekeringsbank (SVB)). The Central Administration Office (in Dutch known as: Centraal Administratie Kantoor (CAK)), organises the payments in case of outsourcing.

Every individual that uses the Wlz is obliged to pay a contribution. The amount of contribution is dependent of the level of income of an individual, age, the amount of equity, whether he is single or in a relationship and if he is living at home or in an institution. Both the Wlz premium and the individual contribution are collected in a 'long-term healthcare fund' and from this fund distributed to CAK and SVB. An overview of the Wlz system is given in Figure 1.8.

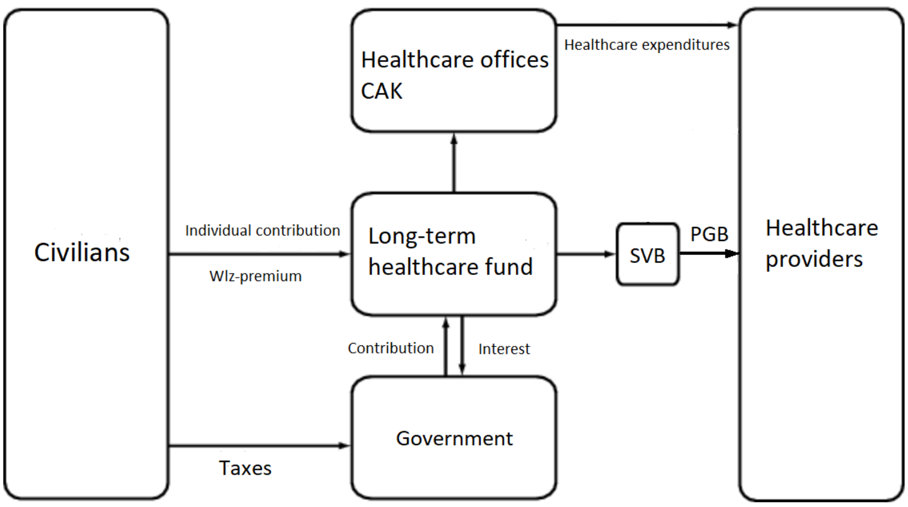


Figure 1.8: Overview of Wlz System, Rijksoverheid (nda).

Wet maatschappelijke ondersteuning (Wmo)

As already mentioned in Section 1.3, the Wmo is a form of healthcare that is provided by the municipalities. The intention of the Wmo is to provide care such that individuals could live in their own homes and participate in society (Ministerie VWS (2016)). If an individual believes she should receive Wmo, she must submit a request at the municipality. The municipality decides whether a person is entitled to receive Wmo and in what kind of form. The municipality has three options to choose from:

1. Verify that an individual is capable to receive the needed care through families and friends.
2. Verify that an individual should receive a general service, such as daily meal delivery.
3. Verify that an individual should receive a personal service, such as an arrangement with multiple services.

A municipality receives a contribution of the so called 'municipality fund', sponsored by the government. From this contribution, stored at a municipality budget that is different for each municipality, the healthcare expenditures are paid. In case of a personal service, an individual contribution might be needed. An overview of the Wmo system is given in Figure 1.9.

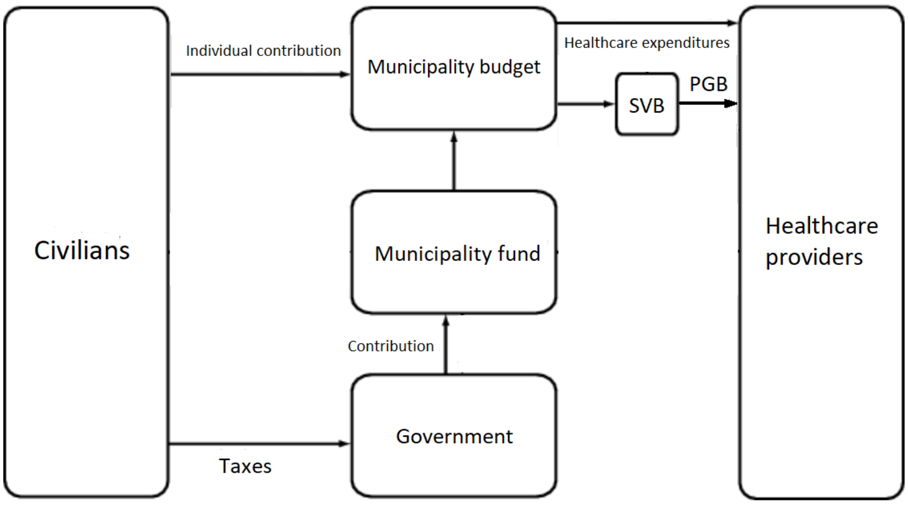


Figure 1.9: Overview of Wmo System, Ministerie VWS (2016).

Jeugdwet

The Jeugdwet is a law that is designed to protect children, provide help with parenting and execute youth rehabilitation. The municipalities are responsible for the compliance of the law. The law is made for children under the age of 18 years old, but in special cases it is applicable to people until 23 years old. The system of the Jeugdwet is comparable to the Wmo system. If individuals feel like they are entitled to receive some kind of contribution, they can ask the municipality for help. The municipality decides whether the request is accepted and what kind of contribution is given. An individual can choose for a direct contribution paid by the municipality, or to have a PGB and organise the provided care himself. Since the law is designed for the youth, an individual contribution is not needed. An overview of the Jeugdwet system is given in Figure 1.10.

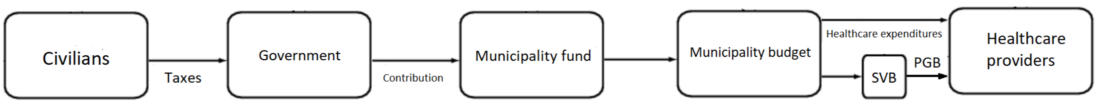


Figure 1.10: Overview of Jeugdwet System, Ministerie VWS (2016).

1.4 Research questions

The social care system is a very sensitive matter in the Dutch society. At the moment, a discussion about an increased AOW entitlement age is going on. There is a conflict of interest between the politicians and the members of the trade unions. Politicians notice that the current situation needs to change, since the AOW expenditures keep increasing (see Figure 1.2), but the trade unions think that it is unfair to increase the AOW entitlement age for the current elderly population, especially for the people that have a physically demanding job.

The introduction of the Zwv in 2006 was done to increase competition between insurance companies and healthcare providers to reduce waiting lists and the overall healthcare expenditures (Ministerie VWS (2016)). In Figure 1.4 we show that the total healthcare expenditures have increased over the past years and are almost €100 billion in 2017. The life expectancy is also increasing (see Table 1.6), which might suggest that the overall healthcare expenditures will further increase in the current demographic landscape of the Netherlands. This cannot be said by certainty, even a research conducted by National Institute for Public Health and the Environment (in Dutch known as: Rijksinstituut voor Volksgezondheid en Milieu (RIVM)) in 2008 is not convinced that an older population is responsible for the increase in healthcare expenditures (RIVM (2008)). Other factors, such as comorbidity and last year of living, seem to have more impact on the healthcare expenditures. However, the expenditures for long-term care in nursery homes seem to increase, which is also a kind of healthcare, organised in the Wlz. All of these elements should be investigated in this master thesis.

Year	**Men**	**Women**
1950	70.29	72.58
1960	71.39	75.3
1970	70.81	76.5
1980	72.48	79.18
1990	73.84	80.11
2000	75.54	80.58
2010	78.77	82.72
2018	80.16	83.33

Table 1.6: Life Expectancy for Males and Females at Birth, CBS (2019b).

We suppose that there is a link between the AOW expenditures and the healthcare expenditures and the pressure on the Dutch social security system because of an ageing population. The goal of this research is to investigate the sustainability of the Dutch social security system. We define the overall research question as follows:

To what extent is the current AOW entitlement age sustainable relating to future AOW expenditures and health care expenditures, in the Dutch pay-as-you-go system?

The main goal of this master thesis is to investigate the current AOW entitlement age taking the healthcare expenditures in to consideration. It is important to make a connection between the AOW expenditures and the health care expenditures since these are the two pillars of the social care system as there is a suspicion that the ageing population takes more advantage of the overall government budget than the younger part of the population. The subject is very politically motivated and the question might arises whether the current AOW policy is in best interest of the entire Dutch population or only one in best interest of the different political parties or specific parts of the population benefiting from the current system. To answer this question, multiple definitions should be identified and assumptions should be made regarding the calculation of the AOW expenditures and the forecast demographic trend. Therefore, additional research questions can be categorised in three subjects, namely demographic developments, AOW expenditures and health care expenditures. The health care expenditures should be investigated to obtain a more accurate analysis about the current AOW entitlement age. Not only the direct AOW expenditures could pressure the current entitlement age, but health care expenditures could also pressure the current AOW system. The additional research questions per category can be given as follows:

- Demographic developments
  1. Which models and parameters are known in literature to predict demographic composition?
  2. What data could we obtain from existing and accessible databases on the demographic composition of the Netherlands over the last 67 years?
  3. How could we model the demographic distribution and AOW entitlement age in the Netherlands for the coming 30 years?
  4. How should we assess model outcome and uncertainty regarding the demographic composition development?
- AOW expenditures
  1. How is the total balance of AOW contributions and expenditures composed?
  2. What data on AOW expenditures and contributions could we obtain on the percentage and absolute GPD of the Dutch system over the last 20 years?
  3. How could we model the balance of AOW contributions and expenditures for the coming 30 years?
  4. How sensitive is the total balance of AOW contributions and expenditures with respect to the AOW entitlement age?
- Health care expenditures
  1. What drivers of health care expenditures are known in literature?
  2. What are the current health care expenditures per age cohort in absolute value for the Dutch system?
  3. What are the current types of health care expenditures per age cohort in absolute value for the Dutch system?
  4. How is the development in demographic composition correlated with the types of health care expenditures?
  5. How could we model the health care expenditures and tax revenues for the coming 30 years?

We will answer these research questions in different chapters. The outline of this master thesis is given in Table 1.7. First, a literature study and methodology is given to set a basic framework for the forecasting model. Before a prediction of the future expenditures can be made, a projection of the Dutch demography must be given. We use existing models for the forecast of the demography and social care system. All the forecasts have a horizon of 30 years. At the end of this master thesis, we will answer the main research question.

Chapter	Content	Research Questions
Chapter 1: Introduction	An outline of the current Dutch AOW system, the Dutch healthcare system and an overview of the research problem with additional research questions are given.	-
Chapter 2: Literature Study	An overview of the different scientific literature that is used to answer the different research questions is given. The most important subjects that are covered are: • Prediction models • Simulation studies	Which models and parameters are known in literature to predict demographic composition? What drivers of health care expenditures are known in literature?
Chapter 3: Methodology	An overview of execution of the research is given.	What data could we obtain from existing and accessible databases on the demographic composition of the Netherlands over the last 67 years? What data on AOW expenditures and contributions could we obtain on the percentage and absolute GPD of the Dutch system over the last 20 years?
Chapter 4: Demographic Distribution	The demographic distribution of the Netherlands is predicted with different input parameters.	How could we model the demographic distribution and AOW entitlement age in the Netherlands for the coming 30 years? How should we assess model outcome and uncertainty regarding the demographic composition development?
Chapter 5: AOW Expenditures	The current AOW expenditures are calculated, even as the distribution related to premium payments and the central government payments. Since the predictions of the demographic distributions are known, a prediction of the AOW expenditures can be made, even as the new distribution related to premium payments and central government payments.	How is the total balance of AOW contributions and expenditures composed? How could we model the balance of AOW contributions and expenditures for the coming 30 years? How sensitive is the total balance of AOW contributions and expenditures with respect to the AOW entitlement age?
Chapter 6: Healthcare Expenditures	The outline of the current health care expenditures, even as a correlation analysis of different input variables are given. After the calculations about the current situation, a prediction is made for the health care expenditures.	What are the current health care expenditures per age cohort in absolute value for the Dutch system? What are the current types of health care expenditures per age cohort in absolute value for the Dutch system? How is the development in demographic composition correlated with the types of health care expenditures? How could we model the health care expenditures and tax revenues for the coming 30 years?
Chapter 7: Conclusion & Discussion	Conclusions are drawn and recommendations are given. Of course, every research has it drawbacks, so discussion points and subjects for further research are given.	To what extent is the current AOW entitlement age sustainable relating to future AOW expenditures and other expenditures, such as health care expenditures, in the Dutch pay-as-you-go system?

Table 1.7: Chapter Outline.

Chapter 2

Literature Study

Contents

2.1 Chapter Summary

This chapter gives an outline of three subjects, namely demographic forecasting, the forecast of social revenues and expenditures and the trends in health care expenditures. It is important to know before reading that every subject is explained in detail and with most of the possibilities that are known in literature. This means that not only the model is explained that eventually will be used in this thesis, but a selection of other models that might be a possibility as well.

The first section is about demographic forecasting. This can be computed by extrapolative models, where the future is based on historical trends, or by using opinions of experts. In these models, we can consider mortality rates, fertility rates or net-migration rates. However, this model is the most complete. The most extended model uses all three parameters, but is more uncertain due to the fertility and net-migration rates. The model that uses all these parameters is the model of Hyndman and Booth (2008). For every parameter, the data are smoothed, an ARIMA model is fitted to the data, a forecast is made and simulated n number of times to create a robust outcome with a certain confidence interval. The outcome of the forecast is the population of a specific country or other group. With this outcome, ratios that show how a population is constructed can be computed.

The second section explains a model that forecast the public liabilities. The first model for this forecast was applied by using generational accounting. The discounted future entitlements and discounted future taxes are computed to see if the system is sustainable. We have a sustainable system if the entitlements and taxes are in balance, meaning that subtracted from each other, the outcome is zero. The generational accounting approach is extended by the model of Alho and Vanne (2006). A simulation study is conducted with a stochastic population forecast used as input parameter. Not only the discounted entitlements and taxes are taken into account, but the wealth of a country as well. The wealth consist of the debt and revenues of a country plus the productivity. The productivity is the real GDP per capita growth series.

The last section is about the trends in health care expenditures. We distinguish two trends. The first one is that the last year of living is a main cost driver for hospital care instead of age. A person at the age of 65 makes more costs in her last year of living than a 85 year old. This is seen as the 'red herring hypothesis', since the assumption is that an ageing population is responsible for the increase in health care expenditures, which is not the case in the last year of living. This is not the case for surviving individuals and individuals that need long-term care. Than, the health care expenditures do increase with age, also known as steepening. Another trend in the increasing health care expenditures is comorbidities. Having two or more diseases result in an increase, for which age is not the driven factor as well. A last note can be made on the users of the health care system. A large part of the costs, especially in hospital care, is made by a very small part of the population. This might have an effect on the forecasting results of health care expenditures.

2.2 Demographic Forecasting

In predicting a demography, multiple parameters should be taken into account, such as the different methods for calculating mortality, smoothing the data and forecasting the data. The most well-known pioneers of mortality forecasting and life table construction are Robert Lee and Lawrence Carter. They made a model for mortality forecasting with historical data from 1933 until 1992, by means of forecasting the index of mortality as a random walk with drift (Lee and Carter (1992)). Another pioneer in the field of forecasting demography is Juha Alho. He already recognised that a deterministic approach of demographics forecasting is not a realistic approach since there will be uncertainty in forecasting different input parameters (Alho (1990)). Therefore, he realised a stochastic forecasting model in which the mortality and the fertility have been predicted. The main difference between stochastic forecasting and deterministic forecasting, is the usage of randomness. Deterministic forecasting does not take randomness into account and only looks at the past without considering any uncertainty. S0, deterministic forecasts are soley based on fixed historical data and do not incorporate random values in this historic data. This is another important feature about stochastic forecasting. The amount of uncertainty in the forecasts expressed in prediction intervals for any desired function of the forecast age distribution and any probability can be chosen (Booth (2006)).

In the last couple of decades a lot of research has been done and new insights have been obtained in demographic forecasting. However, the complexity and possible model choices still makes it difficult to produce an accurate forecast. According to Booth (2006), three type of models can be distinguished:

1. Extrapolative Methods

   This is the most common approach in forecasting. The main assumption of this model is that the future is a continuation of the past. This is a very robust assumption, but can also lead to mistakes in the forecast if changes in trend or structural changes are missed (Booth (2006)). This method takes no exogenous variables into account or expert opinions. Differently said, the model does not use values that are not obtained from the historical data. One of the most commonly used methods is univariate ARIMA modelling, a method in time series analysis.

2. Methods Based on Expectation

   This method uses individual data, collected by e.g. surveys, or opinions of experts to make a prediction about the future demography. This method might have more useful information for a prediction model if therea are not enough historical data, which is becoming less of a problem in developed countries. However, supporters of the this method argue that it is preferable to a time-series approach because expert opinion takes into account the possibility of future structural change and unexpected events (Lutz et al. (1996)). On the other hand, opponents claim that expert opinions give a subjective judgement that often influence the forecasts (Alders and de Beer (2019)). Especially for mortality forecasts, the expert opinion method does not seem suitable, since mortality is seen as a biological factor. However, for fertility forecasting and migration forecasting it might be more appropriate, since these parameters are more behaviourally driven.

3. Structural Modelling

   This method seeks to explain demographic processes by using structural models based on theories relating demographic quantities to other variables (Booth (2006)). An advantage of this method is the ability to foresee turning points or structural changes, like the baby-boom generation. However, the danger of model misspecification is high because of a lack of theoretical basis: most economic-demographic relations are merely hypotheses (Ahlburg and Land (1992)).

Besides the choice of a model, the number of factors modelled should also be decided. A model might have zero, one, two or three factor(s) where a factor may be viewed as a classificatory variable intrinsic to the data (Booth (2006)). Zero-factor models are simple time series of age-specific rates. A one-factor model combines demographic rates as a function of age. Two factor models combine age, also seen as duration, and period, also seen as time. The most extensive model is a three factor model in which age, period and cohort effects are included, called a APC model (Booth (2006)). The APC model is more useful in describing the past instead of forecasting the future since a cohort should completely pass away to make reliable forecasts.

The last choice to be made in defining a demographic prediction model is the use of decomposition and disaggregation. Decomposition is the breakdown of the input parameters, for example the mortality by cause of death, or fertility by parity, and disaggregation is the division of the base population beyond age and sex, for example, by education or region (Booth (2006)). Decomposition and disaggregation could be useful on the short term or medium term, however due to lack of the right useful data, the method is still not used to the full advantage.

In the description of the different models, three different input parameters are appointed, namely mortality, fertility and migration. These three parameters are seen as the input variables for demographic forecasting. Even though mortality is the input parameter for which most research has been done, fertility and migration are seen as components of population change and should be forecast separately (Booth (2006)). Currently, fertility and mortality rates are both declining in Western countries (Harper (2014)). The decline in fertility rates has to do with changing cultural environments and a more self focused society. The decline in mortality is mainly caused by a lower child mortality and an increase in life expectancy. International migration has been largely neglected in traditional demographic modelling and forecasting (Booth (2006)), but is more and more incorporated nowadays. Mostly, this is done by computing the net-migration. This is the difference of the immigration and emigration hence it can be a positive number or negative number.

Since explorative methods are seen as the most reliable forecast methods by different researchers, the method we use in this master thesis is also an explorative method using not only mortality and fertility, but also net-migration. This is the model created by Hyndman and Booth (2008), who are claiming that their method is an improvement on existing demographics prediction models in three aspects:

1. It is a coherent stochastic model of the three demographic components.
2. It is estimated entirely from historical data with no subjective inputs required.
3. It provides probabilistic prediction intervals for any demographic variable that is derived from population numbers and vital events, including life expectancy, total fertility rates and dependency ratios.

Even Alho (1990) stated that the subjectivity of expert opinions has caused systematic bias in forecasts. Therefore, it is good to notice that the model of Hyndman and Booth (2008) does not have an issue with this matter. On the other hand, forecasting fertility and net-migration are less developed and more sensitive to recent developments. For example, at the moment, the civil war in Syria leads to higher immigration numbers throughout whole Europe. The reason to still consider to implement fertility and net-migration is that explorative methods are more stable than methods based on expectation and structural modelling. However, the results produced by the model of Hyndman and Booth (2008) should still be critically interpreted and a realistic prediction interval should be chosen to make the most reliable conclusions.

2.2.1 Input Parameters

In Hyndman and Booth (2008), three demographic components, or input parameters are needed to forecast the demography. For our purposes, the fertility and net-migration can be obtained by data provided by CBS. The mortality data can also be provided by CBS, however, first some computations need to be made using population data and exposure to risk data.

Mortality

Before the mortality data can be computed, the exposure to risk has to be computed. The exposure to risk is described as the population at a certain age that is exposed to risk at 30 June of a certain year (Hyndman and Booth (2008)). Exposed to risk means that a part of the population has survived until next year even if there was a possibility that a part of the population would not survive. The method used to calculate the exposure to risk of a population, has been established by CBS. First, it is necessary to collect population data before the exposure to risk can be calculated. Not only the population data are necessary, but also the number of deaths for a certain age in a certain year. Ultimately, the formula for the exposure to risk is as follows (Stoeldraijer and Harmsen (2017)):

$$E_t^S(x) = 0.5 * (P_t^S(x-1) + P_{t+1}^S(x) + D_t^S(x)) \tag{2.1}$$

$D_t^S(x)$: Deaths in calendar year t of persons of age x on 31 December of sex S.
$P_t^S(x)$: Population of age x at 1 January of year t of sex S.

Equation 2.1 takes the average population of age $x-1$ and x and the number of deaths in a certain year to compute the exposure to risk. For example, to know the exposure to risk at age 18, the population at age 17 and age 18 are required, as well as the number of deaths at the age of 18. By taking the average of this number, we will have the population at age 18 that is exposed to risk at 30 June of year t. Both the population with age 17 and with age 18 are required, since individuals have different birthdays, which indicate that some individuals are already 18 years old and others still have to turn 18 in year t.

The sex S can be male or female. It is important to compute the input variables for male and female separately, since the life expectancy and mortality rates are higher for females (see Table 1.6). Higher life expectancy indicates lower mortality rates. Calculating the exposure to risk, and consequently the mortality rates for both male and female as one, gives very high mortality rates for females and very low mortality rates for male and therefore not a realistic view of the demography.

There is always a beginning of the mortality table and an endpoint. A mortality table is a table that shows for each age the probability of dying, and therefore not survive until next year. The first point in the mortality table is the age of 0 and the endpoint is mostly a summarised group of latest years, for example 99+. The corresponding formulas for the exposure to risk are as follows (Stoeldraijer and Harmsen (2017)):

$$E_t^S(0) = P_{t+1}^S(0) + D_t^S(0) \tag{2.2a}$$

$$E_t^S(\hat{x}) = 0.5 * \left(\sum_{x=\hat{x}-1}^{\infty} P_t^S(x) + \sum_{x=\hat{x}}^{\infty} P_{t+1}^S(x) + \sum_{x=\hat{x}}^{\infty} D_t^S(x) \right) \tag{2.2b}$$

The mortality rates can be calculated by dividing the number of deaths in a certain year for a certain age ($D_t^S(0)$) by the exposure to risk. There are two formulas, a general formula and a formula for the ending of the mortality table (Stoeldraijer and Harmsen (2017)):

$$q_t^S(x) = \frac{D_t^S(x)}{E_t^S(x)} \tag{2.3a}$$

$$q_t^S(\hat{x}) = \frac{\sum_{x=\hat{x}}^{\infty} D_t^S(x)}{E_t^S(\hat{x})} \tag{2.3b}$$

These formulas will be used to construct a mortality table, also known as a life table. It is important to notice that there are different methods to calculate the different age population groups. A well-known method to illustrate all these types of population groups is through a Lexis diagram. A Lexis diagram represents any dynamics in vital events such as births and deaths that involve change over calendar time, age, and/or cohort (Rau et al. (2017)). It is a coordinate system with on the x-axis time and with age of the population on the y-axis. In Figure 2.1 the pure effects of different methods are represented. The same colour indicates the same value in the variable of interest, in this case the mortality rates (Rau et al. (2017)). The pure age effect only has variation in the age dimension, regardless of time period (calendar year) or cohort. The pure period effect only has variation in the period dimension and the pure cohort effect only has variation in the birth cohort. A birth cohort moves in a 45° line and means that a person is one year older, one year later (Rau et al. (2017)).

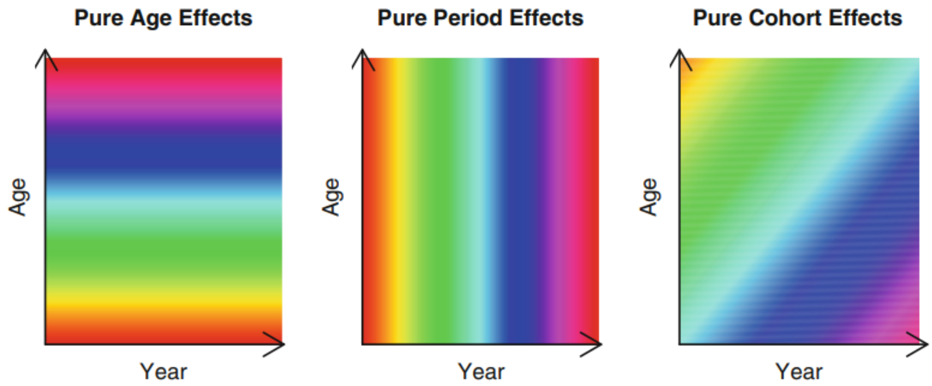


Figure 2.1: Pure Age-, Period-, and Cohort-Effects on the Lexis Diagrams (Rau et al. (2017)).

Since pure effects are seen as an unrealistic view of implementing a method for e.g. mortality rates, a combination of effects can be implemented, also seen as the method of intersections (Department of Economic and Social Affairs - Statistics Division (2004)). In case of the method provided by CBS, two intersection methods are possible, namely a period-cohort method and an age-cohort method (van der Meulen (2009)). The period-cohort method takes the average age on the 1st of January and the age-cohort method takes the age of a person on his last birthday. In Figure 2.2 the difference is shown in a Lexis diagram. The difference is also noticeable by mixing the pure Lexis diagrams. For the period-cohort method it is expected that it will go up with an angle of 45° and for the age-cohort it is expected that the diagram will go horizontally with an angle of 45°. Two examples of the composition of the Lexis diagrams are given in Figure 2.3.

A final remark has to be made related to Lexis diagrams and life tables. The Lexis diagrams given in Figure 2.3 are examples of a period life table and an age life table instead of a cohort life table. A cohort life table is the most desired life table, but is only possible to create if a full cohort has passed away (van der Meulen (2009)). For example, a cohort born in 1900 can be computed since nobody of that cohort is still alive. Therefore, in most cases, a period life table is established, based on the period-cohort Lexis diagram. This is done to make it possible to produce predictions about mortality rates and life expectancy. An important assumption is made to realise these predictions. The known mortality rates are the basis for further computations (van der Meulen (2009)). For example, the mortality rate for a 10-year old in 2004 is the same for a 10-year old that is born in 2004 and will become 10 in 2014.

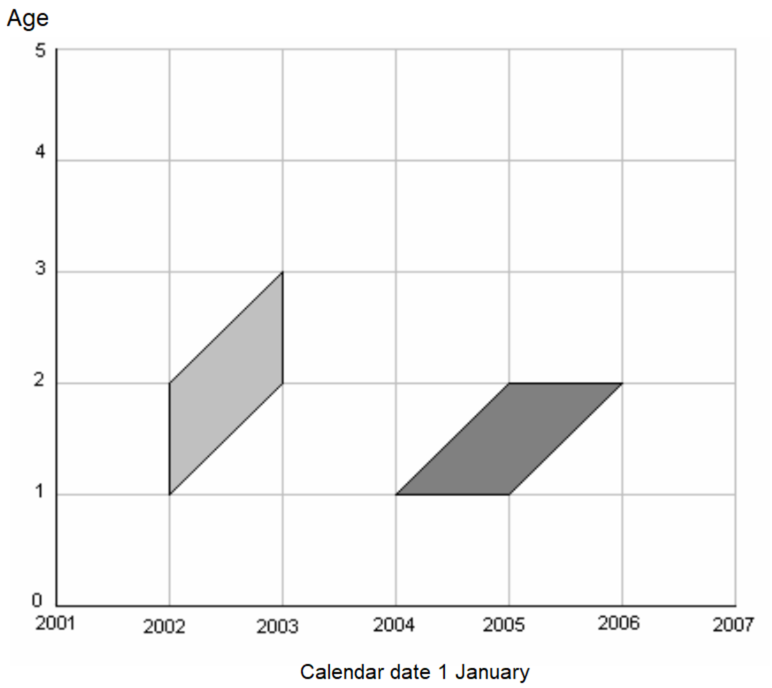
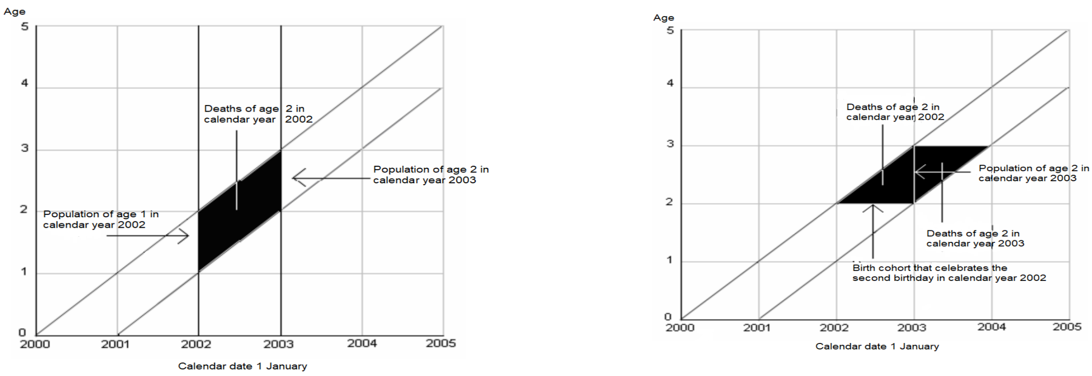


Figure 2.2: Period-Cohort in Light Grey and Age-Cohort in Dark Grey, van der Meulen (2009).



(a) Example Period-Cohort Lexis Diagram.

(b) Example Age-Cohort Lexis Diagram.

Figure 2.3: Examples Lexis diagram van der Meulen (2009).

Fertility

Another input parameter for the model of Hyndman and Booth (2008) is the fertility. Fertility is described as the quality of being able to produce young (Cambridge Dictionary (nd)). Looking at the definition, it makes sense to include fertility in predicting future demography. The fertility rate is calculated by dividing the number of births by the exposure to risk (Hyndman and Booth (2008)):

$$f_t(x) = \frac{B_t(x)}{E_t^F(x)} \tag{2.4}$$

$B_t(x)$: Births in calendar year t to females of age x.
$E_t^F(x)$: Population of females (F) of age x exposed to risk in calendar year t. This is the same exposure to risk that is calculated in section mortality described above.

The fertility rates have been fluctuating the past decades. During World War II, the fertility rates declined, but after the war ended, the number of babies born increased drastically, and therefore the fertility rates. The fertility rates started to decline in the early seventies, since the introduction of the anti conception pill. These fluctuations in fertility rates make it more difficult to produce a more accurate forecast (Hyndman and Booth (2008)). A variable to compute the change in fertility rates is the Total Fertility Rate (TFR). This can be seen as the the ratio of births to period mean size of the mothers' generation (Ortega (2006)). The TFR can be calculated using the following formula:

$$TFR_t = \sum f_t(x) \tag{2.5}$$

Even as it is seen as an indicator for fertility developments, it only looks at the child bearing behaviour of a country and not at the replacement measures, for which mortality, fertility and migration are combined (Ortega (2006)). One replacement indicator that combines all these input parameters, is the Birth Replacement Ratio (BRR). It is also seen as the ratio of births to the size of the mother's generation at birth (Ortega (2006)). Nowadays, the replacement ratio is roughly seen as 2.05. The idea of a replacement ratio could be interpreted relatively easy. For a mother to 'replace' herself, she needs to produce a girl and if she also wants to 'replace' the father, she needs to produce a boy (Smallwood and Chamberlain (2005)). Since more boys have been born than girls in the past decades, in an average ratio of 1.05, the replacement ratio is 2.05. However, this might be too short-sighted and the BRR can be calculated using different formulas. The TFR is an input parameter of the BRR. First of all, the mother's generation size at birth in year t, BG_t, is calculated as a weighted average of female births in the past (Ortega (2006)):

$$BG_t = \sum \frac{f_t(x)}{TFR(t)} * B^F(t-x) \tag{2.6}$$

$B^F(t-x)$: Number of female births in period $t-x$.

The BRR can defined as:

$$BRR_t = \frac{B_t}{BG_t} \tag{2.7}$$

This is a replacement ratio for which both the mothers as the fathers are 'replaced'. To know the ratio where only the mothers will be replaced, the Net Birth Replacement Ratio (NBRR) is calculated (Ortega (2006)):

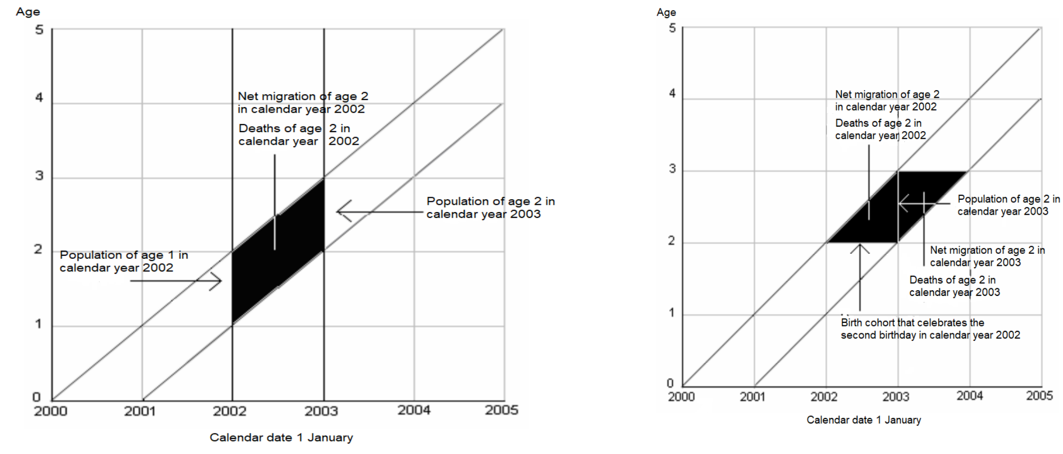
$$NBRR_t = \frac{B_t^F}{BG_t} \tag{2.8}$$

The replacement ratio and the TFR can differ significantly. The main drivers of this difference is the emigration, immigration and mortality. We will explain this in more detail in the section below.

Migration

The last input parameter of the model designed by Hyndman and Booth (2008), is the net-migration. This is the difference between immigration and emigration and can therefore be negative. Both for the calculation of mortality rates and the population size, and for the BRR, the net-migration can be an important factor. In Figure 2.3, a cohort is given by including the number of deaths and the size of a population in a certain amount of time. However, the net-migration also has an influence on these cohort sizes as shown in Figure 2.4.

As already mentioned in the section fertility, net-migration has an impact on the BRR, just as the mortality. For countries with low mortality and a lot of immigration, the TFR will be lower than the BRR (Ortega (2006)). Intuitively, this makes sense, since the population growths faster than the number of people that will leave the population, due to death or emigration. The replacement level should be higher than the TFR to compensate for this. On the other hand, countries with high mortality and a lot of emigration will have a lower replacement level than the TFR (Ortega (2006)). Overall, we conclude that net-migration is an important input parameter to predict the demography, since it has an influence on the mortality and the fertility.



(a) Example Period-Cohort Lexis Diagram with Net-Migration.

(b) Example Age-Cohort Lexis Diagram with Net-Migration.

Figure 2.4: Examples Lexis diagram with Net-Migration (van der Meulen (2009)).

2.2.2 Model

The model used by Hyndman and Booth (2008) incorporates some steps before a statement can be made about the prediction of the demography. As already mentioned in the introduction of this section, a stochastic approach is much more realistic than a deterministic approach since a probabilistic aspect is added to the forecast model. Fully probabilistic population forecasts have the major advantage of probabilistic consistency among all forecast variables, including derived indices (Lee and Tuljapurkar (1994)). Therefore, the model created by Hyndman and Booth (2008) is a stochastic model. The model is an explorative model, two factor based with no recognition of decomposition or disaggregation in the original form. The input parameters are combined using the cohort-component method and Monte Carlo simulation to produce probabilistic population forecasts by age and sex (Hyndman and Booth (2008)). An overview of the cohort-component method is given in Figure 2.5.

The idea is that we look at components of population change, so mortality, fertility and migration, for different cohorts. The starting point is the launch year population that is divided into age-sex cohorts, since females and males have different mortality rates. The age cohorts can be divided in several ways, but most commonly used are the one to five year groups (Smith et al. (2013)). The oldest cohort is a final cohort, for example 95+. The first step is to calculate the migration rates. This can be calculated using net-migration or for immigration and emigration separately (Smith et al. (2013)). The model of Hyndman and Booth (2008) uses net-migration, denoted as G_t, and estimate this parameter by using the demographic growth-balance equation. This equation is given as follows:

$$\begin{aligned} G_t(x,x+1) &= P_{t+1}(x+1) - P_t(x) + D_t(x,x+1) \\ & \qquad x = 0,1,2,...p-2; \\ G_t(p-1^+,p^+) &= P_{t+1}(p^+) - P_t(p^+) - P_t(p-1) + D_t(p-1^+,p^+); \\ G_t(B,0) &= P_{t+1}(0) - B_t + D_t(B,0) \end{aligned} \tag{2.9}$$

$G_t(x,x+1)$: net-migration in calendar year t of persons aged x at the beginning of year t.
$D_t(x,x+1)$: Deaths in calendar year t of persons aged x at the beginning of year t.
$D_t(p-1^+,p^+)$: Deaths in calendar year t of persons aged $p-1^+$ and older at the beginning of year t.
$G_t(p-1^+,p^+)$: net-migration in calendar year t of persons aged $p-1$ and older at the beginning of year t.
$D_t(B,0)$: Deaths in calendar year t of births during year t.
$G_t(B,0)$: net-migration calendar year t of births during year t.

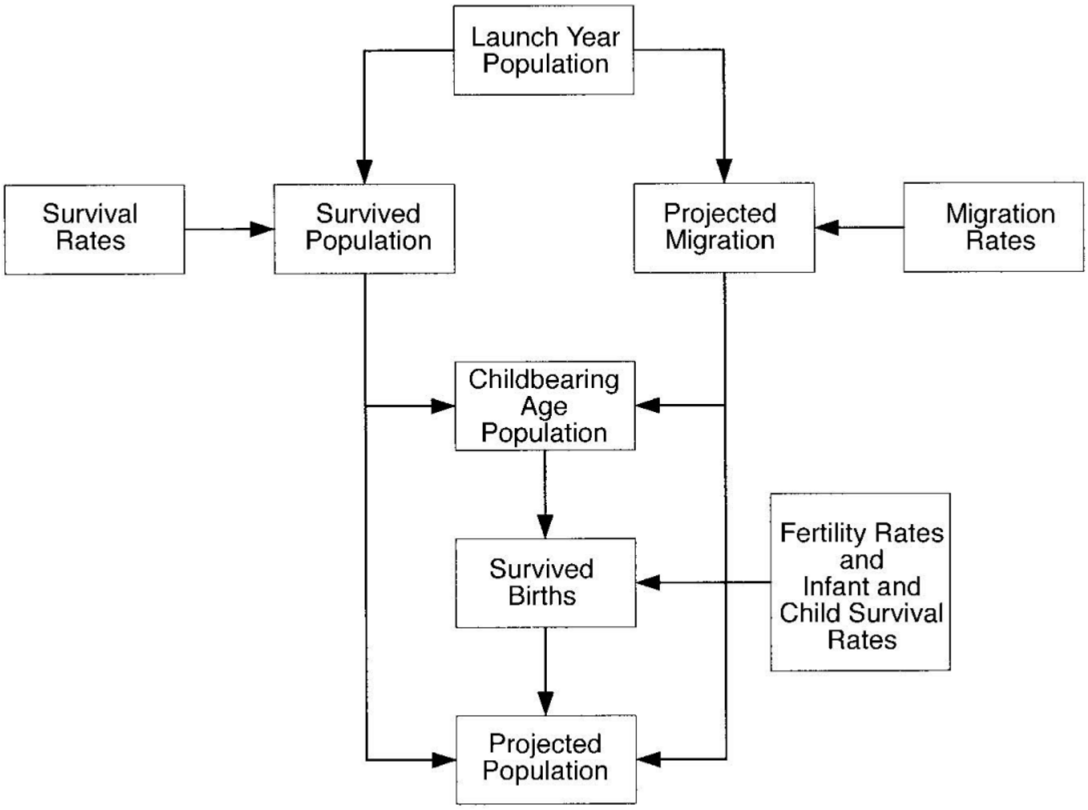


Figure 2.5: Cohort-Component Overview (Smith et al. (2013)).

It must be said that the method of using net-migration instead of immigration and emigration is less accurate. At first, the method of net-migration forecasting and emigration and immigration forecasting separately, did not differ that much, but after informed judgement, the net-migration forecast seems to be too low (Booth (2006)). This can be seen as a drawback in the use of the method of Hyndman and Booth (2008).

The second step in calculating the projected population is calculating the number of people that will survive (according to the method of CBS in this master thesis). The third step in the cohort-component method is the computing of the number of births that will occur. This is accomplished by applying age-specific birth rates to the femal population in each age cohort (Smith et al. (2013)). The final step is to add the number of births to the survived population and the net-migration population, for male and female separately computed. This process is repeated until the final target year is reached (Smith et al. (2013)). So, to obtain the demographic forecast, a forecast of the five sex-specific components is made, namely $q_t^F(x)$, $q_t^M(x)$, $f_t(x)$, $G_t^F(x, x+1)$ and $G_t^M(x, x+1)$ (Hyndman and Booth (2008). In Appendix B, an overview of the algorithm is given, used by Hyndman and Booth (2008).

Functional Data Model

The model of Hyndman and Booth (2008) uses a functional data model, also seen as functional data analysis. This type of statistical analysis is gaining more publicity. Besides the 'standard' goals of statistical analysis such as representing the data in ways that aid further analysis and studying important sources of pattern and variation among the data, like other statistics methods, functional data analysis also compares two or more sets of data with respect to certain types of variation, in which two sets of data can contain different sets of replicates of the same functions, or different functions for a common set of replicates (Ramsay and Silverman (2005)). More data are becoming available, even in time series. Functional data analysis provides an tool for analysis in the form of a function. The five sex-specific components are converted in functional time series models, according to Hyndman and Booth (2008). Or, more technically described: Assuming that functional data for replication i arrive as set of discrete measured values, $y_{i,1}, ..., .y_{i,n}$, the first task is to convert these values to a function x_i with values $x_i(t)$ computable for any desired argument value t (Ramsay and Silverman (2005)). There are two differences in this process, namely interpolation and smoothing. In the first case it is assumed that the discrete values are error-free and in the second case the discrete values have some observational error that need to be removed (Ramsay and Silverman (2005)). Since it is likely that the sex-specific components have observational errors, the smoothing procedure is used in the functional data model of Hyndman and Booth (2008).

Hyndman and Booth (2008) use different model steps for estimating the time series model in the functional data model. They follow the model described by Hyndman and Ullah (2007):

1. Estimate smooth functions ($s_t(x)$) for every input parameter (mortality, fertility and migration) with a nonparametric method for each year t. For input parameter $y_t(x)$ is the quantity that should be modelled with as function $y_t(x) = s_t(x) + \sigma_t(x)\epsilon_{t,x}$ and $\epsilon_{t,x}$ is a randomness element. For which $\sigma_t(x)$ allows the variation to change with age and time. This is the error in the smooth function and is given as $s_t(x) = \mu_t(x) + \sum_K^{k=1} \beta_{t,k}\phi_k(x) + e_t(x)$. For which $e_t(x) \sim N(0, v(x))$ is the model error.
2. Estimate the mean ($\mu(x)$) of $s_t(x)$ across years.
3. Estimate series coefficients ($\beta_{t,k}$) and the orthogonal basic functions $\phi_k(x)$. $k = 1, ..., K$ using a principal component decomposition of $[y_t(x) - \hat{\mu}(x)]$.
4. Fit univariate time series models to each of the coefficients $\beta_{t,k}, k = 1, ..., K$

Ultimately, the coefficients are forecast, such that the three different input parameters can be forecast (Hyndman and Ullah (2007)):

5. Forecast each of the coefficients $\beta_{t,k}, k = 1, ..., K$, for $t = n+1, ..., n+h$ using the fitted time series models.
6. Use the forecast coefficients with the smoothing function to obtain the forecasts of $y_t(x), t = n + 1, ..., n + h$.
7. The estimated variances of the error terms in the smoothing function and the function of the input parameter are used to compute prediction intervals for the forecasts.

In the next sections, we explain the different steps in a little more detail.

Smoothing

A smoothing function is used to remove observational errors. There are several methods for doing this, but only two methods are explained in more detail by Hyndman and Booth (2008). The first method is called 'weighted constrained penalized regression splines', also known as weighted splines. The function $y_t(x) = s_t(x) + \sigma_t(x)\epsilon_{t,x}$ (computed for all three input parameters) has a variation component, namely $\sigma_t(x)$. This component causes heterogeneity. The weighting takes care of the heterogeneity and a monotonic constraint for upper ages can lead to better estimates (Booth et al. (2014)). The monotonic constraint is implemented since the observational error has higher variance at very old ages, since the populations sizes are becoming smaller. The weights are equal to the approximate inverse variances, so $w_{x,t} = \frac{y_{x,t}}{E^S_{x,t}}$ (Booth et al. (2014)). Splines are used to create a smooth line, based on different observational points, to estimate the curve $s_t(x)$ for every year.

The weighted splines method is preferred because the three input parameters can be computed quickly, and allow monotonicity constraints imposed relatively easily (Booth et al. (2014)). On the other hand, it only takes a smooth function of x (age) in stead of t (time). Hyndman and Ullah (2007) argue that the occurrence of wars and epidemics meant that $y_t(x)$ should not be assumed to be smooth over time. To solve this problem, a method of two-dimensional P-splines was designed by (Currie et al. (2004)). It must be said that it was designed to smooth the mortality rates. They used a generalised linear modelling framework for the Poisson deaths ($D_{x,t}$) with two-dimensional B-splines.

If we look at the outcome of these two different methods, the weighted splines method is more appropriate in the age dimension, so age is the horizontal axis in a figure with the mortality rates on the y-axis. This has to do with a better estimate on the oldest age due to monotonic constraint (Booth et al. (2014)). On the other hand, the two-dimensional P-splines makes a better estimate on the time dimension, so time is on the horizontal axis in a figure with the mortality rates on the y-axis.

Besides the choice in smoothing method, another transformation has to be made to ensure correct calculations, the so-called Box-Cox transformation. This method is used to transform dependent variables to a normal distribution (Box and Cox (1964)). The parameter λ determines the strength of the transformation. The Box-Cox transformation is given as follows:

$$y^{(\lambda)} = \begin{cases} \frac{y^{(\lambda)}-1}{\lambda} & \text{if } \lambda \neq 0 \\ log(y) & \text{if } \lambda = 0 \end{cases} \tag{2.10}$$

If $\lambda = 1$, we can derive from the Box-Cox transformation that no transformation is made. In case of $\lambda = 0$, a log transformation is computed. For every input parameter in the demographic model, an estimation of λ should be made such that the correct Box-Cox transformation is computed.

Fitting

After the smoothing procedure, the data are fitted to the Hyndman and Ullah (2007) method, as described above. We will treat this as the original model, or HU-model. An extension of the basic model is possible in two ways. First of all, a robustness element can be incorporated to ensure that outliers will not affect the performance of modelling and forecasting (Booth et al. (2014)). Zero weight is assigned to outliers to decrease their influence on the outcomes. This model is seen as the robust Hyndman-Ullah method with a corresponding name: HUrob. Another extension of the HU-method is the use of weights. The original model does not incorporate weights in the principal component analysis which results in the same weights for every year in the historical data set. The weighted Hyndman-Ullah method (HUw) makes recent data more important such that recent years have a greater influence on the forecast (Booth et al. (2014)).

The principal components are used to explain the variance that is present in the data. Hyndman and Booth (2008) decided to choose a large value for K. The slightly increased computing time in selecting a large K is less important than the increased forecast accuracy, since more variance is explained. Time series models are fitted to each of the coefficients $\beta_{t,k}$, where $k = 1, ..., K$ as the number of principle components. For the HU methods, ARIMA modelling is used. ARIMA models consist of three elements, namely an autoregressive part, the degree of differencing a model and a moving average part, for which it is possible to have a model which holds all three elements. We will discus the idea of ARIMA modelling shortly.

ARIMA stands for Autoregressive, Integrated, Moving Average. So, the first part is the autoregressive model (AR). Autoregressive models are based on the idea that the current value of the series, x_t, can be explained as a function of p past values, $x_{t-1}, x_{t-2}, ..., x_{t-p}$, where p determines the number of steps into the past needed to forecast the current value (Shumway and Stoffer (2011)). This will result in the following formula for AR(p):

$$\begin{aligned} x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + ... + \phi_p x_{t-p} + w_t \qquad or \\ x_t = \sum_{i=1}^{p} \phi_i X_{t-i} + w_t \end{aligned} \tag{2.11}$$

where w_t is the Gaussian white noise with mean zero and variance σ_w^2, unless otherwise stated. This formula can be written in a shorter way by including an autoregressive operator that summarise the past values:

$$\begin{aligned} x_t = \phi_1 B x_t + \phi_2 B^2 x_t + ... + \phi_p B^p x_t + w_t \\ x_t = \sum_{i=1}^{p} \phi_i B^i X_t + w_t \end{aligned} \tag{2.12}$$

The moving average model of order q (MA(q)), differs from the AR model since in the AR model, the errors are assumed to be uncorrelated, which seems an unrealistic assumption in some scenarios. In the MA model, the errors are correlated and used in making forecasts. The formula of the MA(q) is given as follows:

$$\begin{aligned} \epsilon_t &= w_t + \theta_1 w_{t-1} + \theta_2 w_{t-2} + ... + \theta_q w_{t-q} \\ \epsilon_t &= \sum_{i=1}^{q} \theta_i w_{t-i} \end{aligned} \tag{2.13}$$

where w_t is assumed to be a Gaussian white noise process with mean zero and variance σ_w^2, unless otherwise stated (Shumway and Stoffer (2011)). It is also noticeable that the errors are correlated since w_t depends on w_{t-1} and so on. The number of lags (q) are the corrected errors in the model. It is possible to work with an operator that summarises the past values:

$$\begin{aligned} \epsilon_t &= (1 + \theta_1 B + \theta_2 B^2 + ... + \theta_q B^q) w_t \\ \epsilon_t &= \sum_{i=1}^{q} \theta_i B^i w_t \end{aligned} \tag{2.14}$$

The last element of the ARIMA model is the Integrated model ($I(d)$). This element is used for differencing, since stationary data are required. A strictly stationary time series is one for which the probabilistic behavior of every collection of values $x_{t_1}, x_{t_2}, ..., x_{t_k}$ is identical to that of the time shifted set $x_{t_1+h}, x_{t_2+h}, ..., x_{t_k+h}$ (Shumway and Stoffer (2011)). The number of differencing is given by d, so if $d = 2$, two times of differencing is used. The first time by taking the difference of the current time period and the previous period and the second time by taking the gap between the differenced data and the previous time period.

Overall, an ARIMA model is given as ARIMA(p, d, q), where p is the number of autoregressive elements, d is used for the number of times of differencing needed to obtain stationary data and q represents the number of lagged forecast errors that are correlated. At the end, this will result in the following formula for an ARIMA model (Hyndman and Khandakar (2008)):

$$\begin{aligned} \phi(B)(1-B)^d x_t &= \theta(B) w_t \\ \phi(B) &= 1 - \phi_1 B - \phi_2 B^2 - .... - \phi_p B^p \\ \theta(B) &= 1 - \theta_1 B - \theta_2 B^2 - .... - \theta_q B^q \end{aligned} \tag{2.15}$$

So, we explained how ARIMA models work and now we have to clarify why ARIMA models are used instead of other time series models and how the fitting procedure works for the ARIMA models on the input parameters. The main reason to choose ARIMA models instead of e.g. exponential smoothing methods is the fact that ARIMA models can make data stationary where exponential smoothing models are non-stationary (Hyndman and Khandakar (2008)). The assumption of stationary data is necessary for using the model of Hyndman and Booth and the model of Hyndman and Ullah, since among others, the mean and variance will be constant over time. By fitting an ARIMA model to the coefficients for each input parameter, the best model is chosen by using the AIC value, which stands for Akaike's Information Criterion (Hyndman et al. (2013)). The AIC is an estimate of the Kullback-Leibler discrepancy between a true model and a candidate model (Shumway and Stoffer (2011)). The ARIMA model with the smallest value of AIC , the model with the least discrepancy between the original time series, is chosen. The AIC is computed with the following formula:

$$AIC = 2k - logL_k \tag{2.16}$$

where L_k is the maximized log likelihood and k is the number of parameters in the model (Shumway and Stoffer (2011)).

During the fitting procedure, a type of HU model is chosen and the different ARIMA models for the coefficients for each input parameter. But Hyndman and Booth (2008) made another distinction in their model in comparison with the model of Hyndman and Ullah (2007). They use a coherent component method to obtain age-specific forecasts of the population by sex (Hyndman and Booth (2008)). By assuming independence of sub populations, in this case by sex, the forecasts of input parameters will almost always diverge in the long term (Hyndman et al. (2013)), which means that the gap between male and female outcomes of mortality and migration rates will increase. This might result in an undesirable side effect and using the coherent component method will ensure the historical structural relationship. The usage of the product-ratio method will result in the coherent component method, with the ratio model as the ratio between male and female. The square roots of the products and ratios of the smoothed rates for each sex are as follows (Hyndman et al. (2013)):

$$p_t(x) = \sqrt{f_{t,M}(x) f_{t,F}(x)} \tag{2.17a}$$

$$r_t(x) = \sqrt{\frac{f_{t,M}}{f_{t,F}(x)}} \tag{2.17b}$$

The functional time series models for $p_t(x)$ and $r_t(x)$ are almost the same as the models of Hyndman and Ullah (2007):

$$p_t(x) = \mu_p(x) + \sum_{k=1}^{K} \beta_{t,k}\phi_k(x) + e_t(x) \tag{2.18a}$$

$$r_t(x) = \mu_r(x) + \sum_{l=1}^{L} \gamma_{t,l}\psi_l(x) + w_t(x) \tag{2.18b}$$

where the functions $\phi_k(x)$ and $\psi_l(x)$ are the principal components obtained from decomposing $p_t(x)$ and $r_t(x)$, respectively, and $\beta_{t,k}$ and $\gamma_{t,l}$ are the corresponding principal component scores (Hyndman et al. (2013)). The function $\mu_p(x)$ is the mean of the set of curves $p_t(x)$ and $\mu_r(x)$ is the mean of $r_t(x)$ and the error terms, given by $e_t(x)$ and $w_t(x)$, have zero mean and are serially uncorrelated (Hyndman et al. (2013)). As you might notice, this is simular to the smoothing functions of the HU method.

The functional time series models are using the HUw model, so more weight is placed on recent data and the fitting of the ARIMA models uses the same procedure as described above.

Forecasting

The forecast procedure is based on the fitted model for each input parameter. First of all, the net-migration is predicted, since we want to take into account the births and deaths among annual migrants. Therefore, the population is first adjusted, by assuming that migrants spend, on the average, half of the year exposed to events (Hyndman and Booth (2008)). This means that half of the computed net-migration in Equation 2.9, is added to the population aged x on 1 January of year t and the other half is added to the population $x+1$ at the end of year t. The population adjusted for the first half of net-migration is denoted by $R_t^S(x)$ (see Appendix B). The same procedure is followed for the births in net-migration and for the oldest ages in net-migration.

The next step is to forecast the mortality rates. Therefore, we need the random number of deaths for the mid-year population, which is computed by the derived life table from CBS data and the population adjusted for the first half of net-migration ($R_t^S(x)$). By using these two sets of data, the expected number of cohort death is calculated and we use this number to forecast $R_{t+1}^S(x)$ (see Appendix B). The product of this mid-year population and $q_t^S(x)$ defines the Poisson distribution from which $D_t^S(x)$ is randomly drawn (Hyndman and Booth (2008)), as is shown in Appendix B.

Finally, we obtain the number of births by the fertility rate $f_t(x)$ and the population adjusted for half of net-migration. Births are assumed to be Poisson distributed with mean $f_t(x)[R_t^F(x) +$

$R^F_{t+1}(x)]/2$ for $x = 15, ..., 49$ (Hyndman and Booth (2008)). A random draw from this distribution determines $B^S_t(x)$ where the male and female births are derived by a Binomial distribution with probability $\rho/(\rho+1)$. The procedure of mortality is applied to the number of births as described above. So, number of deaths $D^S_t(B,0)$ is divided into deaths to births in year t and deaths at age 0 to births in year $t-1$. The last fraction is the population that is still 0 in year t, but would turn 1 if they had not died.

Ultimately, we forecast each of the input parameters to obtain the population for next year. This process is repeated until the desired forecast period is derived. In the formula form, this will look as follows:

$$\hat{y}_{n,h}(x) = \hat{s}_{n,h}(x) = \hat{\mu}(x) + \sum_{k=1}^{K} \hat{\beta}_{n,k,h}\hat{\phi}_k(x) \tag{2.19}$$

The formula for the product-ratio method, with the product and ratio part combined, is looking as follows:

$$\hat{y}_{n+h|n,j}(x) = \hat{\mu}_j(x) + \sum_{k=1}^{K} \hat{\beta}_{n+h|n,k}\hat{\phi}_k(x) + \sum_{l=1}^{L} \hat{\gamma}_{n+h|n,l,j}\hat{\psi}_{l.j}(x) \tag{2.20}$$

Both forecasting methods deal with forecast variance. The basic method has the following formula for the variance:

$$V_h(x) = Var[s_{n+h}(x)|\mathcal{I},\Phi] = \hat{\sigma}^2_{\mu}(x) + \sum_{k=1}^{K} u_{n+h,k}\hat{\phi}^2_k(x) + v(x) \tag{2.21}$$

where $\mathcal{I} = y_t(x_j)$ denotes all observed data, $\hat{\sigma}_{\mu}(x)$ is the variance of the smooth estimate $\hat{\mu}(x)$ and can be obtained from the smoothing method used,
$u_{n+h,k} = Var(\beta_{n+h,k}|\beta_{1,k}, .., \beta_{n,k})$ can be obtained from the time series model and $v(x)$ is estimated by averageing $\hat{e}^2_t(x)$ for each x (Hyndman and Booth (2008)). This means that the smoothing error is given by $\hat{\sigma}^2_{\mu}(x)$, the error due to predicting the dynamics is given by $\sum_{k=1}^{K} u_{n+h,k}\hat{\phi}^2_k(x)$ and the error due to the unexplained dynamic variation is $v(x)$ (Hyndman and Booth (2008)). If we include the observational error, the variance for the whole forecast will be:

$$Var[y_{n+h}(x)|\mathcal{I},\Phi] = V_h(x) + \sigma^2_t(x) \tag{2.22}$$

The forecast variance of the product-ratio method is given as:

$$\begin{aligned} Var(y_{n+h,j}(x)|\mathcal{I}_n) = \hat{\sigma}^2_{\mu_j}(x) + \sum_{k=1}^{K} u_{n+h|n,k}\hat{\phi}^2_k(x) + \\ \sum_{l=1}^{L} v_{n+h|n,l,j}\hat{\gamma}^2_{k,j}(x) + v_e(x) + v_{w,j}(x) + \sigma^2_{n+h,j}(x) \end{aligned} \tag{2.23}$$

where $\mathcal{I}_n$,$\hat{\sigma}^2_{\mu_j}$, $u_{n+h|n,k}$ and $v_{n+h|n,k}$ fulfill the same function as in the original model. $v_e(x)$ is estimated by averageing $\hat{e}^2_t$ in the product formula and $v_{w,j}(x)$ is estimated by averageing $\hat{w}^2_{t,j}$ in the ratio formulas (Hyndman et al. (2013)). It is possible to add all the different errors since there are no correlations between the terms in the forecasting formula. The correlations between ages are dealt with naturally in the formulation due to the smooth functions of age (x) and the correlations between years are handled by the time series models for the coefficients $\beta_{t,1}, ..., \beta_{t,K}$ (Hyndman and Booth (2008)).

A final note to the forecasting procedure is the number of years to be forecast. Time series models are used in the extrapolative methods, but are not designed for long-term forecasting, since these type of forecasts are based on ex ante estimation, so estimation based on the previous forecast instead of the reality, which result in estimates that depends on the particular forecasting method used (Booth (2006)). This might result in unrealistic point forecasts and prediction intervals. The same phenomenon applies to the product-ratio method, since the long-term forecasts of the ratio function will converge to the age-specific mean ratios, which are determined by the choice of fitting (Hyndman et al. (2013)). We would expect that methods based on expectation would solve this problem, since this method is robust to changes in the probability and the distributional form. However, methods based on expectation are not suited to short-term forecasting where variation may be greater than can be captured by the combined assumptions of linearity and normality (Booth (2006)) and this also seems the case for long-term forecasting. Therefore, it is important to make a forecast that has not a long forecasting period, so not longer than 50 years ahead.

Simulating

After setting the forecast values for mortality, fertility and net-migration, each of these values need to be simulated to create reliable future populations. We have the possibility to establish the future populations by an analytic approach, or by performing a Monte Carlo simulation. The analytical approach involves the specification of a stochastic Leslie matrix and permits the assessment of the relative contribution of errors in mortality, fertility and net-migration to the population error (Booth (2006)). The drawback of this approach is the complexity and therefore the need for assumptions and approximations. Monte Carlo simulation avoids these problems since each step of the forecast is generated by randomly drawn parameters for the distributions of mortality, fertility and net-migration (Booth (2006)). So in case of the Hyndman and Booth model, we will simulate for each of $G_t^S(x, x+1)$, $q_t^S(x)$ and $f_t(x)$ a larger number of future sample paths by using the time series models to generate random sample paths of $\beta_{t,k}$ for $t = n+1, ..., n+h$ conditional on $\beta_{1,k}, ..., \beta_{n,k}$. Random values of $e_t(x)$ are also generated by bootstrapping estmated values (Hyndman and Booth (2008)). The population distribution is derived from the percentiles of the set of forecasts (Booth (2006)).

The usa of Monte Carlo simulation is connected with the number of simulations paths that need to be generated to get a reliable forecast, also known as the number of iterations to be made. If we assume normality, which is possible if we use the Box-Cox transformation, the formula for the required number of iterations is given as follows (Bukaçi et al. (2016)):

$$n = \left[\frac{100 z_c S_x}{E\overline{x}}\right]^2 \tag{2.24}$$

where n is the number of iterations, z_c is the value of confidence coefficients, E is the percentage error of the mean, S_x is the estimated standard deviation of the output and $\overline{x}$ is the estimated mean.

Forecast Accuracy

A forecasting model always contains uncertainty since we try to draw conclusions of a period that not even happened. Therefore, we can work with prediction intervals that will take into account a certain amount of uncertainty in the forecast parameters. The uncertainty is created by the randomness in the Hyndman and Booth model. If we look at Equations $y_t(x) = s_t(x) + \sigma_t(x)\epsilon_{t,x}$ and $s_t(x) = \mu(x) + \sum_{k=1}^{K} \beta_{t,k}\phi_k(x) + e_t(x)$, we see three different sources of randomness (Hyndman and Booth (2008)):

- $\epsilon_{t,x}$ represents the random variation in births, deaths or migrants from the relevant distribution.
- $e_t(x)$ represents the residual error in modelling $s_t(x)$ using a finite set of basis functions.
- $\beta_{t,k}(x)$ is the randomness inherent in the time series model, which drives the dynamic changes in $s_t(x)$

These sources of randomness create forecast errors. This is not a bad thing, the aim is to use a model that creates the lowest forecast errors, or differently stated, has the best forecast accuracy. Therefore, we first need to understand what the several forecast errors are, understand the different types of correlation in the forecast errors and lastly, have formulas to compute the forecast accuracy.

By using explorative methods, the model specification has the most important influence in the forecast accuracy. As mentioned above, a lot of different choices can be made until eventually a forecasting model is created. So, it is possible to have a model misspecification, either by choosing the incorrect underlying model of the forecast or by choosing the wrong time series model (Booth (2006)). If we use methods based on expectation, it might occur to have errors in informed judgment. Informed judgement in statistical modelling refers to 'prior' beliefs about model parameters and the weight given to them in forecasting (Booth (2006)). Both forecasting methods can increase or reduce the forecast accuracy.

Correlation among forecast errors may occur. There could be temporal or serial (auto)correlation, which is negligible if we determine the population growth in the long-term instead of one year (Booth (2006)). The correlation across age is mostly positive since forecasting methods often take advantage of the regularity of age patters or assume a fixed age pattern (Booth et al. (2014)). Positive correlations between sexes also arise if a perfect correlation between them is assumed which result in some overestimation of the population forecast uncertainty (Booth (2006)).

The measurement of the forecast accuracy is done by computing the mean squared error (MSE) and the integrated squared error (ISE). The MSE is a measure of forecast accuracy averaged across years and the ISE is a measure of forecast accuracy integrated across ages (Hyndman (2019)). This means that the MSE will give the amount of error during the ages and the ISE will give the amount of error during the years. We might expect that the ISE will increase by a forecast further in time. Both should be as low as possible and stated with the following formulas (Hyndman and Ullah (2007)):

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2 \tag{2.25}$$

$$ISE_t(k) = \int_x e^2_{t,k}(x)d(x) \tag{2.26}$$

2.2.3 Output Parameters

In this section we discuss the output parameters of the demography forecast. We make a distinction between the direct model output and the indirect model output. The direct model output are the forecast input parameters, the basic functions, the component coefficients and the forecast population. The indirect output parameters are the ratios, such as the BRR, that can be computed from the direct output parameters.

Model

The model output consists of the time series coefficients ($\beta_{t,k}$) which explain the time variance and the orthogonal basic functions ($\phi_k(x)$) which explain the age variance (Hyndman and Booth (2008)). In most cases, the first coefficient explains the most variance. Besides the coefficients, we get a forecast output of the input parameters. From these parameters, we can derive the forecast population. For every forecast output, we will see a confidence interval, for which we would expect that the confidence interval is wider for the years further into the future.

Ratios

Firstly, we can compute the future BRR from the new population parameters by using the method described in Section 2.2.1. Another set of ratios that can be computed are the dependency ratios, namely the old-age dependency ratio, the child dependency ratio and the total dependency ratio, since these ratios provide an indication of the composition of the demography. The old-age dependency ratio is described as the population size that is 65 years old or older in comparison with the working-age population, which have the ages of 15-64 years old (Muszyńska and Rau (2012)). In the same way, the child dependency ratio can be described as the younger part of the population, so 15 years or younger in comparison with the working-age population. The total dependency ratio combines the older and younger part population and compares this with the rest of the population. In total, we derive three formulas:

$$\text{Old-age dependency ratio} = \frac{P_t^S(65^+)}{P_t^S(15-64)} \tag{2.27a}$$

$$\text{Child dependency ratio} = \frac{P_t^S(0-14)}{P_t^S(15-64)} \tag{2.27b}$$

$$\text{Total dependency ratio} = \frac{P_t^S(0-14) + P_t^S(65^+)}{P_t^S(15-64)} \tag{2.27c}$$

To draw conclusions from the dependency ratios, we will use the values of the Population Reference Bureau to categorise the different demographic statuses a country might have, as shown in Table 2.1. So, if we take high child dependency as an example, we would have more than 45 children in the age group of 0 - 14 years and less than 15 old-age people for every 100 people in the working-age population.

Dependency	**Value Child Dependency Ratio**	**Value Old-Age Dependency Ratio**
High Child Dependency	>0.45	<0.15
Moderate Child Dependency	0.29-0.45	<0.15
Double Dependency	0.29-0.45	$\geq$ 0.15
High Old-Age Dependency	<0.29	$\geq$ 0.15
Low Overall Dependency	<0.29	<0.15

Table 2.1: Different Dependency Ratios, PRB (2018).

2.3 Model Social Security System

Forecasting expenditures of a social security system seems relatively simple. We know the demography of a population and therefore we know the total tax incomes and the total expenditures, which will result in a shortage or a surplus, depending on whether the total incomes or expenditures are higher. Unfortunately, this process is too simple. Every national economy does not only have tax-related cash flows, but also with revenues from (financial) investments and payments for debt. Besides, we have to take into account the concept of discounting, where one euro today is worth more than it would be worth tomorrow.

These two concepts make it much more difficult to forecast the social security revenues and expenditures. However, pioneers in the field of fiscal planning are Auerbach et al. (1999). They introduced the concept of generational accounting. Its goals are to assess the sustainability of fiscal policy and to measure the fiscal burdens facing current and future generations. They assumed that either current or future generations pay the government's bills. If the present value of future net tax payments of current generations are subtracted from the tax incomes, we would get the present value of the net tax burden for future generations caused by the current financial policy. Net tax payments are stated as paid taxes without the social security, welfare and other transfer payments received.

Auerbach et al. (1999), required that the present value of future net tax payments of current and future generations be sufficient to cover the present value of future government expenditures. They created a formula to represent this requirement:

$$\sum_{k=t-D}^{t} N_{t,k} + (1+r)^{-(k-t)} \sum_{k=t+1}^{\infty} N_{t,k} = \sum_{s=t}^{\infty} G_s (1+r)^{-(s-t)} - W_t^g \tag{2.28}$$

The left-hand side of the formula represents the generational net tax payments. The first summation stands for the present value of the remaining lifetime net payments, so for the existing generations. $N_{t,k}$ represents the net tax payment of the generation born in year k. As stated in the formula, $k = t - D$, where t is the year a person is born and D is the maximum length of life. The second summation represents the present value of the net tax payments for the future generations, where k still is the year of birth. The second summation is discounted using the government's real return r. $N_{t,k}$ is the net tax payment for a whole generation, so we can show that this is computed based on an individual level:

$$N_{t,k} = \sum_{s=\kappa}^{k+D} T_{s,k} P_{s,k} (1+r)^{-(s-\kappa)} \tag{2.29}$$

We notice that $N_{t,k}$ consists of two elements. $T_{s,k}$ denotes the projected average net tax payment to the government made in year s by a member of the generation born in year k. The term $P_{s,k}$ stands for the number of surviving members of the cohort in years s who were born in year k, where $\kappa = max(t, k)$. Auerbach et al. (1999) used the mortality and immigration rates to calculate $P_{s,k}$.

The right-hand side of Equation 2.28, expresses the financial status of the government. The summation stands for the present value of the government consumption in year s. As shown, these consumption's are also discounted with factor r. W_t^g denotes the government's net wealth in year t, which is the government's assets minus the debt.

So, the idea of generational accounting is clear. We now introduce a model that is further developed. Alho and Vanne (2006), made a simulation study to predict the shortage or surplus in the financial planning of a country. A major improvement to the original generational accounting method is that this method is combined with the stochastic population forecasting method. This adjustment is made to create a more realistic financial forecasting model for the governments budget. We are looking for a sustainable financial planning, which means that the difference between total expenditures and revenues must be zero. This indicates that each cohort pays exactly what it gets from the public sector. Alho and Vanne (2006) used a general formula to compute the sustainability, or lack of sustainability, of a financial planning:

$$\begin{aligned} IPL = &\textit{(discounted future entitlements of all current and future generations)} \\ &-\textit{(discounted future taxes of all current and future generations)} \\ &-\textit{(current public wealth)} \end{aligned} \tag{2.30}$$

IPL states for intertemporal public liabilities. The formula looks quite similar to the generational accounting formula of Auerbach et al. (1999). However, the entitlements and taxes are based on a stochastic population forecasting method and the public wealth is computed with different economic variables. We will discuss the IPL in more detail in the sections below.

A constant demography is not a realistic view for computing the IPL. On the other hand, a stochastic population forecast is very uncertain in essence, which could also lead to an unrealistic IPL. We must notice that the IPL calculations may be substantially in error, so therefore, it is not a precise forecast but an indication of the possible outcomes of the IPL. Since Alho and Vanne (2006) use demographic and economic variables that will only be known in the future, we see the IPL as a reasonable forecasting model.

The model of Alho and Vanne (2006) can be summarised in three modelling steps:

1. Stochastic Population Forecasts
   Alho and Vanne (2006) used a forecasting model where the fertility rates and net-migration rates are assumed to be fixed and only the mortality rates appear to change over time. This is different from the model that we explained in Section 2.2.2. Therefore, we will use the model that we already described in this section.

2. Forecasting Economic Variables
   Alho and Vanne (2006) use three variables, namely the real interest rates, the stock returns and the productivity to indicate the public wealth of a country.

3. Forecast the IPL
   In this step, the stochastic population forecast and the forecast of the economic variables is combined to get the IPL. If we look at Equation 2.30, we would have an outcome of zero

to have a fully sustainable system. It is more realistic that the IPL is not zero, indicating an unstable financial planning. If the IPL is negative, there is a surplus and if the IPL is positive there is a shortage.

In the sections below, we will explain step 2 and 3 in more detail.

2.3.1 Economic Variables

A first indication of the development of the economic variables is the primary balance. This is the public revenue in percentage of GDP minus the public expenditures in percentage of GDP. If this rate is positive, we already might expect an increase of the public wealth. Only looking at the primary balance would be to short-sighted since a national economy also growths by investments and productivity. Alho and Vanne (2006) state that increases in productivity typically increase the tax revenues, earnings related pensions and standard of social services. Therefore, a major source in uncertainty in the IPL is the future development of productivity. Besides the usage of the productivity for the increase or decrease in the public wealth, we also should taken into account the composition of the public wealth, namely by identifying the amount of debt and the amount of assets. Alho and Vanne (2006) use the real interest rates to indicate the amount of debt and the stock returns for the amount of assets, where W_1 represents the debt owed in bonds and W_2 is the wealth owned in stocks. So, the total public wealth is $W = W_1 + W_2$. The real interest rates and the stock returns are an indication of the amount of debt and wealth. In real life other factors could be included as well.

There are more theories in literature to account for economic variables to forecast the public net wealth. Creedy and Scobie (2005) not only use productivity, but also the initial productivity (defined as GDP per employed person), employment rates, participation rates, and the population of working age. In case of the article of Alho and Vanne (2006), this is represented in the productivity variable, since it reflects productivity per person. labor force participation and unemployment rate for males and females.

Real Interest Rates

Alho and Vanne (2006) state that the value of the government debt varies according to the real interest rate on government bonds. They used the German real interest rate since they found the stability of the euro not proven at that time. They used the real interest rate instead of the nominal interest rate since the real interest rate is corrected for inflation.

The real interest rate is a time series, which means that we can use ARIMA models to choose the best model that fits with the given time series. We discussed this type of models in more detail in Section 2.2.2. Alho and Vanne (2006) found an AR(1) model, so $x_t = \phi_1 x_{t-1} + w_t$. We may conclude that the real interest rate is dependent on the most recent past value.

Before we continue with the determination of W_1, we need to clarify an important assumption of the model. This is done in the spirit of the original generational accounting method for which is assumed that the government has a fixed value portfolio. So, if the value of the stocks increases, enough are sold such that the portfolio value stays the same and vice versa. In order to sell, the government must pay an interest to satisfy the time preference of the buyers, which means a discount rate. This is the expected real interest rate of bonds or $E[m_1]$, where m_1 is derived from the AR(1) model.

Eventually, Alho and Vanne (2006) stated that W_1 is the discounted sum of the income and out-payments it generates, if held at the current level. Since the discount rate equals the average rate of return of the bonds, the mean of the random variable corresponds with the current debt, or $E[W_1]$. This means that we can give the following formulas for computing the debt of the government:

$$W_1 = E[W_1](1 + X_1) \tag{2.31a}$$

$$X_1 = \frac{m_1 - E[m_1]}{e^{E[m_1]} - 1} + \sum_{u=1}^{\infty} e^{-E[m_1]u} x_u \tag{2.31b}$$

X_1 is sampled from a Normal distribution with mean zero and variance given as below:

$$\mathrm{Var}(X_1) = \frac{\sigma_{m1}^2}{(e^{E[m_1]} - 1)^2} + \frac{\sigma_1^2}{(1 - \phi_1 e^{-E[m_1]})^2 (e^{2*E[m_1]} - 1)} \tag{2.31c}$$

Stock Returns

Alho and Vanne (2006) use the Dow-Jones index to compute the returns of the government stock portfolio. They used a international index since a lot of Finish government's stocks were traded in foreign countries. Most of the time, a stock index series is uncorrelated, which implies an ARIMA(0,0,0) series, also known as a white noise model. Alho and Vanne (2006) found indeed a white noise model and assumed normality, although this may eliminate the possibility of major price movements down.

An ARIMA(0,0,0) only consists of white noise, which means that $x_t = w_t$. This is used in the calculation of W_2, also known as the discounted wealth held in stocks. The formulas for computing W_2 look quite similar to the formulas for the calculation of W_1. The expected real interest rate of bonds is also used. This is done to fulfil the principle that the government must pay interest in case they sell a certain number of stocks. The formulas of W_2 are given as follows:

$$W_2 = E[W_2](DV + X_2) \tag{2.32a}$$

DV stands for the discounted value of all expected future returns for a unit investment and is computed using $DV = \frac{E[m_2]}{(e^{E[m_1]}-1)}$

$$X_2 = \frac{m_2 - E[m_2]}{e^{E[m_1]} - 1} + \sum_{u=1}^{\infty} e^{-E[m_1]u} w_u \tag{2.32b}$$

X_2 is sampled from a Normal distribution with mean zero and variance given as below:

$$\mathrm{Var}(X_2) = \frac{\sigma_{m2}^2}{(e^{E[m_1]} - 1)^2} + \frac{\sigma_2^2}{(e^{2*E[m_1]} - 1)} \tag{2.32c}$$

Productivity

Alho and Vanne (2006) stated that both the taxes and entitlements follow the productivity of labor, which depends on national economic structures. Therefore, they used the real GDP per capita growth series. The growth series is a ARIMA(0,0,1) model, also known as the MA(1) model. This means that we have one lagged forecast error that is correlated. A MA(1) process is given as $\epsilon_t = w_t + \theta_1 w_{t-1}$. The productivity will be used in the computation of the IPL, which will be explained in the section below.

2.3.2 IPL

We already gave the verbatim description of the formula of the IPL in Equation 2.30. We notice three elements. The first element is the discounted entitlements, which we indicate as S. The second element is the discounted taxes, which is indicated with a T. The last element is the public wealth, denoted as W, which we already explained in the sections above.

The amount of entitlements or taxes is dependent on three variables, namely the structure of the population, the amount of taxes or entitlements for each individual and the productivity. The structure of the population has three elements, age, gender and the year the taxes and entitlements are received. This means that we have to take into account two different population groups, one for males and one for females. This means that S and T can be declared as $S = S^F + S^M$ and $T = T^F + T^M$. For the amount of taxes or entitlements, Alho and Vanne (2006) chooses to have a baseline year, which take the gender and the age structure into account. We denote this baseline year for the entitlements as $\hat{S}$ and for the taxes as $\hat{T}$. The last element is the productivity. Therefore, we need the difference between the discount rate and the growth rate of the GDP. The latter is the mean of the ARIMA model, $E[m_3]$. This difference is given as d. Eventually, we compute the productivity in every year with the MA(1) model in mind. This will give the following formulas for S and T:

$$S(z) = \sum_{u=1}^{\infty} \Big\{ \sum_{x=0}^{\infty} V(x, z, u)\hat{S}(x, z) \Big\} exp(-du + u(m_3 - E[m_3]) + \sum_{k=1}^{u} x_{t+k}) \tag{2.33a}$$

$$T(z) = \sum_{u=1}^{\infty} \Big\{ \sum_{x=0}^{\infty} V(x, z, u)\hat{T}(x, z) \Big\} exp(-du + u(m_3 - E[m_3]) + \sum_{k=1}^{u} x_{t+k}) \tag{2.33b}$$

where $V(x, z, u)$ is the number of individuals at age x, who are of sex z during year u, also known as the structure of the population. $\hat{T}(x, z)$ and $\hat{S}(x, z)$ are seen as the baseline years and the term $exp(-du + u(m_3 - E[m_3]) + \sum_{k=1}^{u} x_{t+k}$ is the productivity with a MA(1) time series model for which $\epsilon_{t+k} = w_{t+k} + \theta_1 w_{t+k-1}$. Alho and Vanne (2006) use a per capita measure for productivity and therefore they assumed that population development and productivity are independent. They also noticed that S and T might become infinite if the productivity grew at an average rate that exceeds the discount rate, such that d becomes negative. Therefore, they eliminated this option by removing all the values of $m_3 \geqslant E[m_1]$.

Eventually, the random public liability is given as follows:

$$L = S - T - W \tag{2.34}$$

This is seen as the predictive distribution of the IPL. The computation of Equation 2.34 in a simulation model, is shown in Appendix E.

2.4 Trends in Health Care Costs

A main difference in the forecasting model of the AOW expenditures and the health care expenditures, is the usage of the system. For the AOW expenditures, we know that every individual that is entitled to receive AOW, approximately receives the same amount of money each year. In the system of health care expenditures, this is very different. Not every individual has the same utilisation. This would imply that a very sick person would use the same part as a very healthy person, which by logical thinking, would never be the case. In this section, we outline the different trends founded in research in the past decades to get a better understanding of the health care system and course of expenditures.

2.4.1 Last Year of Living

The main assumption by assigning health care expenditures is that an increasing age results in higher costs. This sounds reasonable, but more recent research indicates that the time till death (TTD) or last year of living, has a bigger influence on health care expenditures than age. Zweifel et al. (1999) are one of the first researchers that discovered this implication. They indicated that there is no difference in the costs during the terminal phase of life whether it occurs at age 60 or age 90. While age and proximity to death are related, it is the relatively greater number of persons in older age cohorts who die, rather than their age per se, that explains the observed correlation between expenditures and age (O'Neill et al. (2000)). O'Neill et al. (2000) all show that for general practitioner care, proximity to death was associated with an increase in the cost of care. Geue et al. (2014) also did research on the TTD approach for acute inpatient care. They also found that the total costs of health care would divergent in the future if TTD would be excluded from the modelling process. One of the reasons for this symptom is that physicians treat younger elderly (so people around the age of 65) more aggressively, since a recovery is more beneficial to them than for the most oldest part of the population. Or differently stated, they have more years remaining to fight for. Polder et al. (2006) did a research in the last year of living for the Dutch society in 1999. They also found a positive effect on the health care expenditures and TTD instead of age on its own. They even found that the average health care costs are amounted to 1100 euro per person per year, while the costs per decedent were 13.5 times higher and approximated 14,906 euro in the last year of life. Most of the costs were related to hospital care (54%) and nursing home care (19%). And also noticeable, the projection of health care expenditures with TTD taken into account resulted in a 10% decline in the growth rate of future health care expenditures compared to methods that do not take this variable into account.

RIVM (2008) published a research which outlines the life course of individuals in comparison with the health care expenditures for hospital care and long-term care. One of the main findings is in hospital care, the time till death is the main cost driver instead of age. A female of 65 years old that died approximately costs 8500 euro while a female of 85 years old has health care expenditures of 5300 in her last year of living. For surviving individuals, the costs are increasing with age, but the amounts are significantly lower, 600 euros at the age of 65 and 1100 euros at the age of 85.

This difference in costs also indicates two different theories for health care expenditures. The TTD approach is referred to as the 'red herring hypothesis', since the assumption that the elderly part of the population is responsible for an increase in health care expenditures is not always correct. The idea that health care expenditures for older people are growing faster that for the rest of the population is referred to as steepening. This can also be seen as the increase in the ratio of per capita expenditures for older people, in this case 65+, divided by the younger over time (Gregersen (2014)):

$$\frac{\overline{Y}_{a\in[65,max.age],t}}{\overline{Y}_{a\in[0,64],t}} > \frac{\overline{Y}_{a\in[65,max.age],t-1}}{\overline{Y}_{a\in[0,64],t-1}} \tag{2.35}$$

It is important to notice that in all the research described above, hospital care data is used as input. RIVM (2008) did this as well to test the hypothesis of the 'red herring', but they also test this idea for the long-term care. It turns out that a person that dies in a certain year is more expensive than a person that survives, but the costs do increase with age, meaning that most expenditures are made for the eldest part of the population. By forecasting the health care expenditures, the distinction between hospital care and long-term care should be taken into account.

2.4.2 Comorbidities

Besides the time till death, comorbidities are seen as an important cost driver in health care. Comorbidity is the presence of two or more diseases at one individual. Hazra et al. (2018) concluded that comorbidity is a stronger driver than age alone as predictor of high costs. The study of RIVM (2008), confirms this idea, by stating that 35% of the hospital care costs is associated with comorbidity. The combination of diseases is important for this factor as well. RIVM (2008) recommended that the prevention of comorbidities would have a positive effect in the reduction of health care expenditures.

2.4.3 Users

A last important distinction about health care expenditures should be made, especially by looking at hospital care. We might conclude that the idea of last year of living and comorbidities seem valid. RIVM (2008) noticed that only a small part of the population uses hospital care, most of them dealing with comorbidities and seems to have multiple hospital admissions each year. This results in uneven distribution of health care expenditures that might be taken into account in further research and forecasting models.

2.5 Conclusion

In this chapter, we gave an outline of the three subjects that have an influence on the course of this master thesis. First of all, the model for demographic forecasting is explained. A lot of possibilities have been discussed, for which extrapolative methods are used the most. The main focus is on the model of Hyndman and Booth (2008) and the different modelling steps. This model uses three input parameters for predicting the demography, namely mortality, fertility and net-migration. It must be said that the fertility and net-migration rates causes more uncertainty in the forecast, which might result in more outliers. On the other hand, using all input parameters, makes the forecast model as complete as possible. This already answered one of our sub questions, namely:

Which models and parameters are known in literature to predict demographic composition?

Besides a model for the prediction of the demography, a model that forecast the public liabilities is given. This is a general model where not only the future entitlements and future taxes are predicted by using the composition of the population, but the public wealth of the a country is taken into account as well. This results in a more complete financial status. The model is based on the concept of generational accounting, but is more developed.

The last subject that is discussed, is the trends in health care expenditures. This corresponds with the research question:

What drivers of health care expenditures are known in literature?

More and more researchers discover that ageing on its own is not a driver for the increasing health care expenditures, but the last year of living. This is an important assumption that influence the idea of health care forecasting. It is not necessarily correct to assign more costs to the eldest part of the population. Besides the last year of living, the influence of comorbidities is an important factor as well. This is in compliance with the idea that only a small percentage of the population is responsible for the health care expenditures, assuming that this is the part that deals with the comorbidities, possibly in the last year of their life.

These three subjects are used as a basic framework for the rest of this master thesis. In Chapter 3, we explain which models and what type of parameters are taken into account for every subject. A research framework is given in the beginning of the chapter to specify how this research is conducted.

Chapter 3

Methodology

Contents

3.1 Research Framework

This thesis examines the sustainability of the Dutch social security system. We have to combine different models, since multiple input parameters are needed to forecast a social system. For these models we need to make various assumptions. The overall research framework is given in Figure 3.1. The idea is simple, we forecast the demography of the Netherlands and use this as input for the AOW system and health care system. Simultaneously, we forecast the economic variables of the IPL as in the model of Alho and Vanne (2006). We only have to do this once, since the economic variables for the Dutch financial system stays the same for both the AOW and health care. If we have a prediction of both social security systems, we will test them by conducting a sensitivity analysis. We change parameters of the systems to see whether the situation is getting better or worse. For example, by increasing the entitlement age or expenditures we are able to see the impact of potential political decisions. Eventually, all this information is gathered and we are able to answer the main research question.

In this chapter, we explain in great detail which model choices and assumptions we make for our own model. The idea of using the prediction of the demography as input parameter for a discounted financial system and forecast the AOW and health care system is quite new. Therefore, we see this methodology as a new overall method, of which we hope that future researchers extend the new methodology to create an even more accurate model.

3.2 Demographic Developments

The ultimate goal of this master thesis is to investigate the sustainability of the social care system with the current AOW entitlement age. Before it is possible to predict the future AOW expenditures and the health care expenditures, the demographic development of the Netherlands should

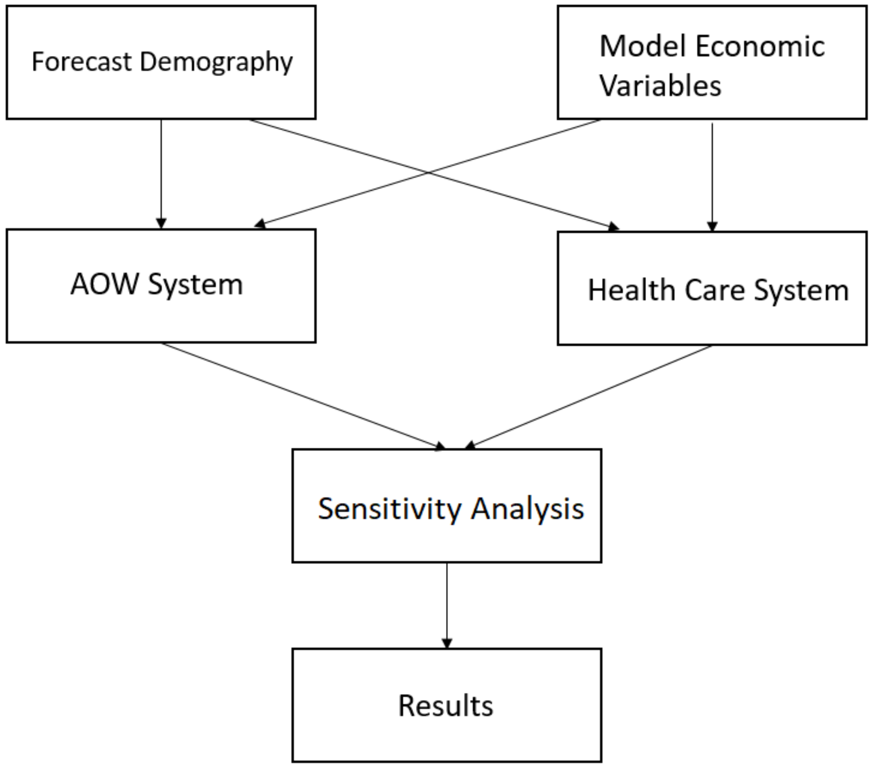


Figure 3.1: Research Framework.

be known. Therefore, the demographics of the Netherlands are predicted to learn more about the AOW entitlement age for different years into the future. Before a model can be programmed, data should be collected and prepared. For example, exposure to risk is a variable that is not been given, but can be calculated using the method designed by CBS. In the sections below, a model explanation is given and the assumptions that have been made.

3.2.1 Data

The data used for the prediction model of the demography, are all collected from CBS. It is important to mention that in collecting the data a first assumption is made. The data used have a time period of 67 years, starting in 1950 and ending in 2017. There are two reasons for this assumption. First of all, the detailed data provided by CBS, for which the data are given for each age step and for male and female separately, is only available for 1950 and further on. Another reason is a more stable environment and more comparible with the current situation that starts at 1950. In the period before 1950, two world wars were fought and the Spanish flu at the end of World War I made a lot of victims, around 30.000 in the Netherlands, mostly young adults (van den Born, Karin and Andere Tijden (2001)). It is possible to work with unstable data, according to Hyndman and Ullah (2007), since robust methods as binary weights can be implemented. However, this will increase the complexity and therefore, the model of Hyndman and Booth (2008) is used with a starting date of 1950.

Hyndman and Booth (2008) use four input variables to predict the demography, namely mortality, fertility, exposure to risk and population. For all input variables, a data set of each year from 1950 until 2017, for every age step and for male and female separately, is provided. Nowadays it is more and more common that people get older than 100 years, but in 1950 it was a very rare event. Therefore, CBS has a restriction on the age step, the latest age step is 99 years and older. This means that for the whole data set, the latest age step is 99 years and older, even if some people are 105 years old in this age step.

CBS is not the only data collection source. A lot of articles use international data, such as the human mortality database or the human fertility database, to predict the demography. In this thesis, we do not use these sources for two reasons. First of all, in case of the mortality data, the method of CBS is known and can be reconstructed. This method is fully adjusted for the Dutch society whereas the method of the human mortality database is uniformly built for multiple countries in the world. Secondly, the fertility data from the human fertility database do not have the granular data as the database from CBS. The human fertility database provide only age groups for the mothers whereas CBS provide age steps for the mothers. So, CBS has age steps starting from 15^- until 49^+ and the human fertility database, for example, has age groups in steps of five. So, $15^- - 20$, $20 - 25$, etc. In this thesis, the age steps are required to show the different population sizes for different ages and therefore the data derived from CBS is a better source.

Before the model to predict the demography of the Netherlands is given, we give a short overview of each input parameter with the assumptions made to construct the forecasting model.

Mortality

The first data set is the mortality data set. As already mentioned, this data set is derived from CBS. Using the CBS procedure, first the exposure to risk must be calculated. The method used for this model has been presented in Section 2.2.1. In both the calculation of the exposure to risk and the mortality rates, an endpoint is necessary, in this case an age group for which all the high ages are summarised. In this case, the last step is 99^+, since CBS has used this maximum age groups for 1950 and onwards. Normally, we know that people still have a possibility of survival after turning 99, and in the CBS method it is also the case. However, in forecasting the mortality rate, it might increase the complexity of the model. Therefore, we decided to have a mortality rate of 1 at the last step of 99^+, which means that every individual that turn 99 will decease.

Another choice must be made in following the CBS procedure, namely the choice between the age-cohort method and the period-cohort method (see Section 2.2.1). In this case, the period-cohort method is used, since the prediction of the mortality rates and the life expectancy is possible by using this method.

Fertility

The fertility rate ($f_t(x)$) is calculated as described in Section 2.2.1. It is important to clarify the definition of births. According to Craig (1994), fertility is measured in terms of live births, so without abortions and still births. According to CBS, the definition of births is a child that has shown signs of life regardless the duration of the pregnancy. This is in accordance with the definition of Craig (1994).

The TFR (Total Fertility Rate) and the BRR (Birth Replacement Ratio) will be calculated according to the formulas given in Section 2.2.1. For the historical years, so 1950-2017, the TFR and BRR can be calculated in the normal way. However, for the prediction values, the computation of the TFR and the BRR become slightly different. Since the fertility rate and the population (and therefore the exposure to risk) are predicted, the number of births need to be computed from these parameters. After calculating the $B_t(x)$, the BRR can be computed.

Migration

The migration parameter has been ignored for quite some time. Nevertheless, it is an important factor in the forecasting model of the demography. Since this parameter is seen as less important, the data available seem quite rare. CBS only provides the correct database from 1995 and onward. With a correct database, a difference in sex and individual age steps is meant. For this reason, the migration forecasts are less accurate, mainly because of having a short historical interval. A solution for this problem is to use the growth-balance equation (see Equation 2.9). With this equation, the net-migration is estimated as the difference between the increment in population size and the natural increase (Hyndman and Booth (2008)). So, the net-migration is used instead of the immigration and emigration separately. This makes the forecast less accurate, as stated in Section 2.2.1. However, since a lot of migration data are missing to make an accurate forecast, even for immigration and emigration separately, the growth-balance equation seems a good estimate to include the migration parameter in the forecast demography model.

3.2.2 Model

We programmed the forecasting model of the demography in R. As many programming languages contain packages, R also has a lot of packages that can be used during programming. In case of programming the demography model, the suitable package 'Demography' is used. This package is developed by Rob Hyndman and follow the steps in the model described by Hyndman and Booth (2008). In short, all different steps are addressed.

Demogdata

First of all, the data sets of different parameters should be established. This is done for the mortality rates and the fertility rates. In the mortality rates, a difference is made between males and females. By creating the demography data, an input parameter database, in this case mortality and fertility, is combined with the database for exposure to risk. Besides combining the databases, it is also important to make conditional constraints. The most important one is the Box-Cox adjustment. Hyndman and Booth (2008) argued that the mortality rates should have a lambda of 0, to make a full transformation of the data. They also claimed that this assumption is consistent with other studies. The choice of lambda for the fertility rates is not uniformly decided, but Hyndman and Booth choose $\lambda = 0.4$. Since it is unclear whether these lambda's are applicable to the Dutch data, we will compute the best value of lambda on the Dutch time series data by checking which model produce the best AIC value for the time series models and the overall best forecast accuracy.

Besides the mortality and fertility data sets, we should also make a population data set, which should not be confused with the exposure to risk data set. The population data are used as the starting point of the population forecast. A Box-Cox transformation might be used, but the value of λ should be computed in the same way as for the mortality and fertility data.

The net-migration data set is computed from the mortality and fertility data. One other input parameter is necessary, namely the male-female ratio, which is the average ratio over the time period 1950 until 2017 and is 1.052 in the Netherlands. It means that for every female born, 1.052 male are born, with the consequence that more male than female are born in the Netherlands.

In the end, we have four demographic data sets, for which the data sets of mortality and population have a starting year of 1950 and an ending year of 2017 with age steps of one, beginning at age 0 until 99^+. Both of them make a distinction between male and female such that for every parameter two data sets are necessary. The fertility data are only female based, with a starting year of 1950 until 2017 and have age steps of 1, beginning at 15^- until 49^+. The net-migration data set has a starting year of 1950 and an ending year of 2016, since the net-migration is combined from the fertility, population and mortality data as shown in Equation 2.9.

Smoothing

After generating the correct data sets, the data should be smoothed to remove observational errors. As described in Section 2.2.2, the weighted splines method and the two-dimensional P-splines are the most common smoothing methods. We will choose the weighted splines method since this method is more focused on the age dimension instead of the time dimension. By choosing a starting year of 1950 for our data, we already erase a lot of time variation in the data and decided that a method with a better focus on the age dimension has a better influence on the overall forecast. The mortality, fertility and net-migration rates are therefore smoothed using a theoretical approach for computing the observational variance.

Fitting

In the fitting procedure, we first have to decide whether we want to use the coherent component method instead of the normal HU method. For the fertility parameter this is an easy choice, since it is not possible to use the coherent component method since only females are incorporated in the fertility rates. We only need to determine whether we want to use the original HU model, the robust HU model or the weighted HU model. We choose to use the original HU model since the fertility rates are not looking stable for the past years. If we would use the weighted HU model, the more recent observations would have a higher impact on the overall forecast. That seems like a undesirable consequence. The same argument is valid for the robust HU model, since the absence of outliers would affect the fertility rates in a more biased way.

For the mortality and net-migration parameters we may decide whether we want to use the original HU model or the coherent component method. As already stated in Section 2.2.2, the coherent component method will prevent the divergent of the input parameters for the two sexes. The life expectancy of males in the Netherlands is increasing faster than that of the female part of the population (CBS (2018)). This indicates that a divergence between males and females is not the case. Therefore, we will use the coherent component method for both the mortality rates as the net-migration rates. The application of the component coherent method to net-migration rates is done to ensure coherence in the calculation of the sex specific input parameters.

All three input parameters have six principal components, so $K = 6$. We expect that $K = 6$ is high enough to explain almost all variance in the present data, especially since most variance is explained in the first two components. The best fitted ARIMA model for every parameter is chosen by the lowest value of AIC.

Forecasting

The forecasting procedure is executed as stated in Section 2.2.2. We have to make two important decisions in the forecasting step, namely the number of years to forecast and the confidence level of the forecast. We have to consider a time period that will not result in a long-term forecast since this will result in unrealistic outcomes and on the other hand a time period that is not too short to draw useful conclusions. We decided to have a forecasting period of 30 years. This will eliminate the problem of a long-term forecast and the possible unrealistic point forecasts and prediction intervals. On the other hand, the time period is long enough to overcome a large part of the baby-boom generation (see Figure 1.1) and for see the elderly situation in the future.

We choose to work with a confidence interval of 90%. This means that in 90% of the cases the confidence interval contains the population mean and in the other 10% of the cases the confidence interval does not contain the population mean. A smaller confidence interval will lead to more uncertain population forecasts and a larger confidence interval might be too strict and could lead to very wide intervals, which make it very hard to draw conclusion from, mainly caused by the principle that population forecasts in general are very uncertain.

Simulating

For the simulation step, we will use the Monte Carlo simulation instead of the Leslie matrix since this will reduce the complexity tremendously. The number of iterations is computed using Equation 2.24 and depends on the values of S_x and $\overline{x}$ that will follow from the forecast model. The others values are respectively $z_c = 1.645$ and $E = 10$ based on the Normal distribution and a confidence interval of 90%. We have three input parameters which means that we might have three different numbers of necessary iterations. We will choose the number of iterations that corresponds with the highest number of iterations needed.

Forecast Accuracy

The forecast accuracy can be computed by forecasting a time period that is already known. The idea is to compare the exact data with the forecast data and determine the forecast accuracy. First, we need to decide which period we want to compare. We choose to compare the last 20 years of the data, so that means that we compare 1997 until 2017. This time period looks very stable and a period of 20 years should be sufficient to make a comparison. Secondly, we have to determine the confidence interval, which in our case is still 90%. So, we make a forecast of the time period 1950-1997 for mortality, fertility and net-migration where we use the same models as described above for the next 20 years and compare the outcome with the known data. This gives us a value for the MSE and ISE for every input parameter and in this way the forecast accuracy.

We always have to take in mind that the choice of the model and parameters have an influence on the forecast accuracy and the correlations. This means that we never should see the forecast population as the absolute truth, but as an indicator of the possible future demography.

3.2.3 Output Parameters

Model

The most important output of the model is of course the forecast of the mortality, fertility, net-migration and the population. In Section 3.2.2, the method is described to create this output. We also made the choice to work with a six principal component model, which means that for every parameter and for every sex, an explanation of the variance, the coefficients ($\beta_{t,k}$) and the basis functions ($\phi_k(x)$) is given. In Chapter 4.1, we will show the amount of variation explained for every input parameter and include an clarification of the coefficients and the basis functions.

BRR and Dependency Ratios

The historical and forecast BRR and dependency ratios are calculated as described in Section 2.2.3. For the historical ratios, we use the data that we know, since this already happened. For the forecast, we use the simulated population mean to compute the ratios.

For the BRR, we need to know the fertility rates, the female part of the population between 15 and 49 years old and the babies that are born each year. We only can predict the BRR until 2032, which is the birth year of a mother that is 15 years old. For the fertility rates, we also use the simulated mean. For the calculation of the BRR, we use a mixture of historical and forecast data. For example, to compute the number of babies born in 2035, we need to take into account all the female births of the mothers generation. In this case, a mother that is 49 years old, was born in 1986 and a mother of 15 years old was born in 2020.

We notice a discrepancy between the historical and forecast data. In the historical data, we have a group of 15 years old, but this group contains all the mothers that are 15 years old or younger. The same idea applies for the 49 years group. However, in case of the forecast data, we do not know how many mothers have the age below 15 years old or above 49 years old. Therefore, the number of possible mothers are slightly lower than in case of the historical data.

We compute the part of the population that is 0 years old from the TFR. We assume a constant male-female ratio of 1.052 to compute the numbers of girls and boys born from the total babies that are born. Eventually, we have all necessary input to calculate the BRR.

3.3 Social Security System

For the computation of the AOW and health care expenditures, we use the model of Alho and Vanne (2006). We make some adjustments by using our own stochastic simulation forecast as described in Section 3.2. We will also make some assumptions for the ARIMA models and data we are using for the real interest rates and the stock index. In this section, we explain the general model for both the AOW and health care system. The assumptions that are unique for each system, are explained in their own sections further on in this chapter.

Before explaining the architecture of our model in more detail, we explain how we use the primary balance to give a first indication of the financial situation. The primary balance is the public revenue in percentage of GDP minus the public expenditures in percentage of GDP. Of course, we would like this to be a positive number such that we have an increase in the public wealth. However, this indicator does not show the distribution of premium payments and central government payments as percentage of GDP as given in Figure 1.2. This is a relevant distribution, since it shows the unstable financial situation of the Netherlands which has an important influence on the national debate relating to the AOW and health care system. Therefore, we make this distribution by computing the amount of entitlements and the amount of taxes. The difference between the entitlements and taxes is the shortage that is paid by the central government. In this way, we can show the entitlements as percentage of AOW or health care divided by taxes and central government payments. So, both the primary balance and the premium distribution are computed.

3.3.1 Stochastic Population Forecast

Alho and Vanne (2006) use a population forecasting method in which the mortality rates change over time, but the fertility rates and the net-migration rates are fixed. It could be discussed whether this type of procedure is correct. We already concluded that the fertility rates and net-migration rates are very unstable to predict. However, assuming that these two parameters are fixed, is not likely. Therefore, we will use the forecasting model that we described in Section 3.2, for which every input parameter is changing over time.

3.3.2 Forecasting Economic Variables

We have three economic variables and we first have to decide how we will use these in our model. It is important to take into account the growth of the Netherlands so we also use the real interest rate to determine the amount of debt, the stock index to decide the amount of revenues and the productivity to ensure the growth rate. However, we use some other indices for the computation of our model. Besides, we explain how we find the best ARIMA model.

Real Interest Rate

We use the Dutch real interest rates between 1999 and 2013 for the computation of this variable, derived from The World Bank (nd). We already see a decline over the past years. This might be caused by a relatively high inflation rate in comparison with a relatively low compensation for expected losses. However, this low real interest rate will result in a less expensive borrowing system, which has an effect on the financial system of the Netherlands.

According to Alho and Vanne (2006), the real interest rate follows an AR(1) time series model. We do not know for certain whether this is also the case with the Dutch data. Therefore, we test the real interest rate to decide which ARIMA model is compatible with the data. Based on the outcomes, we specify Equations 2.31a, 2.31b and 2.31c.

Stock Returns

The stock returns stand for the returns of the government stock portfolio. Alho and Vanne (2006) use the Dow-Jones index as indicator of the stock returns for the Finnish government. If we look at the Dutch government portfolio, we see a lot of Dutch companies, such as the Dutch railway but also ABN AMRO and KLM which are both listed in the AEX. Therefore, we find the AEX index an accurate representation of the stock portfolio of the Netherlands.

We use the daily percentage change from January 4 1999 until August 2 in 2019 as time series input. Again, we test the data to determine the best fitted time series model for the stock index. The outcome defines the interpretation of Equations 2.32a, 2.32b and 2.32c.

Productivity

Alho and Vanne (2006) use the real GDP per capita growth series as indicator of the productivity. We will use this definition with the data of CBS. They record the yearly percentage growth change of the GDP since 1996. This means that we make a time series for the productivity from 1996 until 2018. Once again, we test which model is the best fitted ARIMA model for the data.

3.4 AOW Expenditures

For the determination of the IPL, we will use the predictive distribution of it, namely the random public liability as shown in Equation 2.34. The wealth is decided using the economic variables. We should make some assumptions for computing the amount of entitlements and received taxes. First of all, we only predict the AOW expenditures. This means that we have to take into account that for the amount of entitlements only the population that is 65 years and older has a positive value, while the other part of the population has no value, since they do not receive an AOW subsidy. On the other hand, for the amount of received taxes, only the working part of the population pays for the AOW as social security, so the part of the population between 15 and 64 years old. This means that the other part of the population has no value. An example of both the data set of $\hat{S}$ and $\hat{T}$ is given in Table 3.1.

$\hat{S}$		$\hat{T}$	
Age	€.	Age	€.
0	0	0	0
1	0	1	0
⋮	⋮	⋮	⋮
14	0	14	0
15	0	15	X
16	0	16	X
⋮	⋮	⋮	⋮
64	0	64	X
65	X	65	0
66	X	66	0
⋮	⋮	⋮	⋮
98	X	98	0
99^+	X	99^+	0

Table 3.1: Example Data Set to determine $\hat{S}$ and $\hat{T}$ where X has a Positive Value.

The second assumption that we should make, is the distribution of elderly that is single or cohabitants. Therefore, we used data from CBS and computed a ratio, at every age, for males and females to determine the average AOW at each age step an individual deserves per year. We would expect that the average AOW will be higher at the more elder ages since more persons will be single, because their spouse has passed away. If we look at Figure 1.3, we have more variables that have an influence on the amount of entitlements. We account for the demographic distribution and the relationship status, no other variables are taken into account. We assume that there are no transitional agreements, transitional payments or cohabitation arrangements and we assume that every individual stayed for 50 years or longer in the Netherlands such that she receives 100% AOW.

Finally, we need to make an assumption for the average income and therefore the average received taxes. It is unlikely to assume that a 15 year old earns the same amount of money as a 40 year old. Therefore, we decided to make the assumption that the income increases with age. Of course, this is not a reflection of reality, since it is not necessarily true, especially if you would divide the working population in part-time workers and full-time workers. However, we think that this assumption takes a very good average of the total received taxes. Besides, the amount of income is based on CBS data for different age groups. We took 17.90% of the income as received AOW taxes.

The model of Alho and Vanne (2006) denotes a benchmark year to forecast the expenditures, as shown in Equation 2.33a and 2.33b, for which $\hat{S}$ and $\hat{T}$ are the benchmark years for the amount of entitlements and the amount of received taxes. We choose to have 2017 as benchmark year, since this is the last known year before we will forecast the population, and so, the AOW expenditures. This means that the data sets as described above are compatible with the total amount of entitlements and taxes as in the year 2017. The total amount of entitlements in 2017 is €37.412 billion and the total amount of received taxes is €23.889 billion. If we compare the total AOW overview in Figure 1.3 with the assumptions we made, we have fewer input variables for the AOW expenditures, as shown in Figure 3.2.

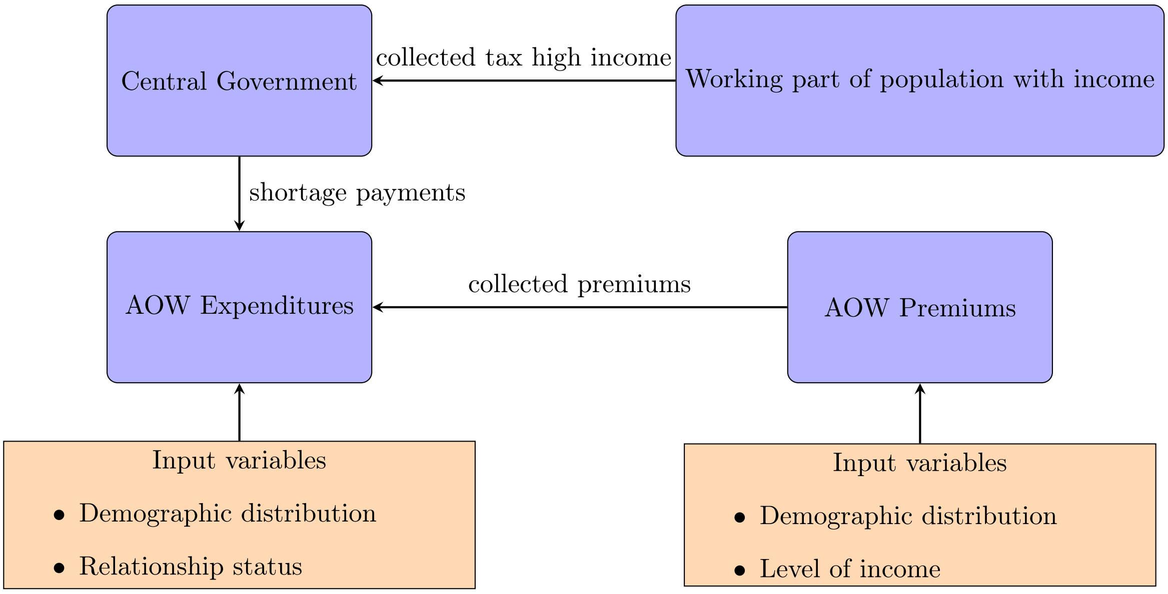


Figure 3.2: Overview of Methodology: AOW Expenditures.

3.4.1 AOW Entitlement Age

As stated above, we make the assumption that the AOW entitlement age is 65 years. This is lower than the age in the current system. The AOW entitlement age was for many years put on 65 and there are political parties that thinks this should still be the case. Therefore, as a first step, we investigate the sustainability of the AOW system with the age set of 65 years old. We already expect that this will not be sustainable, since increase the AOW enttitlement age would never be enabled if there was no need for it. To test if the current AOW system is sustainable, we increase the entitlement age to 68 and 71 years old. This means that we make two more data sets with the same outline as Table 3.1. For the age of 68 years old, three more years of taxes are paid, and three fewer years of entitlement payments. In the case of 71 years old, this corresponds with a shift of 6 years. The data are based on the benchmark year of 2017 with the age of 65 years.

3.5 Health Care Expenditures

The health care expenditures are a different social security than the AOW, mainly due to the payment approach. The idea of the AOW system is that the younger part of the population pays for the elderly, but in the health care system, the elderly part of the population keeps paying taxes. This immediately increases the total revenues of the system, which results in a more complex distribution in case of the health care expenditures. We first have to examine which costs do we take into account. The Dutch health care system is based on four sub systems, namely the Zvw, Wlz, Wmo and Jeugdwet. Most of the cost are related to the Zvw, since hospital care is financed in this system. Wlz is responsible for most of the rest of the expenditures. Besides, these two sub systems are organised by the government. For these reasons, we only look at the Zvw and Wlz for the sustainability system.

We would like to make the same data set for the health care expenditures as shown in Table 3.1. Unfortunately, a clear division of costs per age is not known exactly, but we have two leads that enables us to make basic assumptions in the distribution of the expenditures. First of all, we have an open data set of Vektis, which shows the anonymous expenditures per age group for different municipalities. From this data set, we can derive a distribution of costs in Zvw for each type of health care at each age. The costs are divided in 22 sections:

- Medical specialists
- Specialised mental care
- Pharmacy
- Subscription fee general practitioner

- General practitioner consult
- General practitioner multidisciplinary care
- Other general practitioner cost
- Appliances
- Dental care
- Physiotherapy
- Other paramedical care
- Seated patient transport
- Lying patient transport
- Maternity care
- Obstetric care
- Basis mental care
- Cross-border care
- Long-term mental care
- Primary support
- Geriatric rehabilitation care
- Nursing
- Other costs

The long-term care organised in the Wlz is not given in this data set. RIVM (2008) concluded that for surviving patients, the costs do increase with age. Therefore, we assume that this is also the case for the Wlz. We still do not know how the costs are distributed over the ages. We take the Vektis data set as guideline, by using a correlation study over the 22 cost sections to the sections that increase with age. We use the correlation coefficient as indicator for this process. This is not so precise as a full regression analysis, but since we only want to know which sections have a positive correlation (meaning costs do increase with age), we see this method as sufficient.

The most common used correlation coefficient is the Pearson's product-moment correlation coefficient (ρ). It assumes linear, normal distributed, homoscedasticity data. If we have non-normal data, it is better to use the Spearman's rank correlation coefficient or Kendall rank correlation coefficient. Both methods rank the data from the smallest value to the largest value and analyse from this point onward whether there is a correlation present. It is assumed that the data has a monotonic behaviour. Spearman's correlation is preferred if there are any ties in the data (Puth et al. (2015)). Correlation can be positive or negative. In our case, a negative correlation means that the costs decrease with an increasing age. The correlation coefficient ρ can have a value between -1 and 1, in which -1 is a pure negative correlation and 1 a pure positive correlation. We indicate a strong positive correlation if $\rho \geqslant 0.7$.

Eventually, we find a selection of the cost section from the Zvw data to ensure the distribution of the Wlz. As already stated, the health care expenditures are much more complex than the AOW expenditures. This is also noticeable by the government incomes and costs. For the AOW system, we only have one source of incomes and one source of expenditures. The health care system has multiple sources, for both the incomes and expenditures. In Table 3.2, the different incomes and expenditures are shown, which corresponds with Figures 1.7 and 1.8. We are only interested in the government financial flows ans therefore we will not use the individual contributions.

Incomes	Distribution based on:	Expenditures	Distribution based on:
Fund Long-term Care	Individual Income	Wlz	Correlation in Vektis data set
Health Insurance Fund	Individual Income	Zvw	Vektis data set
AWBZ	Individual Income	AWBZ	Correlation in Vektis data set
		Contribution Education Hospitals	Equally divided per individual
		Contribution Education Medical Faculty	Equally divided per individual
		GGZ	Vektis data set, only GGZ sections
		Health Care Providers	Vektis data set
		Care Allowance	Individual Income

Table 3.2: Incomes and Expenditures of the Government with Distribution of Cash Flows.

The table is based on the year 2017, which we see as the benchmark year. We want to clarify a few things in Table 3.2. First of all, the AWBZ is still present as income. This is based on the old regulation and will slowly disappear. Since it is the older version of the Wlz, we will treat this income as Wlz income and base the cash flow distribution on the positive correlation between age and expenditures. Secondly, the GGZ is derived from the Vektis data set but only on the GGZ sections. The corresponding quantities of money are given in Table 3.3.

$\hat{T}$	**€.**	$\hat{S}$	**€.**
Fund Long-term Care	€ 14742	Wlz	€ 18168
Health Insurance Fund	€ 37977	Zvw	€ 40677
AWBZ	€ 1704	AWBZ	€ 0
		Contribution Education Hospitals	€ 455
		Contribution Education Medical Faculty	€ 249
		GGZ	€ 111
		Health Care Providers	€ 208
		Care Allowance	€ 4240

Table 3.3: $\hat{S}$ and $\hat{T}$ for Health Care Expenditures in 2017 in Millions.

With this assumptions, we can finally make the age specific costs and incomes as in Table 3.1. The incomes are still derived from taxes, which means that the population of 14 years and younger does not pay for the health care system.

3.6 Conclusion

In this chapter, we explained in great detail which model choices and assumption we made. First of all, we choose the model of Hyndman and Booth (2008) with the mortality, fertility and net-migration rates as input parameters. We will use data from CBS for the computation of the mortality, fertility and net-migration rates as input for the total population forecast. This already answered the research question:

What data could we obtain from existing and accessible databases on the demographic composition of the Netherlands over the last 67 years?

We also gave an outline which data we use for the prediction of the economic variables of the model of Alho and Vanne (2006). Eventually, we explained how we set up the distribution for $\hat{S}(x, z)$ and $\hat{T}(x, z)$ for both the AOW system as the health care system. This answered the following research question:

What data on AOW expenditures and contributions could we obtain on the percentage and absolute GPD of the Dutch system over the last 20 years?

For the health care system, we need to make an additional analysis by looking at the positive correlation between expenditures and age.

Chapter 4

Demography

Contents

4.1 Chapter Summary

This chapter covers the additional research question: How could we model the demographic distribution and AOW entitlement age in the Netherlands for the coming 30 years? We first look at the historical development of the Dutch demography. We notice that the baby-boom generation has an influence on the balance of the population, but the decrease in fertility rates even further increase the imbalance of the Dutch population.

In 30 years from now, we see that more individuals are entitled to AOW. It is only from the year 2037 and onward that the balance between the working part of the population and part of the population that is entitled to AOW is recovering, which is also shown in the development of the dependency ratios.

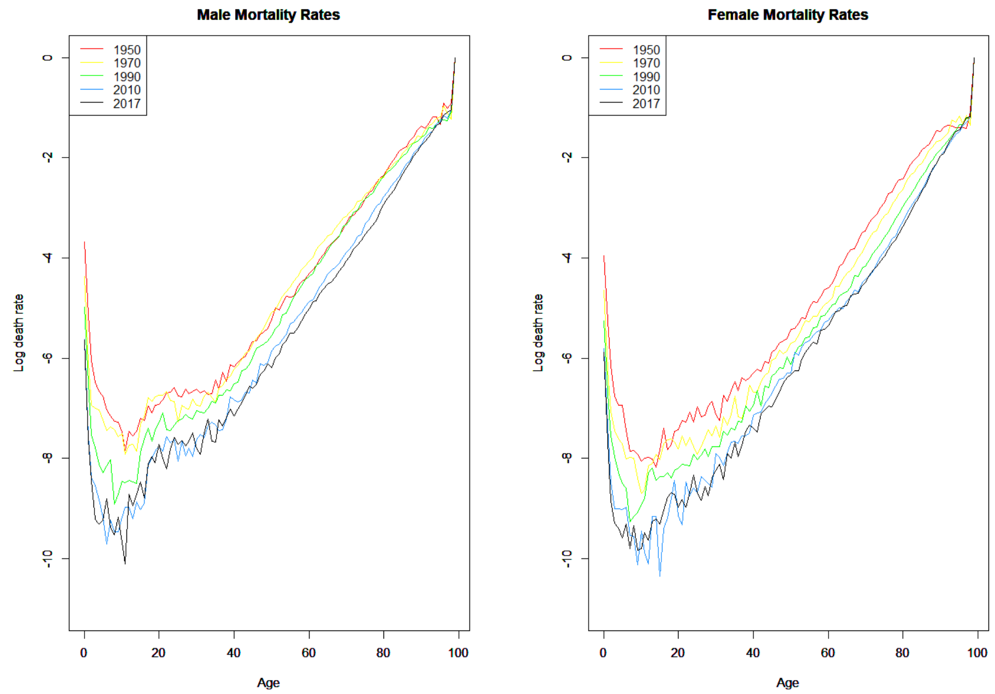
We noticed that the forecast of the mortality rates is quite certain. However, the forecast of the fertility rates and net-migration rates are more insecure. This has an impact on the population forecast in general and is visible by the wide confidence intervals in Figure 4.9 at the younger part of the population. So, we conclude that the distribution of the AOW entitlement age is quite certain, but that the balance between the working part of the population and the part of the population that is entitled to AOW is less known.

4.2 Overview Historical Data

The demographics of the Netherlands have gone through some major changes since 1950. The biggest difference is the role of the female part of the population in society which resulted in lower fertility rates. The mortality rates also have increased over the past decades. In this section, we briefly analyse the development of the different input parameters over the past decades to indicate possible patterns. The BRR and the dependency ratios are analysed as well.

4.2.1 Mortality Rates

We would expect that the mortality rates increase by time and are almost null at the age of zero. However, as it is noticeable in Figures 4.1a and 4.1b, the mortality rates are quite high at the age of zero. This is the influence of newborns. There is always an increased risk at birth, although we fortunately notice that the mortality rates at the age of zero have declined in the last couple of decades. We also see an unnatural steep at the age of 99^+. This is created by our assumption that everybody at the age of 99 and older will not survive and therefore has a log death rate of null. We also see that the mortality rates for females are lower than of males. This corresponds with the development of the life expectancies.



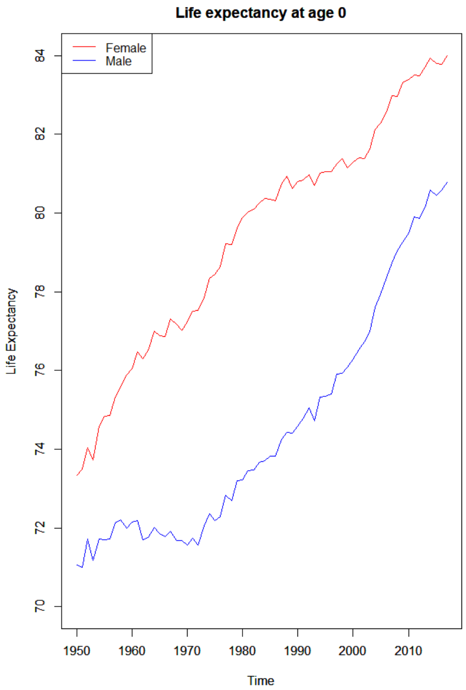
(a) Historical Male Mortality Rates. (b) Historical Female Mortality Rates.

Figure 4.1: Historical Mortality Rates.

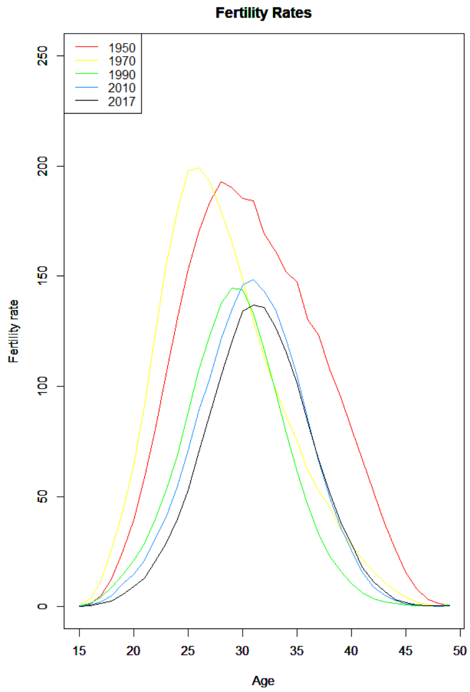
The life expectancy for males and females at the age of zero is given in Figure 4.2a. In the more recent years, the life expectancies of both sexes are getting more close. This means that the life expectancy of males is increasing faster than that of females which means that there is no divergent development. The choice of using the coherent component method instead of the original HU method, seems to be logical. The rising life expectancy for males is caused by the quitting of smoking. Males started doing this earlier than females, which results in the lower difference between male and females life expectancies.

4.2.2 Fertility Rates

In Figure 4.2b, the fertility rates for the last couple of decades are shown. We can see two trends, namely the decline in fertility rates and the shift of the age peak in fertility rates, the rates are more skewed. This means that Dutch mothers have fewer children and the age of conceiving children increases. These trends are in line with the development of welfare in Dutch society. The development of the fertility rates has drastically changed over the last period which means we might expect that forecasting the fertility rates is very difficult. Especially the introduction of the anti-conception pill in 1970 is shown in Figure 4.2b, since from that moment onward, the fertility rates start declining. On the other hand, we could argue that the fertility rates will not increase since the level of the fertility rates are more or less the same since 1990. The development of the age of the mothers might be more unknown.



(a) Life Expectancy for Males and Females.



(b) Historical Fertility Rates.

Figure 4.2: Historical Life Expectancy and Fertility Rates.

4.2.3 Net-Migration Rates

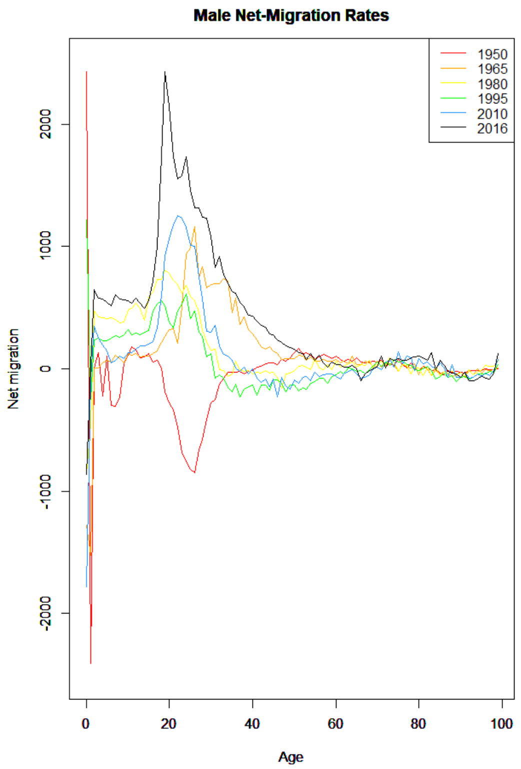
The net-migration rates are gathered by combining the mortality and fertility rates. This means that even in the historical data, we are not entirely sure whether this is the correct situation of the Netherlands. However, if we look at the development of the net-migration rates in Figures 4.3a and 4.3b, it seems plausible. Since the nineteen-sixties. a lot of immigration took place in the form of migrant workers and refugees, mostly in the age period of 18-40 years. Before this time, a lot of people emigrated to other countries in the aftermath of World War II. The peaks at the age of zero can be formed by the high mortality rates at the age of zero compared to other children ages. We believe that these are less reliable rates in comparison to the other net-migration rates.

4.2.4 BRR and Dependency Ratio

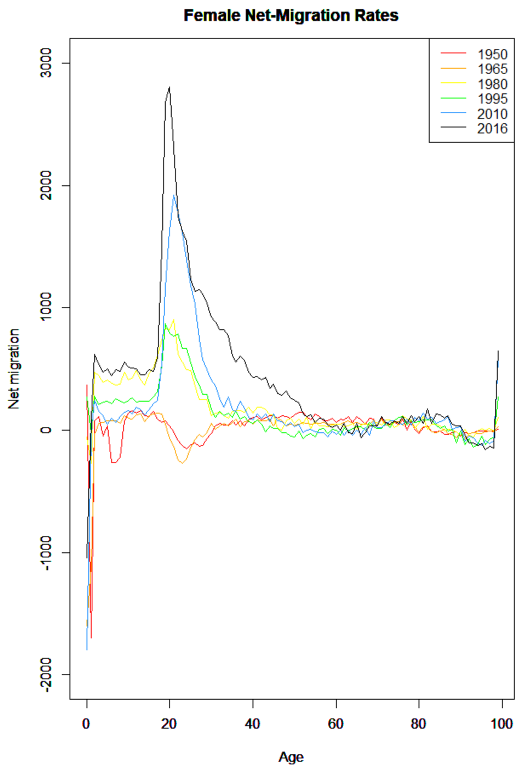
The Birth Replacement Ratio is an indicator of number of children that should be born to guaranty an equal population size in the future. It takes mortality, fertility and net-migration into account. The BRR for the Netherlands is given for the years 1999 until 2017, see Figure 4.4a. Since we need the mothers generation size at birth and the highest age level of a mother is 49, the earliest computing year is 1999. Since 1999 $-$ 49 years is 1950, this is the first year for which we have detailed birth information about.

We notice that in most years, the BRR is below 2.05, the number in the most optimal situation for replacing boys and girls. The lower number of BRR could be clarified by the influence of net-migration, since the Netherlands has a positive net-migration number. Especially for the most recent years in which most of the net-migration is in the age group that mothers might get children.

A dependency ratio shows the ratio of the working population in comparison with the part of the population that is not working. So, in our case, we have the younger part of the population of the ages $0-15$ and the elderly part of the population that is $65-99^{+}$ that we see as the not working part of the population. In Figures 4.4b, 4.4c and 4.4d, the development of the three dependency ratios are displayed. We immediately see the rising problem of the old-age dependency ratio since this ratio has been rising since 1950. The dependency ratio is higher for the female part



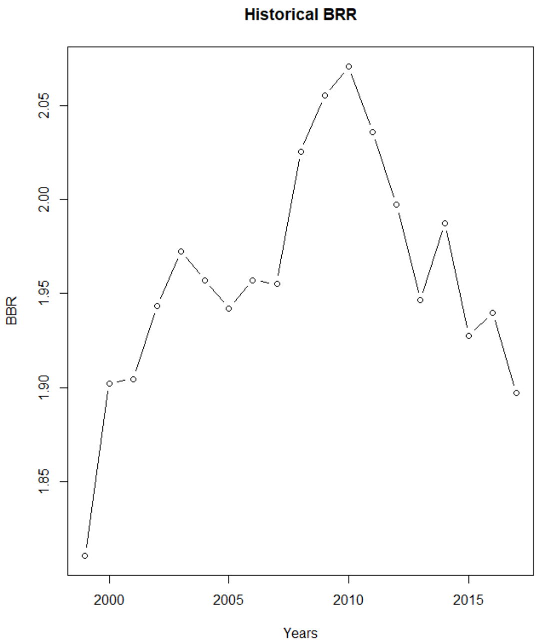
(a) Historical Male Net-Migration Rates.



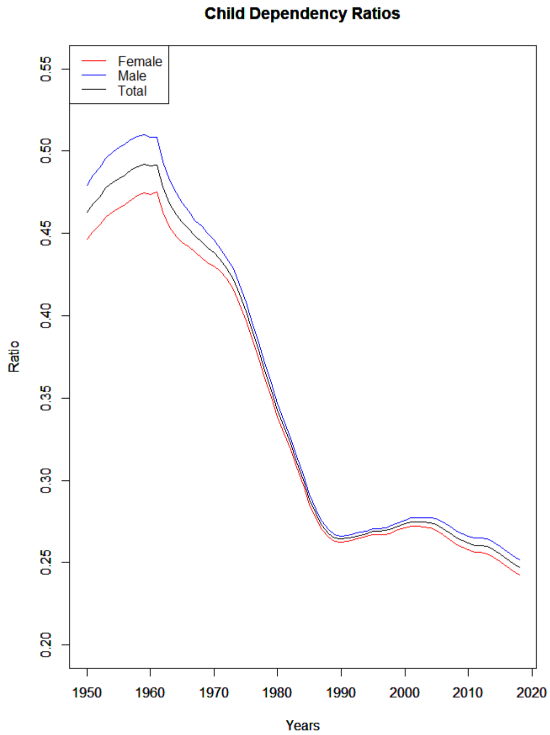
(b) Historical Female Net-Migration Rates.

Figure 4.3: Historical Net-Migration Rates.

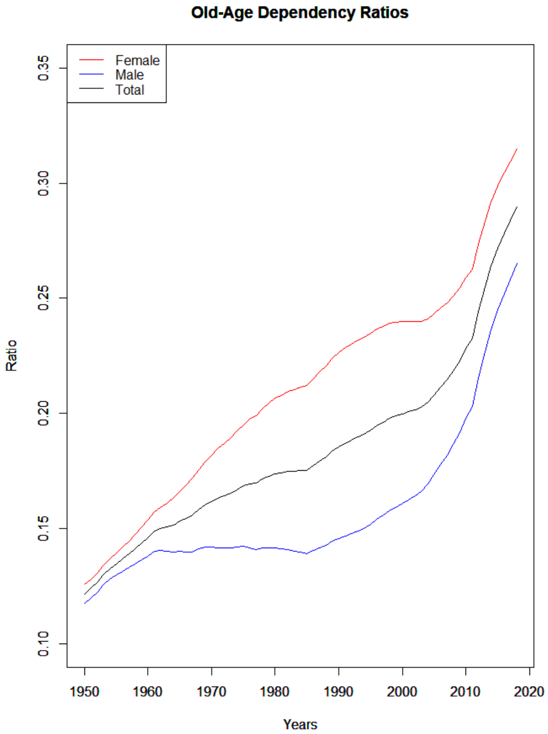
of the population, which is caused by higher life expectancy age. The child dependency ratio has decreased in the past decades which corresponds with a decline in the fertility rates. The total dependency ratio is increasing, even-though the child dependency ratio has declined. This means that the old-age dependency ratio has a significant influence on the overall dependency ratio and clarifies even more the rising problem of Dutch demographics. It is remarkable to realise that in 1950, the Netherlands had a high child dependency, since the ratio is above 0.45 and the old-age dependency below 0.15 and that this changed in a high old-age dependency with a ratio above 0.15 and a child dependency below 0.29 in just over 60 years.



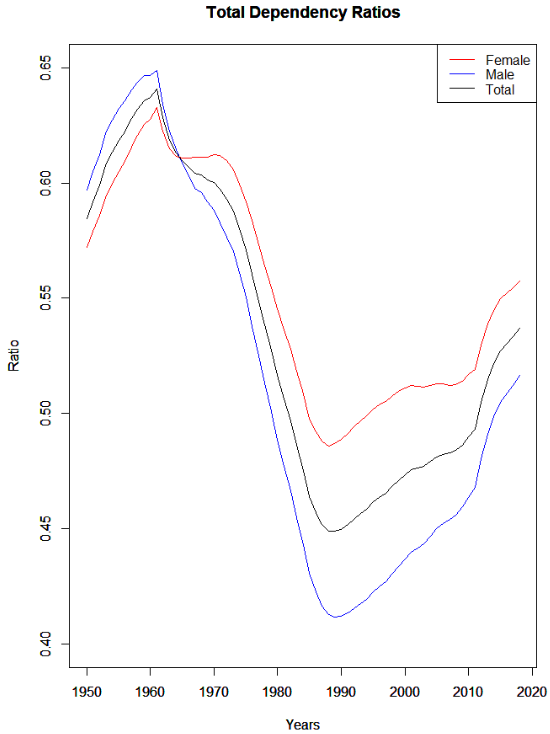
(a) Historical BBR.



(b) Historical Child Dependency Ratios.



(c) Historical Old-Age Dependency Ratios.



(d) Historical Total Dependency Ratios.

Figure 4.4: BRR and Dependency Ratios.

4.3 Forecasting Results

The historical data show a shift in the demography of the Netherlands, with lower mortality rates and fertility rates and overall positive net-migration rates. This results in an increasing elderly population which is also shown in the development of the dependency ratios. In this section we will see whether this trend will continue in the next 30 years. Not only the demographic changes are shown, but also the development of the dependency ratios and the BRR.

4.3.1 Input Parameters

Before we can give the different forecasts of the input parameters and the population, we first have to determine the lambdas for the Box-Cox transformation for each demographic data set. As mentioned in Section 3.2, Hyndman and Booth choose to have a $\lambda = 0$ for the mortality data and a $\lambda = 0.4$ for the fertility data. We also have the exposure to risk data which need a Box-Cox transformation. Ultimately, we used an automated function in R that determines the best lambda for each data set. The lambda for the mortality rates turned out to be around 0.10, however, since many articles conclude that a full transformation is needed for the mortality data, we used a lambda of 0. A lambda of 0.3017 was used for the fertility data and the average of the exposure to risk data for males and females gave a lambda of 0.3617.

During the fitting procedure, an ARIMA model is chosen for every input parameter for each coefficient. An overview of each ARIMA model is given in Appendix C. The mortality rates have the lowest AIC, especially for the first coefficient that explains the most variance in the data, which might suggest that this is the best fitted parameter and thus the parameter with the most accurate forecast.

We calculated the number of iterations for the Monte Carlo simulation according to Equation 2.24. We choose to use the mortality forecast as a guideline, since this forecast is seen as the most certain. We found a S_c of 0.03708168 and a $\overline{x}$ of 0.03459248. This means that the number of iterations that is needed is as follows:

$$n = \left[\frac{100 * 1.645 * 0.03708168}{10 * 0.03459248}\right]^2 = 310.9476 \tag{4.1}$$

Since the fertility and net-migration rates are considered as less certain, we will use 1200 simulations to ensure that we use enough iterations to make a steady simulation model. The fertility rates turned out to be the most uncertain variable, therefore we used 50,000 iterations to create a more stable confidence interval.

4.3.2 Demography

First we show the forecasts of the input parameters before the population forecast is shown. We take four data points in the forecast of the input parameters, namely 2017 as a reference, and 2027, 2037 and 2047 to show the trend in the forecasts. For net-migration, we take 2016 as a reference year and show the forecast of years 2026, 2036 and 2046. In some figures, the 90% confidence interval is given. We will show the one year forecast and the thirty year forecast to show a possible trend in the forecast and the development of the confidence interval. We might expect that this will increase further into the future.

Mortality Rates

In Figure 4.5 we see the forecast of the mortality rates for males and females and the confidence intervals for the years 2018 and 2047. Overall, we see a decrease in the mortality rates, especially in the younger ages. At the last age group of 99^+, a mortality rate of 1 is not applicable anymore. This means that the forecast model indicates that people will survive, even if they have the age of 99. We definitely see the smoothed curves of the forecast instead of the pointy actual data of 2017.

If we look at the simulated data of the mortality rates for 2018 and 2047, we not only see a decrease in mortality rates, but also a wider confidence level of the forecast that is more into the future. This corresponds with our intuitive feeling that drawing conclusions about the further future is more insecure, which is presented with a wider confidence interval. Overall, the confidence interval of the mortality rates is not so wide, which could mean that the forecast of the mortality rates is quite accurate.

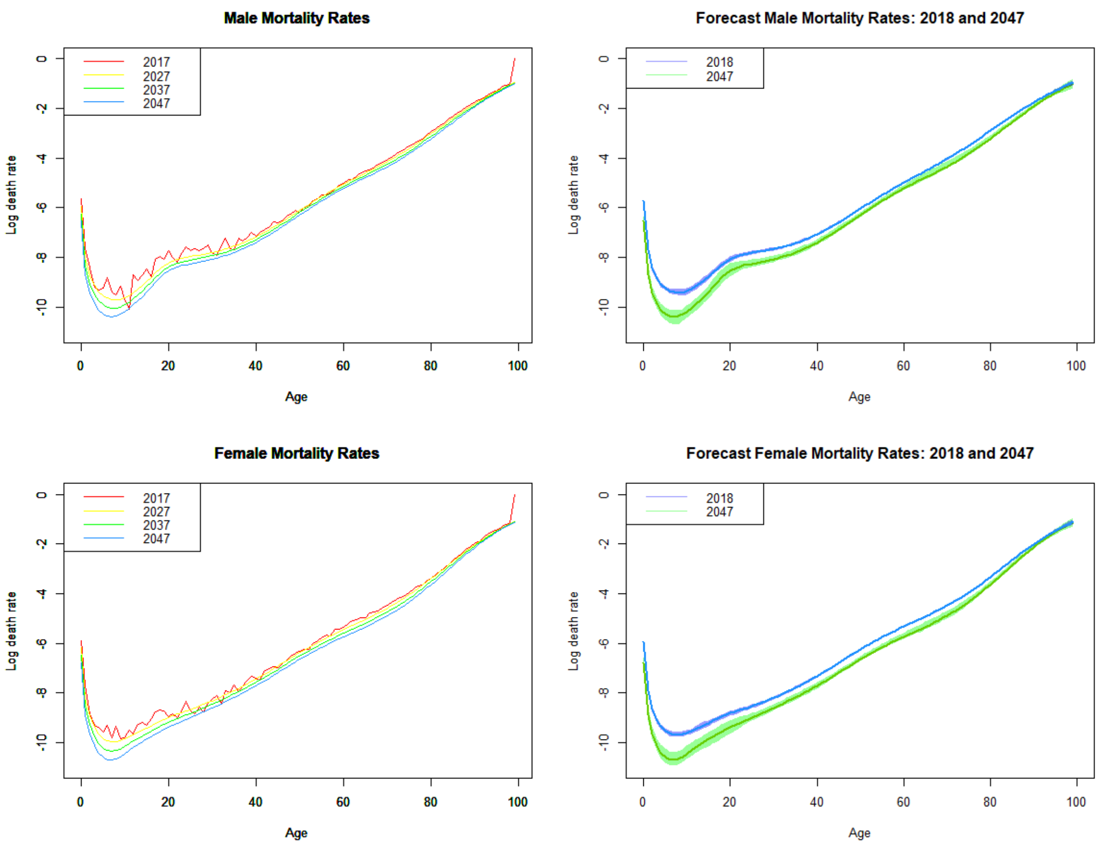


Figure 4.5: Simulated and Forecast Mortality Rates.

In Figure 4.6, the life expectancies for both males and females are plotted. For both we see an increase. Due to the usage of the product-ratio method, the historical structural relationship is still present, instead of the divergent of the life expectancies in the long term. We would expect that the life expectancy of males would increase faster than that of females, since this is a trend that has been seen for the past years. However, this is still a prediction that contains an uncertain element. It might be possible that the faster increase in male life expectancy will continue.

Fertility Rates

Forecasting fertility is seen as a challenge since more uncertainty is present than in forecasting mortality rates. If we look at Figure 4.7, this is noticeable by the big confidence interval for the year 2047 and the fact that we needed 50,000 iterations to create this figure. Apparently, the forecast model is not as precise as the mortality forecast. On the other hand, the one-year forecast has a very small confidence level, which indicates an almost perfect fertility forecast.

If we look at the development of the fertility rates the next thirty years, we notice a smaller plot. This means that the region of the mothers age is getting more centralised, so instead of a range of 20-45 years with a peak around 31 years, this will shift to a range of 25-45 years with a peak of 33 years. In general, the mother's age is increasing. The fertility rates are also increasing, which means that more babies will be born in the coming years. However, as already stated, forecasting fertility rates can be very insecure, so we should remain critical to the outcomes of the forecast fertility rates.

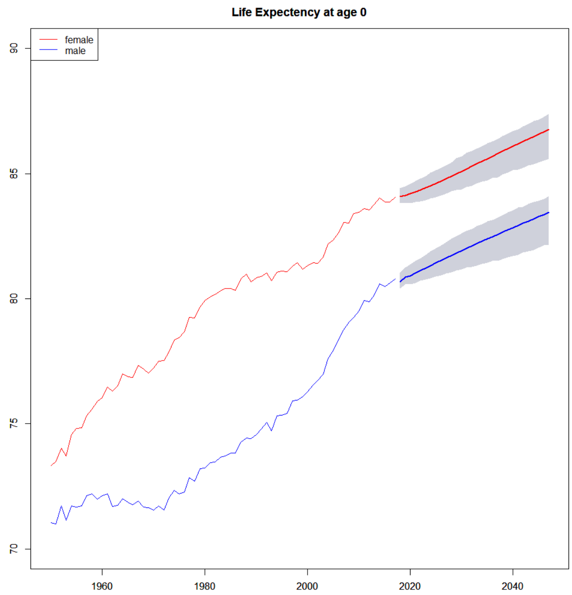


Figure 4.6: (Forecast) Life Expectancy.

Net-Migration Rates

Even as the fertility rates, the net-migration rates are difficult to forecast. As we see, the data of 2016 show an enormous peak around the age of 20 years, for both males and females. In the forecast rates, we see that the peak is less high and the data are more smoothed. It is hard to say if this forecast is accurate by only looking at this plot. The forecast rates for 2026, 2036 and 2046 are almost identical to each other, which, intuitively, seems incorrect. Overall, a positive net-migration rate would remain, which will also have an influence on the BRR.

The uncertainty in the net-migration forecast is also shown in the width of the confidence intervals. Even for the one-year forecast, we have a pretty wide interval, especially for the younger ages. For the ages 0 to 60, the uncertainty of the forecast drastically increases going more into the future. The forecast of the elderly people seems quit secure, since the confidence bounds are very small.

Population

Ultimately, the forecast of the three input parameters will determine the population forecast. We show for different population forecasts, for both males and females, the new demography in comparison with the last known year. So, in this case we compare the year 2017 with the forecasts years of 2018, 2027, 2037 and 2047.

The first thing that we notice is the increase in the width of the confidence intervals if we look more into the future. It is logical that this will increase, however it mostly happens for the younger ages. This means that the uncertainty in fertility rates, and how many babies are born, immediately have an uncertain influence on the total population forecast. We saw that the forecast of the net-migration rates is uncertain, but this is less evident in the population forecast, since the confidence interval around the age of 20 (where the peak is allocated) is not so wide. The forecast of the mortality rates is quite accurate, since the confidence bounds at the elderly ages are very small, which indicates that the population forecast for those ages are quite certain.

Overall, we see that the elderly population is growing in comparison with the year 2017, but we must notice that the balance between the older part of the population and the younger part is restoring. We see that in the year 2047, the working part of the population has increased and there is a growth in babies that are born. We would expect that this has a positive influence on the balance in the costs of the social security system, especially for the AOW expenditures. This

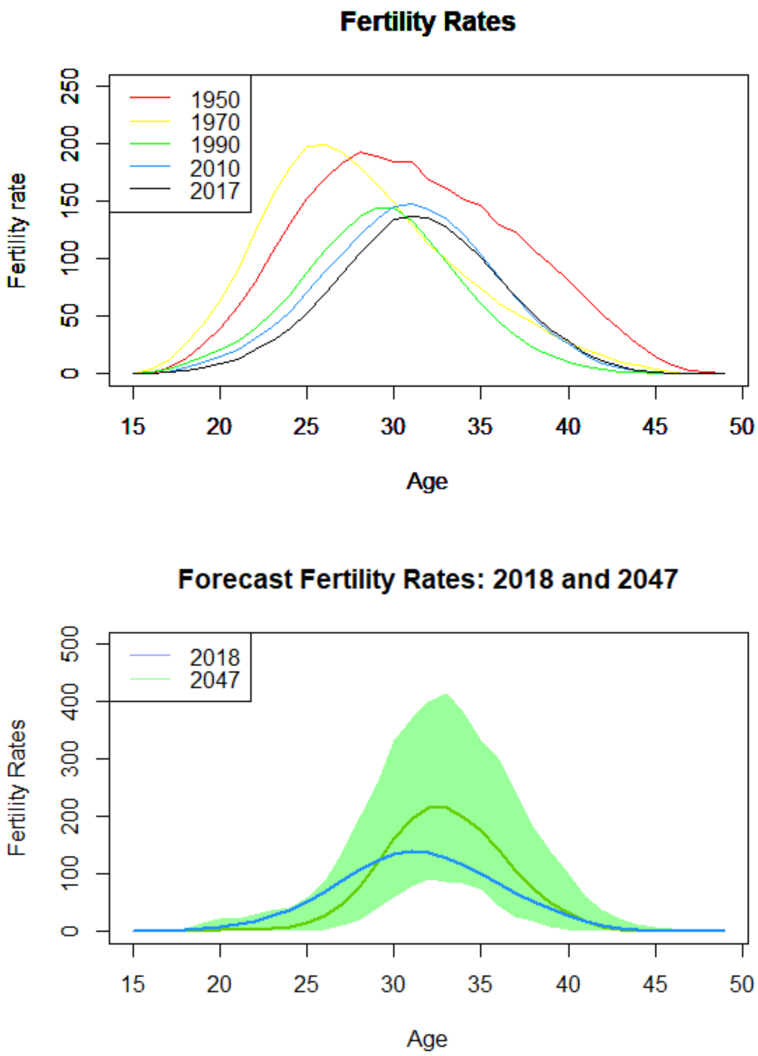


Figure 4.7: Simulated and Forecast Fertility Rates.

hypothesis will be explained in more detail in Chapter 5. A last note is that the overall population of the Netherlands is increasing the coming years, which might result in other problems but is not discussed in this master thesis.

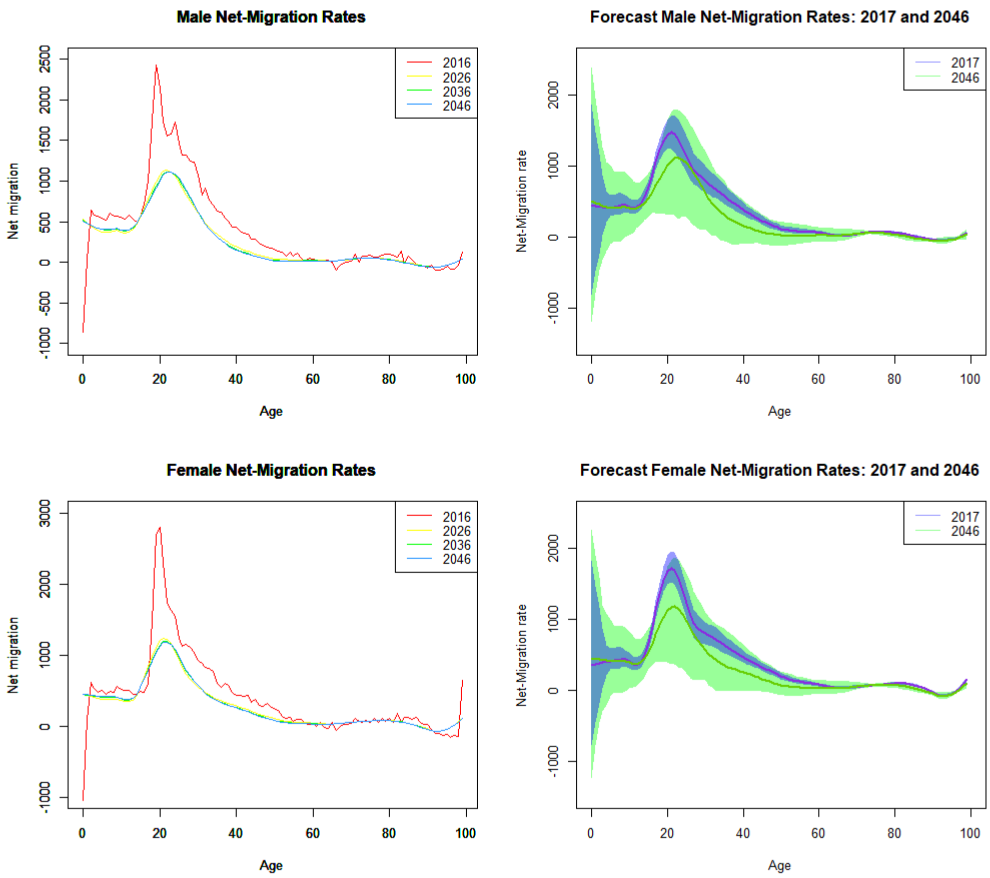


Figure 4.8: Simulated and Forecast Net-Migration Rates.

4.3.3 Output Parameters

Model

The main output of model is described in Section 4.3. In this section, we give the percentage of variance explained for each K and the clarification of the basis functions and the coefficients. Finally, we show the forecast accuracy for each parameter.

In Table 4.1, the percentage of variance explained for each K is shown. The uncertainty in the forecast of the fertility and net-migration rates is shown, since the most of the variance is explained by the first three principle components instead of the first one. We may conclude that we made the right decision to use at least six principle components.

In Appendix D, we made a summary of the basis functions and coefficients. The first three basis functions and the coefficients are shown, since for every input parameter this already explains more than 95% of the variation. We take the fertility as an example. The first basis function shows that the fertility rates decline faster around the age of 24 and 42. The coefficient shows a steady decline for the fertility rates. The introduction of the conception pill is also shown by a faster decline around the years 1970. A forecast of the coefficients is also made, in case of the fertility rates, the model predict a further steady decline in fertility rates over time.

In Figure 4.10, we see the MSE and ISE for the three different input parameters. The MSE shows the forecast accuracy averaged across years. For the mortality rates, the forecast seems quite accurate for the ages. This confirms the assumption that the mortality rates are very predictable. In our case, we see an outlier at the age of 99. This follows from our model choice to have a mortality rate of 1 at the age 99^+. The fertility rates show a less accurate forecast for the ages between 25 and 35 years old en from 42 years and onward. This means that the forecast model has some difficulties with forecasting the shift in changing fertility rates and the ages of the mothers.

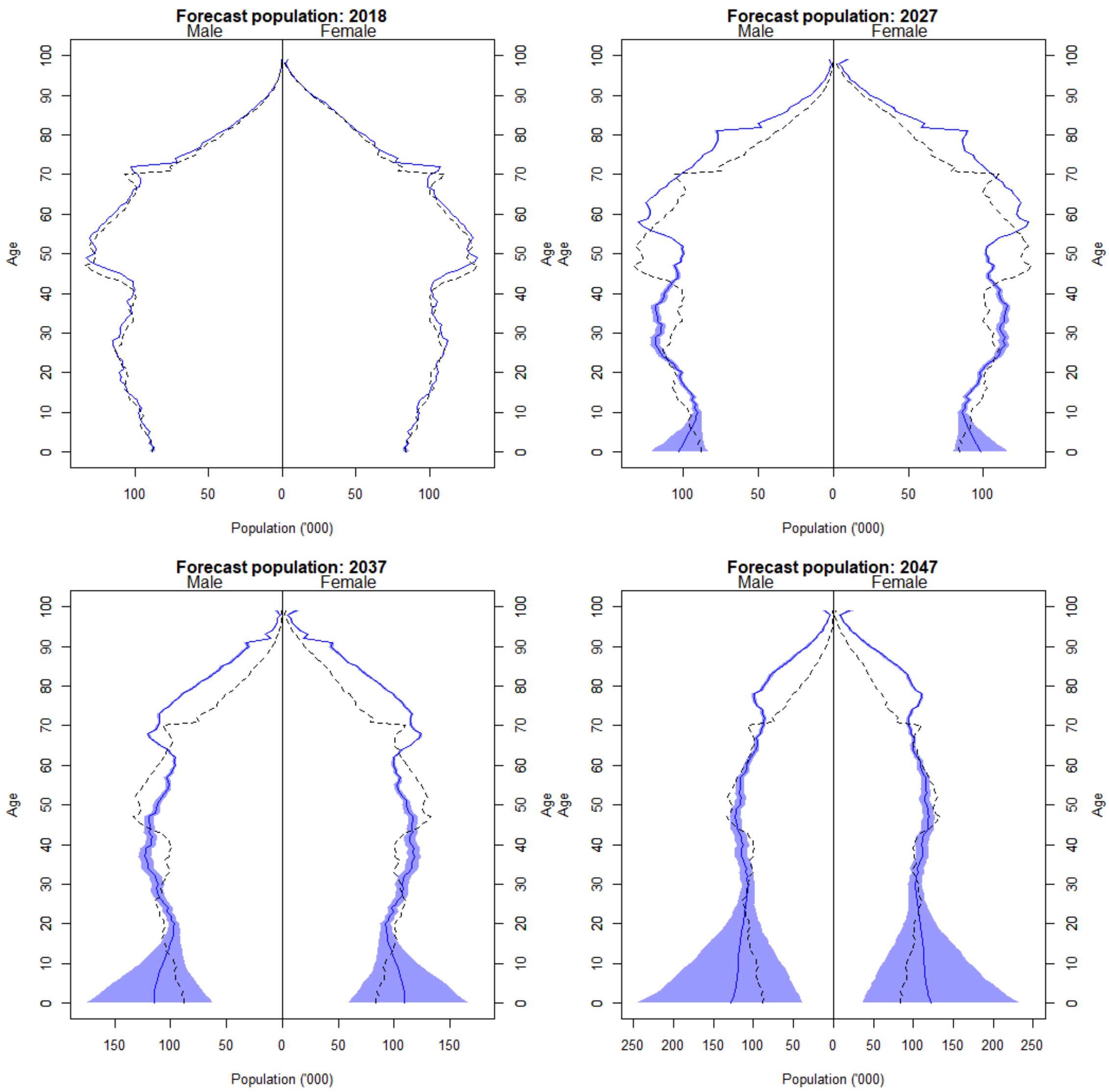


Figure 4.9: Population Forecasts.

The MSE for the net-migration rates is only very high at the age of zero, which means that the forecast is not that precise for this age. On the other hand, the forecast of the remaining ages is pretty accurate.

The ISE is a measure of forecast accuracy integrated across ages. For every input parameter we may conclude that the further into the future, the forecast is less accurate. For the net-migration rates, there is a peak around the year 2005. In this year, the net-migration is less high than in the surrounding years, which results in a less precise forecast.

Overall, we may conclude that more into the future, the forecast becomes less accurate, as what we already expected. The fertility and net-migration forecast are less precise as the mortality forecast. Especially the fertility forecast contains a lot of uncertainty for the ages, which we should taken into account by drawing conclusion for the population forecast. However, by validating our model, we see a useful working population forecast.

Mortality					
$K = 1$	$K = 2$	$K = 3$	$K = 4$	$K = 5$	$K = 6$
96.4334608	1.5686222	0.7002692	0.4056834	0.2564951	0.1557409
Fertility					
$K = 1$	$K = 2$	$K = 3$	$K = 4$	$K = 5$	$K = 6$
68.08662807	29.17185701	1.67107657	0.75487867	0.14086174	0.05521436
Net-Migration					
$K = 1$	$K = 2$	$K = 3$	$K = 4$	$K = 5$	$K = 6$
55.8002203	33.2588701	6.5932261	2.6317395	1.1153888	0.2833739

Table 4.1: Percentage of Variance Explained.

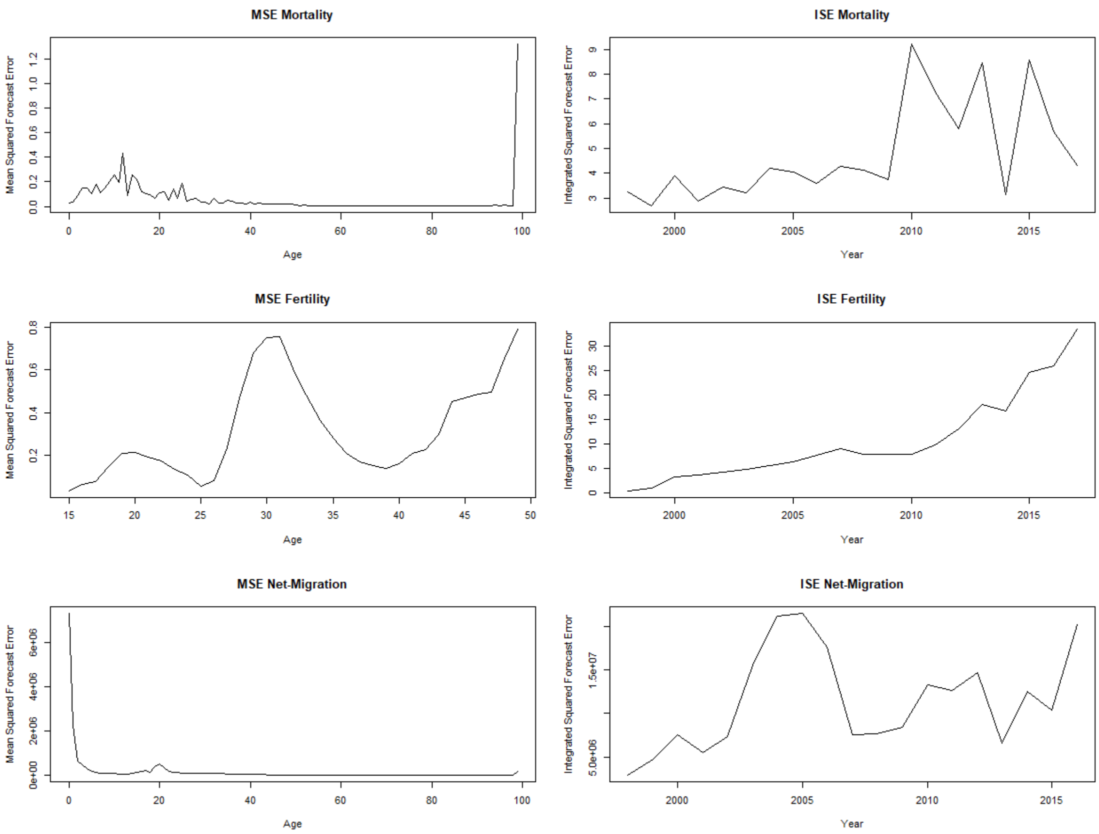


Figure 4.10: MSE and ISE for Mortality, Fertility and Net-Migration.

BRR and Dependency Ratio

In Figure 4.11, we see the BRR and the three different dependency ratios. The BRR continues to grow in the future. We expect that this has two reasons. First of all, the fertility rates will increase, which immediately has an influence on the weighted average on female births in the past (BG_t), since this parameter will increase as well. Therefore, there is a possibility that more females might, or should, conceive more babies to replace themselves. The other reason is the decrease in the female net-migration rates. Less females will enter the Dutch demography, which means that the females that are already lived in the Netherlands should conceive more babies to establish the continuity of the Dutch population size.

In Figure 4.11, we also see the development of the different dependency ratios. As we might expect, the growth in the old-age dependency ratio continues for quite some years. It appears that a start in the decline of this ratio will happen in the year 2037. This seems logical, since the current baby-boom generation has an age between 50 and 70 and with the current mortality rates, a part of this population will have passed away in twenty years from now.

We also notice an increase in the child dependency ratio. This might be the result of the increase in fertility rates. The fact that more boys are born in the Netherlands is still shown. Since both the old-age dependency ratio and the child dependency ratio are increasing, the total dependency ratio will increase as well. However, the total dependency ratio also starts decreasing at the year 2037. This still means that the old-age dependency has a big influence on the total dependency ratio. If we look at the status of a population according to PRB (2018), we will have a double dependency ratio in twenty years from now.

The mean highest ratio for the old-age dependency is around 0.43 in the year 2037. This means that for every working individual, 0.43 elderly individual is present. The ratio already increased from 0.28 in 2017 to 0.43 in 2037. At the current moment, the elderly part of the population is to high such that the AOW expenditures are not fully covered by the working part of the population. A tremendous increase in the dependency ratio would suggest that the shortage in AOW coverage will further rise and that the problem of the AOW entitlement age would increase even more. We will investigate this hypothesis in Chapter 5.

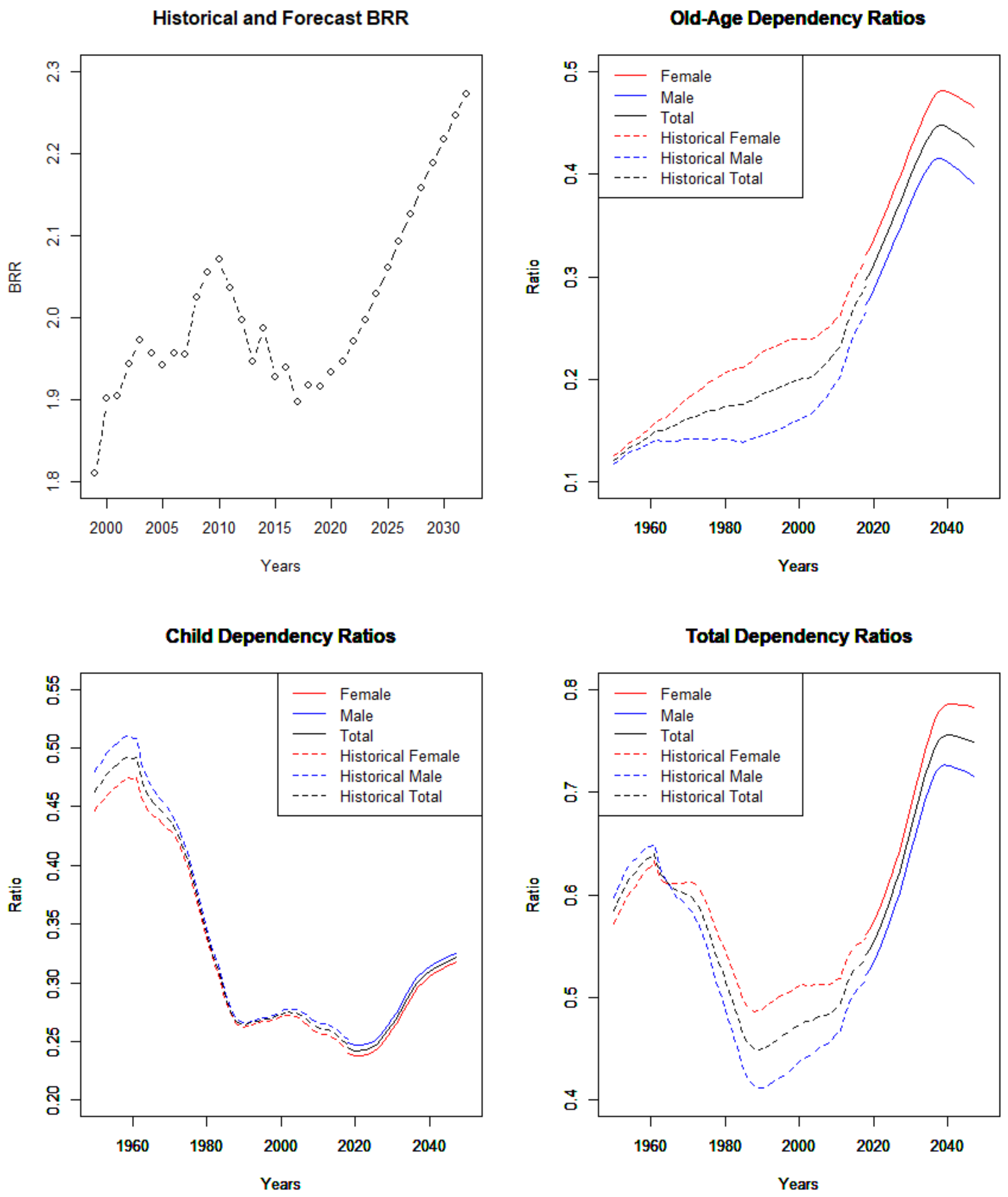


Figure 4.11: Historical and Forecast BRR and Dependency Ratios.

4.4 Conclusion

This chapter covers the historical trends of the Dutch demography and tries to forecast the demography for the next 30 years. At a historical point of view, the decrease in fertility rates has an important impact on the balance of the population. The children that were born after Word War II already caused an increase in the younger part of the population. This is also shown by a very high child dependency ratio, but the decrease in the fertility rates from 1970 and onward has an even further distorting effect on the demography. The positive net-migration rates recover the decline in population growth at the more younger ages a little bit.

The 30 year forecast shows an even further increase in the elderly part of the population. The old-age dependency ratio increases drastically until the year 2037. From that moment on, the ratio starts declining. This is also shown in Figure 4.9 for the year 2047, where we notice that the bulge of the baby-boom generation is smoothed, meaning that most of the individuals in this age group have passed away.

One of the additional research questions that can be answered in this chapter is as follows:

How could we model the demographic distribution and AOW entitlement age in the Netherlands for the coming 30 years?

We first must notice the top of the problem is not even reached. In the Netherlands, we see the AOW entitlement age as a national debate, where it sometimes feels like that most of the baby-boom generation already reached the AOW entitlement age, but by looking at the year 2018 in Figure 4.9, we notice that the biggest bulge is around the age of 50, which means that this part of the population is not entitled to AOW, but will be in less than 20 years from now. The system seems even more in balance at the moment since this part of the population is paying taxes for the AOW. Of course, a part of the baby-boom generation is already receiving AOW and a part of them will not live 20 years from now. Still, we might expect that the AOW shortage would even increase the next 20 years. To answer the additional research question, we conclude that the future demographic distribution of the AOW entitlement age increases even more the next 20 years. The balance between the working part of the population and the population that is entitled to AOW is improving from the year 2037 and onward, which might result in a more sustainable AOW system.

A last notion that we want to make for this chapter is the uncertainty in forecasts. We conclude that the mortality forecast is quite certain, but the forecast of the fertility rates and net-migration rates deal with wide confidence intervals. This has also an influence on the population forecast. However, since the fertility rates and net-migration rates have an impact on the younger part of the population, we are quite certain of the population forecast for the AOW entitlement age. Besides, the forecast is based on 1200 iterations for mortality and net-migration and 50,000 for fertility rates, which reduces the possibility of random chance. We also did a validation of the forecast model by forecasting the years 1997 until 2017 based on the data of 1950 until 1996. We compared the forecast data with the known data of the years between 1997 and 2017. This results in answering the following research question:

How should we assess model outcome and uncertainty regarding the demographic composition development?

We notice that the forecast model gives a good prediction for the mortality rates, both for the different ages as for the different years. The fertility rates produce the most uncertainty in the model. This is due to the shift in the age of the mothers. The net-migration rates are most uncertain for the time parameter, which means more uncertain into the future. The model predicts the net-migration rate quite accurate for the different ages.

Chapter 5

AOW System

Contents

5.1 Chapter Summary

This chapter is focused on the sustainability of the AOW system. First of all, we are creating the model of Alho and Vanne (2006) for the Dutch situation. This is the basic model that is not only used for the AOW system, but for the health care system as well, since the economic variables do not change for the two systems.

Secondly, we make the distribution of $\hat{S}(x,z)$ and $\hat{T}(x,z)$. The revenues are based on the average income an individual earns. The expenditures are based on the division of singles and cohabitants, since this makes a difference in the amount of AOW contribution. We notice that females receive more AOW in general, since they live longer and are forced to become single if their husband pass away.

We show the current situation of the AOW system, for which we already notice an increase in percentage of GDP and an increase in government payments. By forecasting the AOW system, we notice that the system is not sustainable, since the predictive IPL is positive and is becoming more positive more into the future. If we increase the entitlement age to 68 years old, the system improves a little bit, but is still not sustainable. By increasing the AOW entitlement age to 71 years old, we see that the system is sustainable for the next four years, but becomes unstable after those years. This suggest that we should connect the life expectancy with the entitlement age to create a sustainable AOW system.

5.2 Model Input

As stated in Section 2.3, Section 3.4 and Appendix E, we need to compute the stochastic forecast population, the forecast of the economic variables, the values of S and T and finally the predictive distribution of the IPL. We first provide the input of the model and give an indication of the course of the expenditures before we discuss the results of the AOW forecast.

5.2.1 Stochastic Population Forecast

The forecast of the population has been given in Chapter 4 and will be used as an input parameter of the model, and will be denoted by $V(x, z, u)$. We decided to simulate 10000 times from the 1200 iterations of the simulated population forecast as given in Chapter 4 as input parameter of $V(x, z, u)$.

5.2.2 Economic Variables

A time series analysis for every economic variable is computed. We obtained an AR(1) model for the real interest rate, also an indication for the debt of the Dutch government. The AEX index, which we use as a reflection of the Dutch revenues, appears to be a white noise model. This seems logical, since the course of the stock returns is very inconsistent, even on a daily basis. Finally, the time series of the productivity, shows a MA(1) time series model. Eventually, all the Dutch time series are identical to the time series used in the model of Alho and Vanne (2006).

Every time series model has a distribution with a mean and variance. In an ARIMA(0,0,0) process, this is the only available distribution since it is a white noise model. In every other model, more distributions are available since the model has an expansion. All these distributions are important for the construction of Equations 2.31b, 2.31c, 2.32b and 2.32c. In Table 5.1, we made a summary of the input of the time series for every economic variable. We used the parameters m_1, m_2 and m_3 to indicate the 'basis' distribution. For the real interest rate and the productivity, we have an extra distribution, indicated with AR(1) as x_u and MA(1) as $\epsilon_{t,k}$.

	Real Interest Rate		Stock Returns	Productivity	
	AR(1) (x_u)	m_1	m_2	MA(1) ($\epsilon_{t,k}$)	m_3
μ	0.003278	0.011979	-0.000279	0.005313	0.02071
σ	0.002651	0.002616	0.000157	0.001582	0.00529

Table 5.1: Parameters Time Series Models.

Overall, we have two distributions per parameter. Even though the stock returns variable has no extra distribution, there is a distribution for the error in the time series, also known as w_u. This is a Normal distribution with $\mu = 0$ and $\sigma^2 = 0.01299$. The summary of every distribution is given in Table 5.2.

Real Interest Rate	Stock Returns	Productivity
$x_u \sim N(0.003278, 0.002651^2)$	$w_u \sim N(0, 0.01299)$	$\epsilon_{t,k} \sim N(0.005313, 0.001582^2)$
$m_1 \sim N(0.011979, 0.002616^2)$	$m_2 \sim N(-0.000279, 0.00157^2)$	$m_3 \sim N(0.02071, 0.00529^2)$

Table 5.2: Distribution Summary Time Series Models.

Hence, we can compute the needed Equations for X_1, X_2, $Var(X_1)$ and $Var(X_2)$:

$$X_1 = \frac{m_1 - 0.011979}{e^{0.019979} - 1} + \sum_{u=1}^{\infty} e^{-0.011979u} x_u \tag{5.1a}$$

$$\text{Var}(X_1) = \frac{0.002616^2}{(e^{0.011979} - 1)^2} + \frac{0.002651^2}{(1 - 0.003278e^{-0.011979})^2(e^{2*0.011979} - 1)} \tag{5.1b}$$

$$X_2 = \frac{m_2 - (-0.000279)}{e^{0.011979} - 1} + \sum_{u=1}^{\infty} e^{-0.011979u} w_u \tag{5.2a}$$

$$\text{Var}(X_2) = \frac{0.000157^2}{(e^{0.011979} - 1)^2} + \frac{0.01299}{(e^{2*0.011979} - 1)} \tag{5.2b}$$

If we look at Step 2 in Appendix E, we notice that we have to sample N values for X_1 from a Normal distribution with mean zero and variance given by Equation 5.1b and N values for X_2 from a Normal distribution with mean zero and variance given by Equation 5.2b. We choose to use 10000 iterations to have a sufficient number to minimise the impact of outliers in a simulation. If we have 10000 values of X_1 and X_2, we are able to compute 10000 values for W_1 and W_2 and finally W.

W_1 corresponds with the amount of debt of the Dutch government. We need the mean current debt of the government. Alho and Vanne (2006) use $E[W_1] = -0.323$ for the Finish government. We indicated that the Finish and Dutch government have a lot of similarities in their percentage of debt to GDP ratio, so we will use the same value for $E[W_1]$. The same reasoning accounts for W_2, which stands for the mean revenues. Alho and Vanne (2006) indicate that $W_2 = 0.913$, which we will use for the Dutch situation as well. Eventually, we can compute the Equations for W_1, W_2 and W, knowing that $W = W_1 + W_2$:

$$W_1 = -0.00323(1 + X_1) \tag{5.3a}$$

$$W_2 = 0.00913(DV + X_2) \tag{5.3b}$$

where $DV = \frac{-0.000279}{(e^{0.011979} - 1)}$

5.2.3 IPL

We computed 10,000 values for W, such that we already computed one variable for the input of Equation 2.34. We also have to compute the values in Equations 2.33a and 2.33b. We first show some figures that corresponds with the assumptions that we have made for the computation of $\hat{S}$ and $\hat{T}$, before we calculate the productivity component. Finally, we compute the predictive distribution of the IPL.

As stated in Section 3.4, we only use the demographic distribution and the cohabitation status of the population as input parameters for the determination of $\hat{S}$. In Figure 5.1, we see the cohabitation situation in 2017. Overall, more females are present in the older age population. This is consistent with the fact that females have a higher life expectancy. The most interesting difference is shown in the part of the population that is cohabiting. We notice that the male part of the population is higher than the female part. If we make the comparison with the single part of the population, we see that there are more females. This means that most individuals do cohabitate and that in most of the cases first the males will pass away, leaving the females behind. This is not a shocking affect, but it has implications for the total AOW payments. More single females will survive, leading to a higher AOW entitlement fee in combination with a higher life expectancy. This could pressure the AOW system even more.

In Figure 5.2 the distribution of incomes is shown for the working part of the population. We notice that the difference between males and females is almost negligible. This might not be the correct reflection of reality, since most males work full-time and will have a higher yearly salary than most females who work part-time, but this gives an indication of the average incomes of males and females.

The distribution of the demography, the amount of income and the distribution of singles and cohabitants is known. Therefore, we can compute the values of $\hat{S}$ and $\hat{T}$ as shown in Table 3.1. For the amount of received taxes, we use 17.90% of an annual salary, which is the tax percentage for the AOW. We also consider the maximum chargeable level of income.

So, we computed $V(x, z, u)$, $\hat{S}(x, z)$ and $\hat{T}(x, z)$. Now we have to complete Equations 2.33a and 2.33b by identifying the productivity part. We know that d stands for the difference between

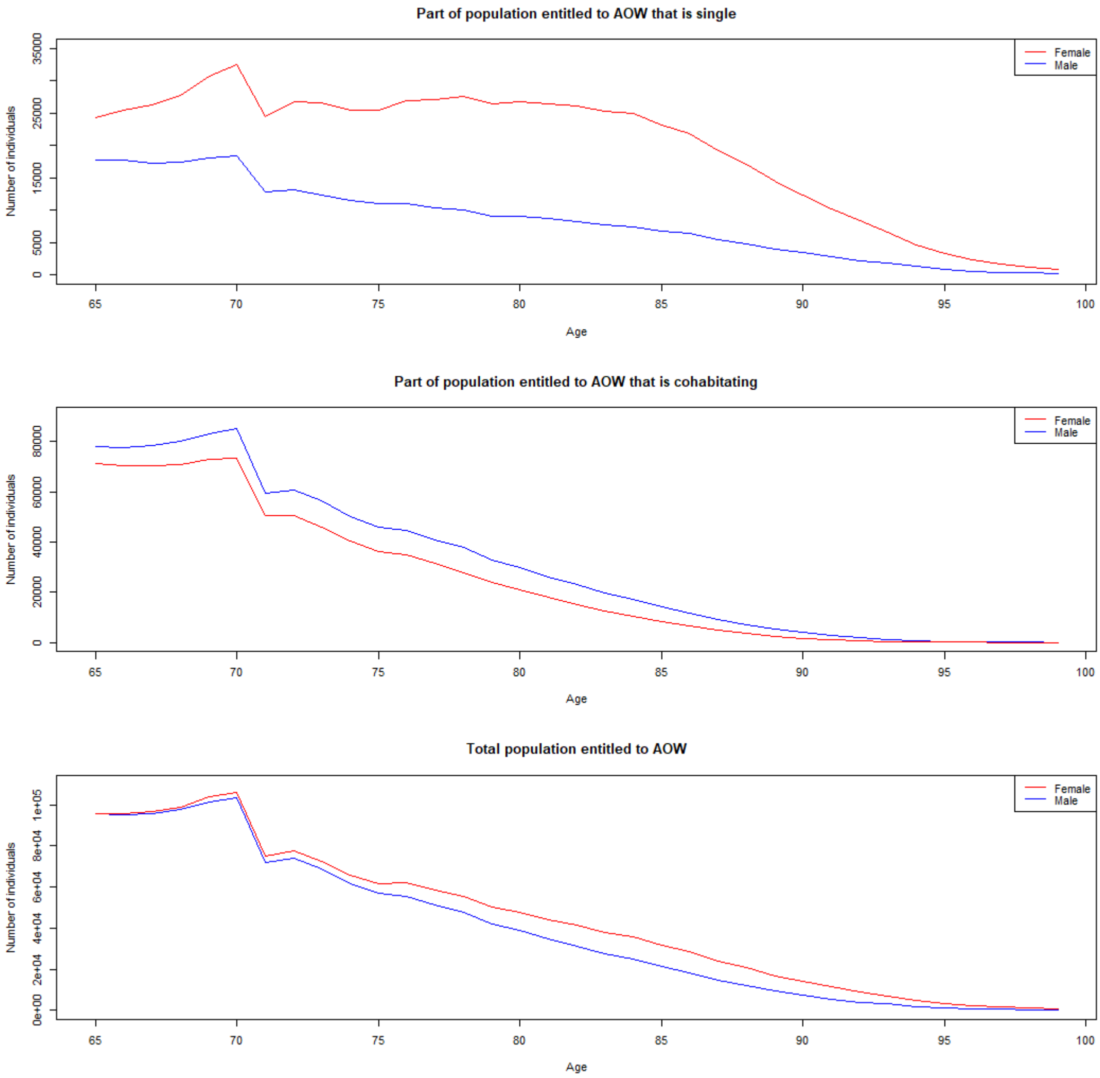


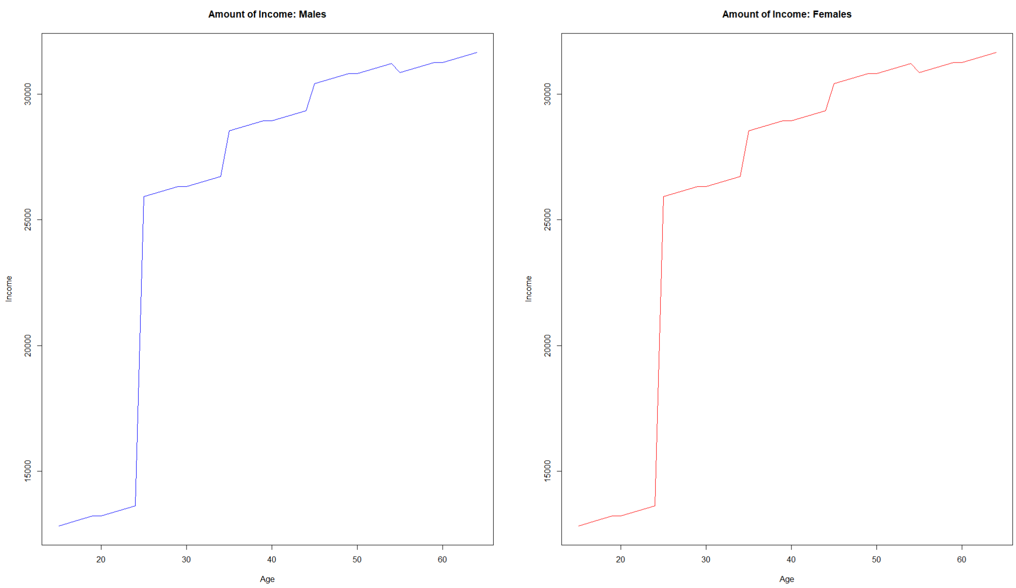
Figure 5.1: Distribution Single or Cohabitant for AOW Entitlement Population.

the discount rate and the growth rate of the GDP, so $E[m_1] - E[m_3]$. This means that $d = 0.011979 - 0.02071 = -0.00873$. Eventually, $S(z)$ and $T(z)$, look as follows:

$$S(z) = \sum_{u=1}^{\infty} \Big\{ \sum_{x=0}^{\infty} V(x, z, u)\hat{S}(x, z) \Big\} exp(-(-0.00873)u + u(m_3 - 0.02071) + \sum_{k=1}^{u} w_{t,k} + 0.005313 w_{t+k-1}) \tag{5.4a}$$

$$T(z) = \sum_{u=1}^{\infty} \Big\{ \sum_{x=0}^{\infty} V(x, z, u)\hat{T}(x, z) \Big\} exp(-(-0.00873)u + u(m_3 - 0.02071) + \sum_{k=1}^{u} w_{t,k} + 0.005313 w_{t+k-1}) \tag{5.4b}$$

This means that we have computed all three input parameters for 2.34. Since we have 10,000 values of W, we also need to compute 10,000 values of $S(x)$ and $T(x)$, which is done by sampling 10,000 values of m_3.



(a) Distribution Income Males.

(b) Distribution Income Females.

Figure 5.2: Distribution of Incomes for Males and Females.

5.3 Indication

Before showing the result of the AOW system, we first want to give an indication of the current and historical situation, by showing the primary balance and the distribution of the AOW expenditures. This is done for 1995 until 2017, since this is the earliest moment that all the required data have been registered.

5.3.1 Primary Balance

The primary balance is an indication of the growth in public wealth, or in our case, the growth in public wealth based on the AOW system. In most of the years, the primary balance is negative, as shown in Figure 5.3, meaning that the resources available for the AOW system are decreasing. This complies with the rising AOW problem.

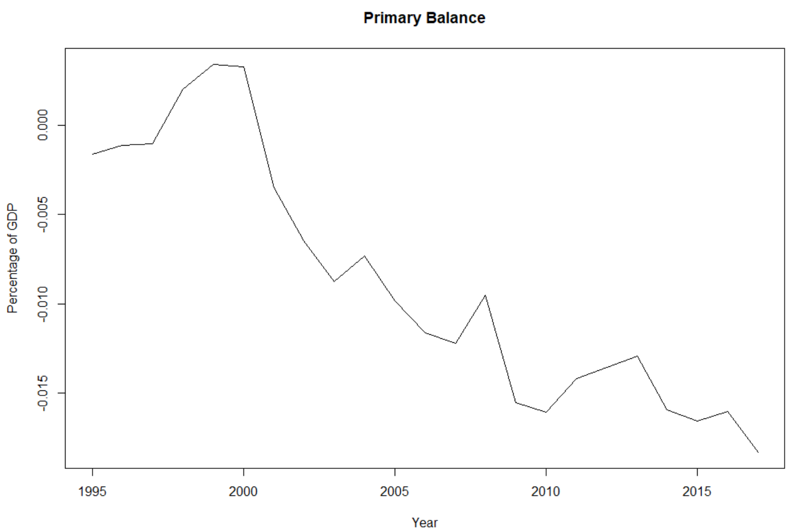


Figure 5.3: Historical Primary Balance.

5.3.2 Distribution AOW Expenditures

The distribution of the AOW expenditures as percentage of GDP is given in Figure 5.4. We notice two things. First of all, the total amount of required AOW entitlements is increasing. In 20 years, it increased with a half percent, which means that the AOW benefits have more impact on the total Dutch financial system than 20 years ago. Secondly, we see that there is a shift in the premium payments and government payments. A higher percentage of AOW benefits is paid by the government, which indicates that the original system is not sustainable anymore.

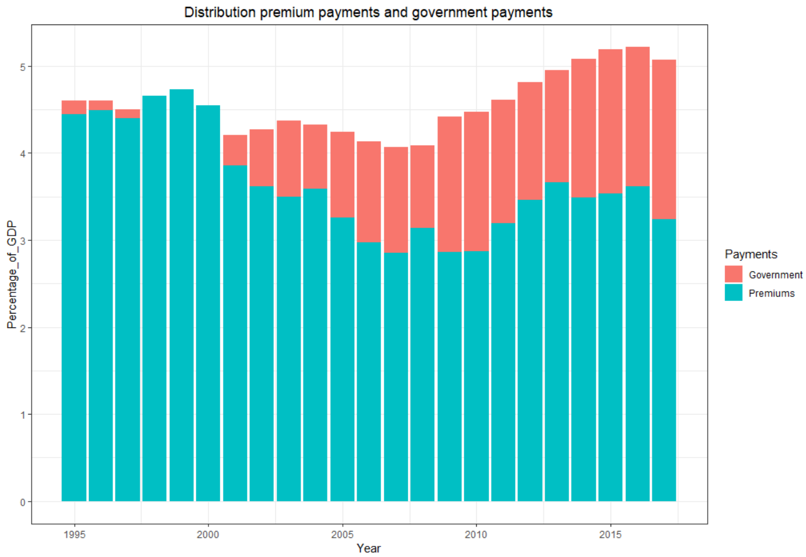


Figure 5.4: Historical Distribution AOW Payments.

In Section 5.4, we will reflect on the primary balance and distribution of AOW expenditures by showing the future scenario.

5.4 Forecasting Results

In this section, we firstly show the forecast of the primary balance and the distribution of the AOW expenditures before the predictive IPL is given. As already mention in Section 3.4, we use 2017 as a benchmark year. This means that both the S and T are given as percentage of the GDP of 2017 in every year. This makes it more practical to compare the different years with each other and for see the course of the different forecasts. Besides, in Equations 2.33a and 2.33b, a real GDP per capita growth series is included such that S and T are the discounted values.

5.4.1 Primary Balance and Distribution AOW Expenditures

In Figure 5.5, the historical and forecast primary balance is shown. We see an even further decrease in the primary balance, meaning that the course of the AOW payments has a negative growth effect on the economy of the Netherlands. We also notice an increase, starting from the year 2037 and on wards. This increase is in accordance with the decline in the old-age dependency ratio, shown in Figure 4.4. So, we notice that from this moment on, the effect of the baby boom generation is rapidly decreasing. However, this will still not fix the problem, since we remain with an overflow of elderly people in comparison with the working part of the population.

The course of the primary balance is the same as that of the government payments in Figure 5.6. We already noticed by reviewing the current distribution of the AOW payments that the government is paying a significant part. By forecasting the AOW system, we see that both trends continue that we noticed in Section 5.3.2. The total amount of AOW entitlements is increasing until 2037 and the percentage paid by the government is increasing as well. If we compare Figure 5.6 with Figure 1.2, we notice a resemblance. The main difference is the percentage of GDP that

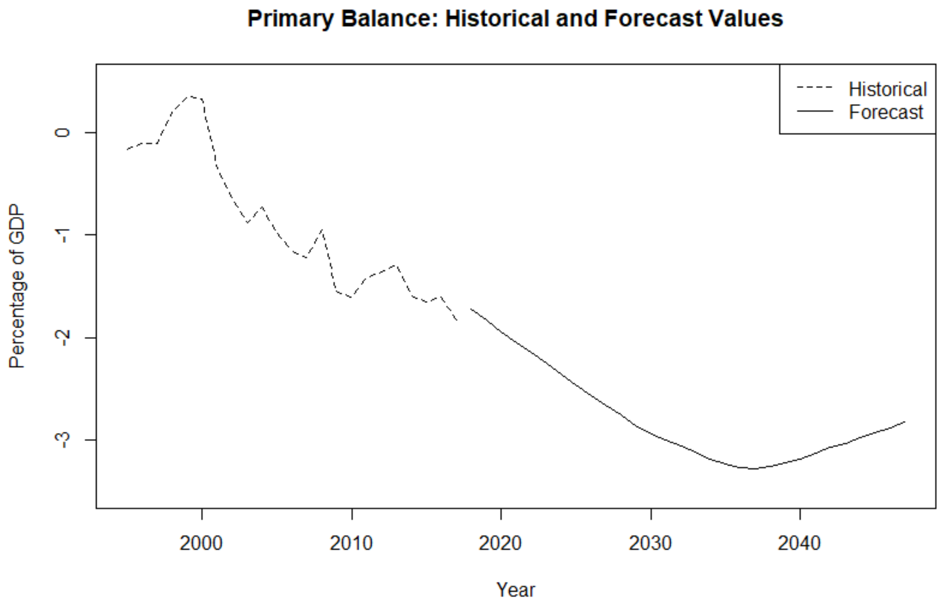


Figure 5.5: Historical and Forecast Primary Balance.

is used for the AOW system. In our forecast, this percentage appears to be lower, fortunately. The difference can be caused by a different forecasting method, for example, without taking the productivity factor into account. Another reason might be the different forecast time frame, since we have more up-to-date data.

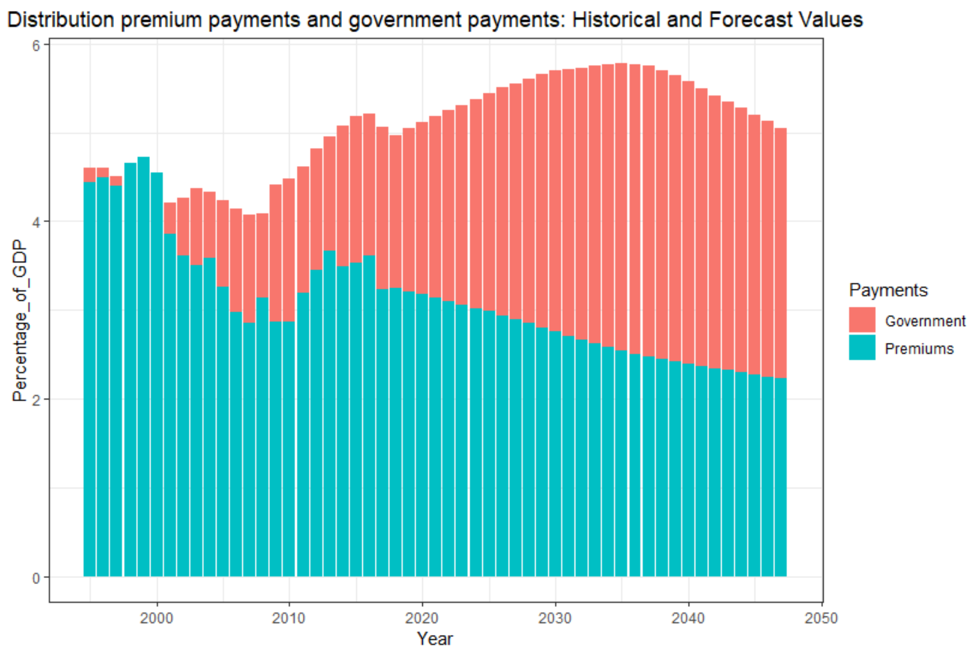


Figure 5.6: Historical and Forecast Distribution AOW Payments.

5.4.2 Forecast IPL

The primary balance and the distribution of AOW payments already gave a accurate reflection of the stability of the AOW system. However, the wealth of the Netherlands is not taken into account in these figures, which is possible by computing the predictive IPL. In Figure 5.7, the predictive IPL is given for the next thirty years. We see a steady increase in the ratio, which already started off positively. This means that more costs are made than incomes generated, which is not a surprise if we look at the primary balance and the distribution of AOW payments. However, in the year 2018, the predictive IPL is almost zero, meaning that the productivity of the Netherlands compensates for the big difference in tax payments and government payments as shown in Figure 5.6. Unfortunately, this factor is not enough to compensate for the increasing entitlements and will result in 0.83 times the GDP as AOW liability in thirty years from now. As shown in Table F.1, the mean of the wealth is negative. This means that this also has an increasing effect on the predictive IPL.

The analysis of variance given in Figure 5.8 shows the percentage of variance explained by the three different variables, namely the demographics ($V(x,z)$), the entitlement and taxes ($\hat{S}(x,z)$ and $\hat{T}(x,z)$) and the wealth (W). For the first year, almost all the variance in the forecast of the predictive IPL is explained by the wealth. This seems logical, since one year from now, the distribution of the demography and the entitlement and taxes are well known, which is also noticeable by the width of the confidence interval in Figure 4.9. More into the future, most of the variance is explained by the demography and less by the wealth. This figure gives us an indication that the forecast of the IPL seems logical and quite accurate.

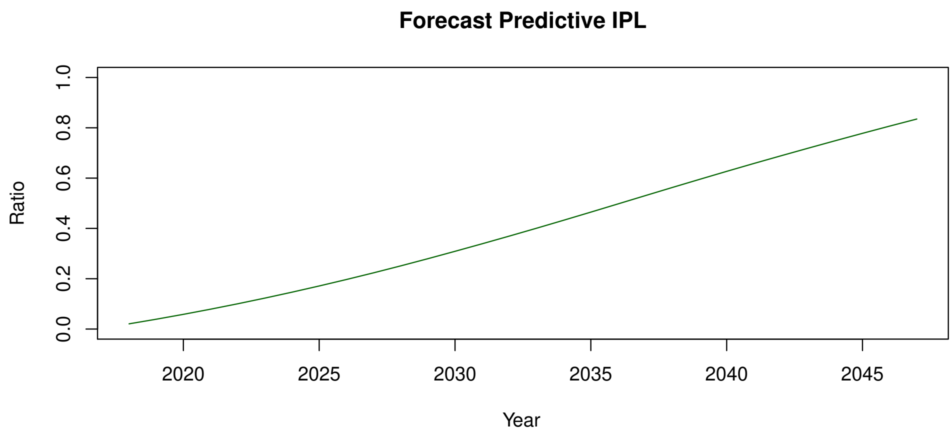


Figure 5.7: Forecast Predicted IPL for Entitlement Age of 65.

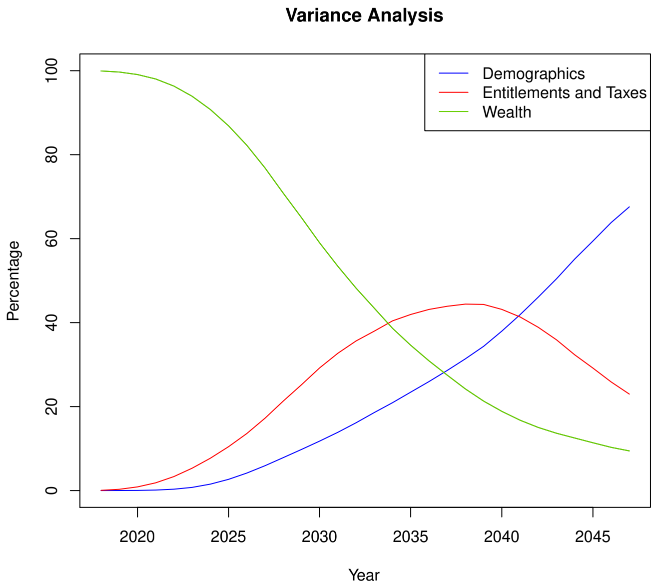


Figure 5.8: Variance Analysis, Entitlement Age of 65.

5.4.3 Sensitivity Analysis

The forecast results in Section 5.4 give a very negative prediction of the IPL and the implication that the AOW system with the entitlement age of 65 years is not sustainable. An entitlement age of 65 was for many years the basic assumption of the AOW system, however, the Dutch government already increased this age. We still wanted to test an entitlement age of 65 years old since there are political parties that believe this is possible. It would be illogical to not take the increasing age into account. Therefore, we used the same model as described above, but increased the AOW entitlement age to 68 years old and to 71 years old, meaning that a smaller part of the population receives AOW and a larger part of the population pays taxes. We show the new primary balance, distribution of AOW payments and predictive IPL for both new entitlement ages. We used an increase of three years for two reasons. First of all, by looking at the tremendous shortages, we expect that an increase of one year still not make the AOW system sustainable. Secondly, the programmed code used for this model, takes approximately 24 hours to simulate a new situation. Therefore, we decided to use only two scenarios to get an indication of an increasing entitlement age, due to lack of time.

The forecasted primary balance for an entitlement age of 68 years old is given in Figure 5.9. We notice an increase in the primary balance in the first forecast year, but this is still negative. This means that the course of the AOW payments has a negative growth effect on the economy of the Netherlands. Eventually, the course of the primary balance is the same as in Figure 5.5 but the starting point of the first forecast year is higher.

The increase in the primary balance is also noticeable in Figure 5.10. The course of the distribution of the payments stays however the same. A positive development is the decrease in percentage of GDP, which means that the AOW system is less intense than in the case of an entitlement age of 65 years old. Another positive trend is the ratio of government payments. With an entitlement age of 65, this will become more than half of the payments, in the case of an age of 68 years old, this will always be lower than the tax payments, as shown in Figure 5.15. However, even with an increase of the AOW entitlement age to 68 years old, it seems that the AOW system is still not sustainable.

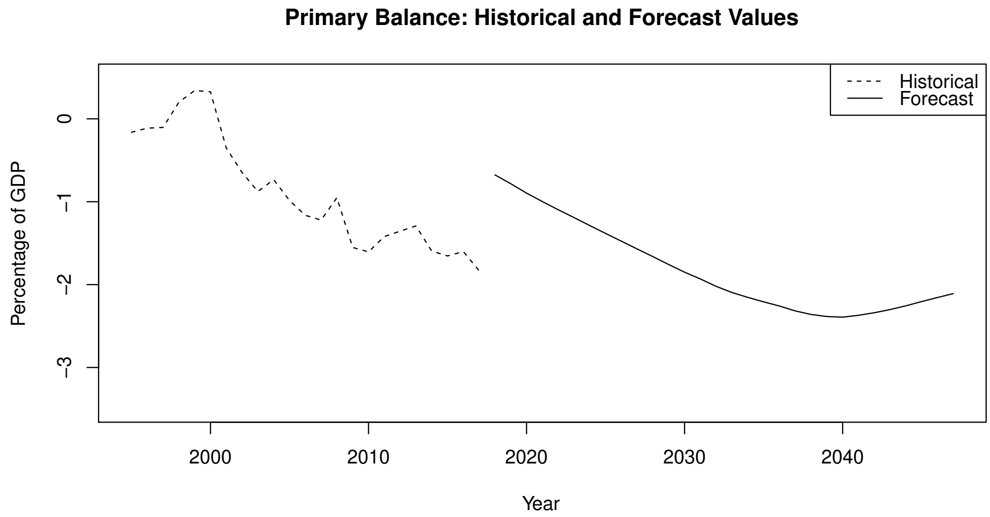


Figure 5.9: Historical and Forecast Primary Balance, Entitlement Age of 68.

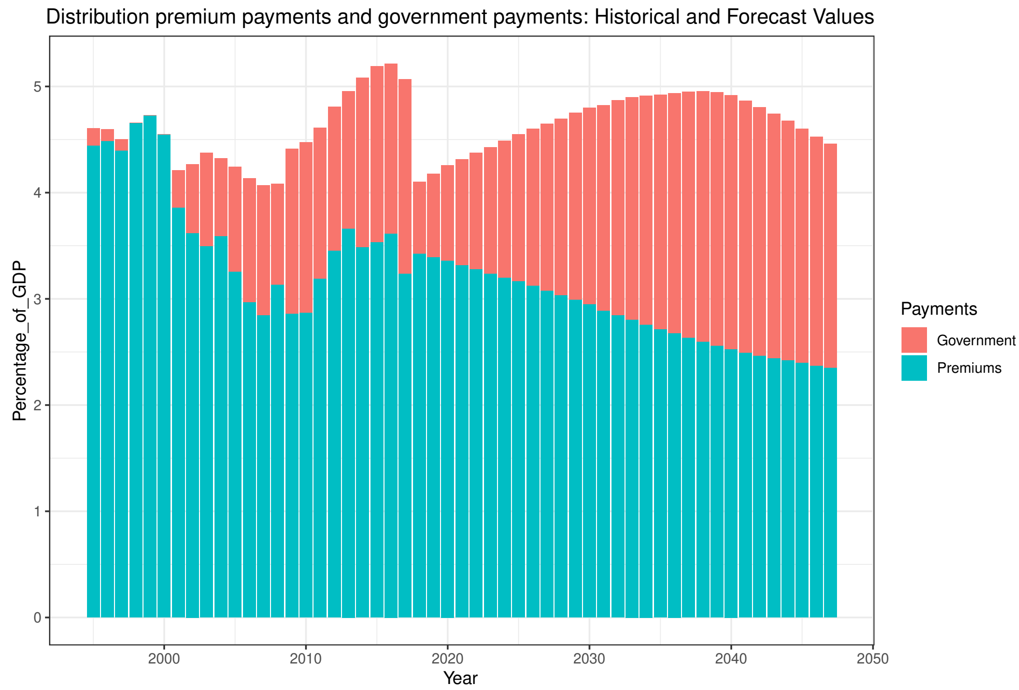


Figure 5.10: Historical and Forecast Distribution AOW Payments, Entitlement age of 68.

Increasing the AOW entitlement age to 71 years old, has a very positive effect on the AOW system. By looking at Figure 5.12, we see that for the first couple of years, there is a positive primary balance. This indicates that more taxes are received than entitlement payments needed. This is also shown in the distribution of tax and government payments, given in Figure 5.13. There are no government payments the first for years. This indicates that the AOW system is sustainable for the next four years by an immediate increase of the entitlement age to 71 years old. From that moment onward, we see that the system has the same development as for the other systems with different entitlement ages. The costs do increase, but after 2037, the costs decrease since the baby boom generation is passing away. The percentage paid by the government is decreasing drastically, since no more than 40% of the AOW payments is paid by the government thirty years from now, as shown in Figure 5.15c.

We did not incorporate the increasing life expectancy in our system. Or differently said, we did not increase the entitlement age more into the future. We have a fixed entitlement age. By looking at the figures of different entitlement ages, we would suggest to connect the entitlement age with the life expectancy. This would result in a more sustainable AOW system.

We also notice that our model seems to work quite accurate. We decreased the AOW entitlement age to 71 years old. This means that the old-age dependency ratio should been decreased as well. By looking at Figure 5.11, we see that this is the case. The decrease in old-age dependency ratio is noticeable in the distribution of AOW payments, since the expenditures decreased a lot.

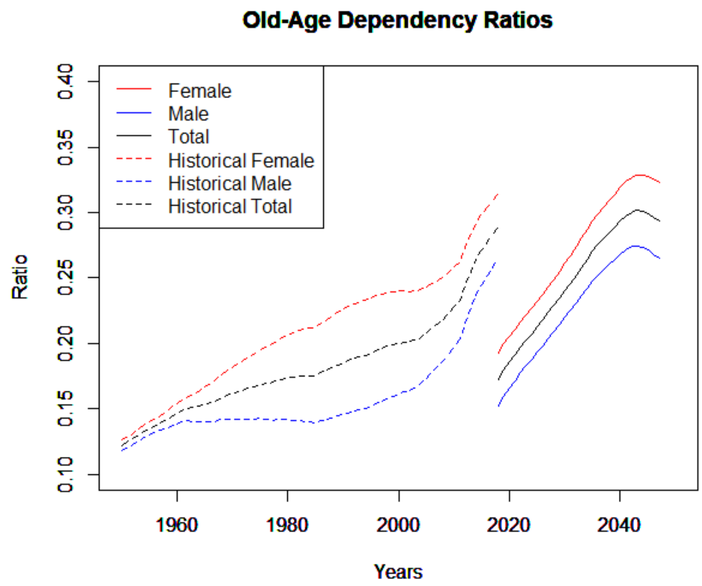


Figure 5.11: Old-Age Dependency Ratio, Entitlement Age of 71.

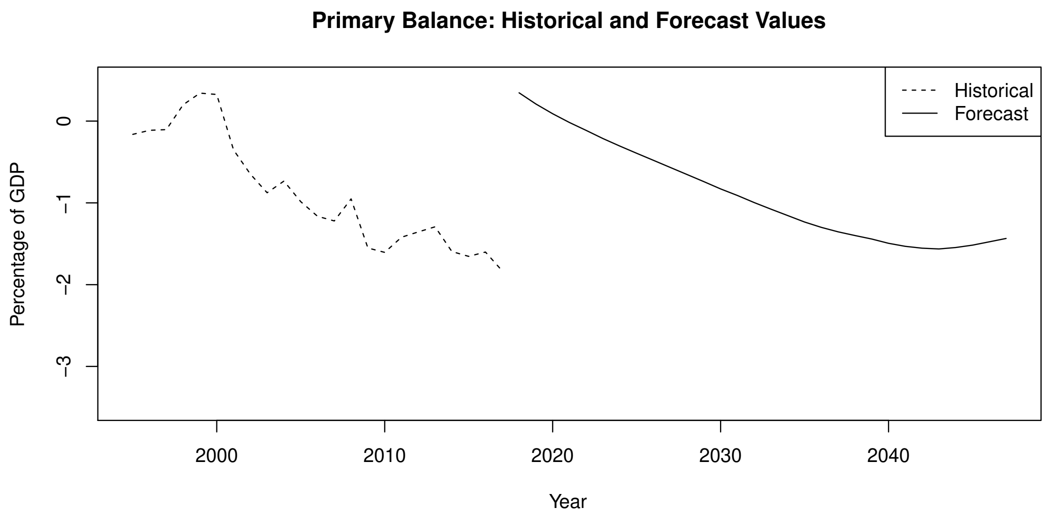


Figure 5.12: Historical and Forecast Primary Balance, Entitlement Age of 71.

The prediction of the IPL is given in Figure 5.14. We notice two trends in comparison with the IPL with an entitlement age of 65. First of all, the IPL decreased significantly, both for an entitlement age of 68 as for 71 years old. Thirty years from now, the AOW liability is 0.55 times the

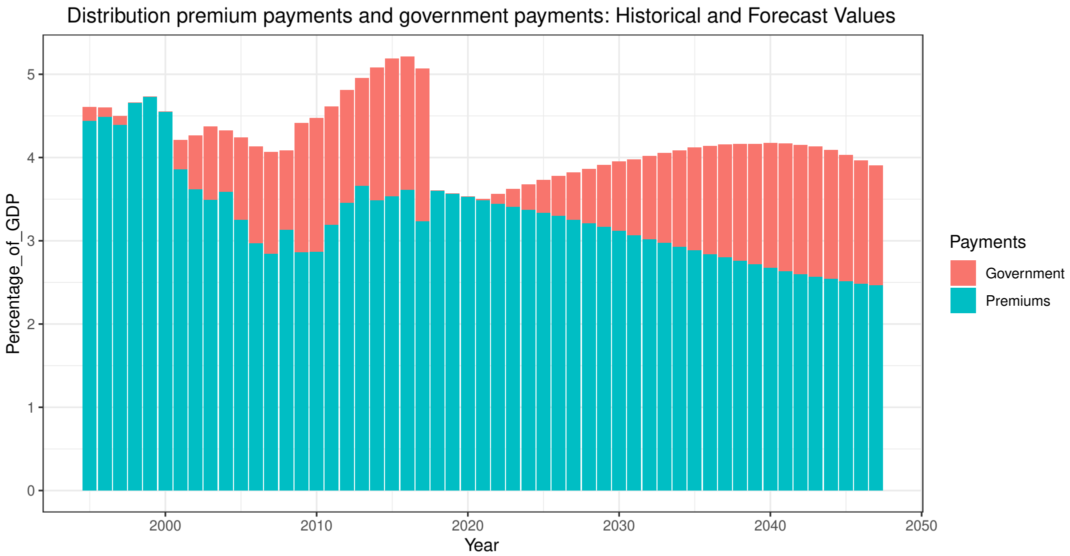


Figure 5.13: Historical and Forecast Distribution AOW Payments, Entitlement Age of 71.

GDP in case of an entitlement age of 68 years old and only 0.25 times the GDP for an entailment age of 71 years old. Another trend is the slower growth of the predicted IPL, which would suggest that a further decrease of the AOW entitlement age leads to a faster decrease in the IPL. However, even with an entitlement age of 68 and 71 years old, the system is not sustainable in the future. This further indicates that the entitlement age should grow with the life expectancy.

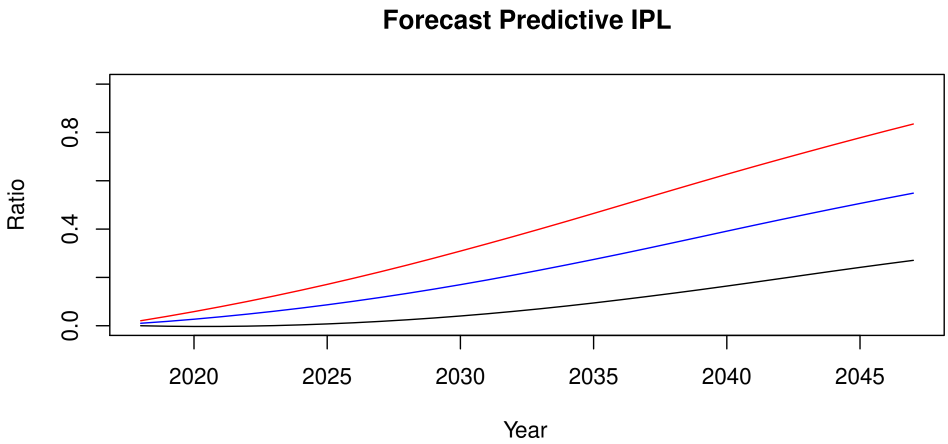
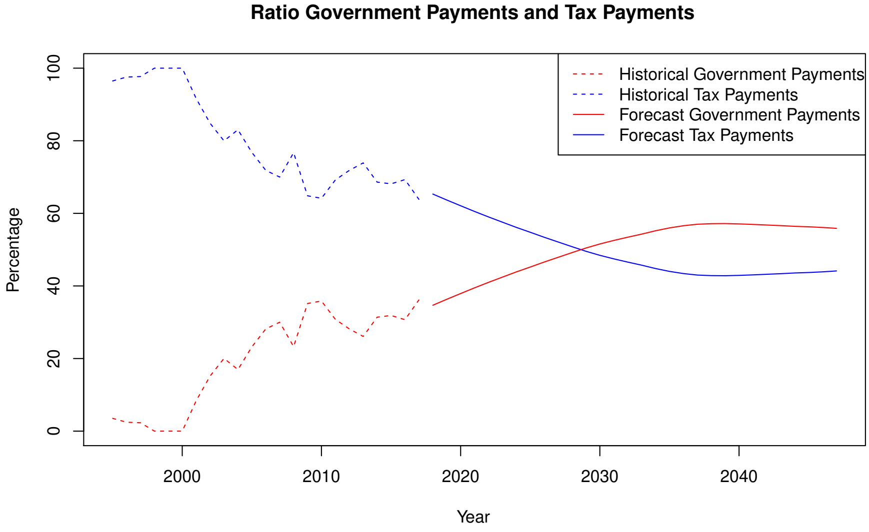
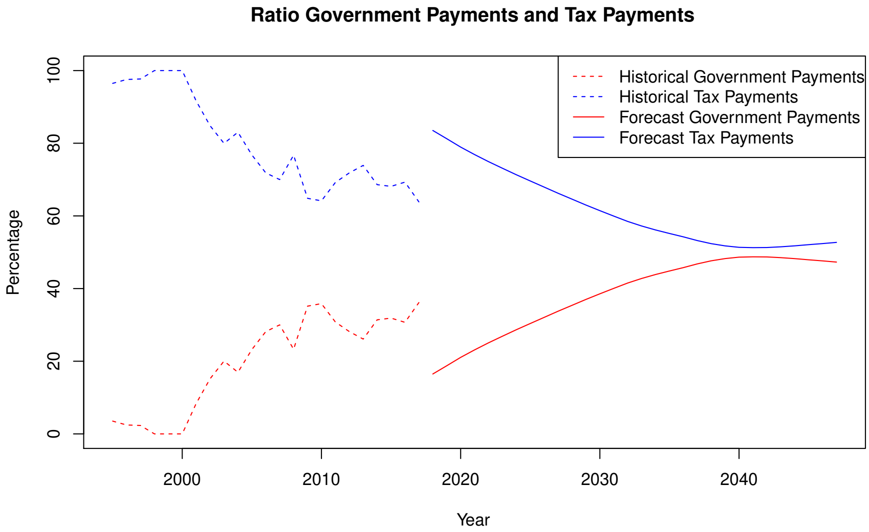


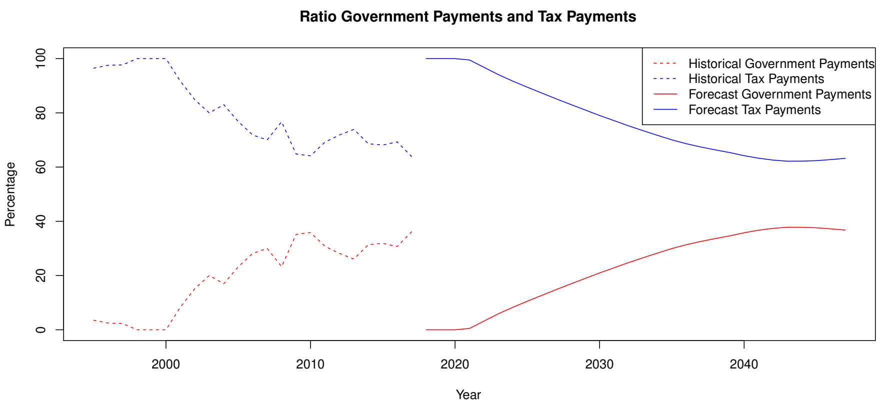
Figure 5.14: Forecast Predicted IPL for Entitlement Age of 65, 68 and 71.



(a) Ratio Government Payments and Tax Payments, Entitlement Age of 65.



(b) Ratio Government Payments and Tax Payments, Entitlement Age of 68.



(c) Ratio Government Payments and Tax Payments, Entitlement Age of 71.

Figure 5.15: Ratio Government Payments and Tax Payments.

5.5 Conclusion

In this chapter, we investigated the sustainability of the AOW system. Before we could say something about this matter, we needed to explain the model of Alho and Vanne (2006) that seems suitable for the Dutch situation. Fortunately, the real interest rate, stock returns and productivity follow the same time series as in the model of Alho and Vanne (2006). This resulted in the formulas given in Equations 5.4a and 5.4b.

We used the distribution of $\hat{S}(x, z)$ and $\hat{T}(x, z)$ in 2017 as input parameter of the forecast model. We see 2017 as our benchmark year. We made the distribution of the expenditures dependent on the division of single individuals and cohabiting individuals. We notice that females use more of the AOW system, since they live longer and become 'single' if they losing their partner.

We showed the current sustainability of the AOW system by giving the primary balance and distribution of AOW payments. This is necessary for answering the research question:

How is the total balance of AOW contributions and expenditures composed?

We noticed that the AOW payments increased as percentage of GDP and that the percentage of government payments increased over the years. This is indicating a negative trend in the sustainability of the AOW system. Eventually, we can answer the following research question:

How could we model the balance of AOW contributions and expenditures for the coming 30 years?

We see a steady increase in the predicted IPL, indicating that the current AOW system is getting more unstable into the further. This is also noticeable by the distribution of tax payments and central government payments. The overall payments have an increasing effect on the percentage of GDP, but the increase in central government payments is even more alarming. The AOW system is not only paid by the social security system, but also by other tax incomes of the government. We can say with certainty that an AOW system with an entitlement age of 65 years old is not sustainable.

The AOW entitlement age is already increasing, and testing the age of 65 is not a representation of the current situation. Therefore, we increased the entitlement age to 68 years old and to 71 years old, which corresponds with the following research question:

How sensitive is the total balance of AOW contributions and expenditures with respect to the AOW entitlement age?

Even with an increase of the entitlement age to 68 years old, we notice that the AOW system is not sustainable. The predicted IPL is not so high as in the scenario with an age of 65 years old, but still very positive thirty years from now. We must say that an increase has the most effect in the first years, indicating that increasing the AOW entitlement age is necessary, but keeping the age the same for the next thirty years is not realistic. An increase of the AOW entitlement age to 71 years old, creates a sustainable system for the next four years. However, even after these years, the system is not sustainable anymore.

In 2017, the AOW entitlement age was set on 65 years and 9 months. So, an immediate increase of the entitlement age to 71 years old, is an increase of little more than five years. This seems a drastic increase, but if we look at the situation in 1957, the introduction year of the AOW, this is not a strange increase. In 1957, the average life expectancy for both males and females is 15.14 years at the age of 65 (CBS (2019b). In 2017, the average life expectancy is 20.30 years. This is an increase of more than five years. With this in mind, an immediate increase of five years of the AOW entitlement age is not so strange anymore. From this moment on, the entitlement age during the forecast in the next thirty years should be connected to the life expectancy. We would expect a less positive predictive IPL, and even a negative IPL, if we would implement this suggestion.

Chapter 6

Health Care System

Contents

6.1 Chapter Summary

This chapter investigates whether the Dutch health care system is sustainable. Before we can make a forecast of the system, we have to make the right distributions for $\hat{S}(x, z)$ and $\hat{T}(x, z)$, which is a lot more complex in comparison with the distribution of the AOW system.

First of all, we compute the distribution of the tax revenues. This is based on the level of income an individual has. The computation of the expenditures is based on the data set of Vektis and assumptions of RIVM (2008). We notice that the 'red herring' theory is present for the persons in there last year of living. The theory of steepening is present in the case of surviving individuals. This is also applicable to the expenditures made in the Wlz.

Finally, we make a forecast of the current health care system. We notice that this system is not sustainable. The Wlz system is not sustainable either. We do notice that in case of the total health care system, the ageing population is not a leading parameter of the course of the expenditures, since we see a decline in expenditures as percentage of GDP. However, we did not take increasing cost elements into account, such as improved technology, better medicines and increasing employee salaries. We expect that the health care expenditures will increase if we would use these parameters.

For the Wlz system, we still see the impact of the ageing population. This makes sense, since most of the components in the Wlz system are used by the most elderly part of the population.

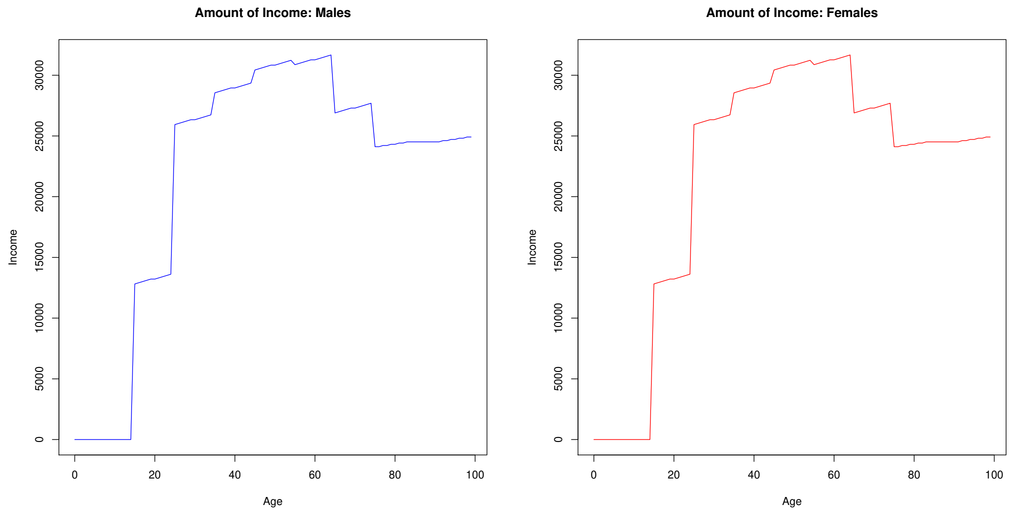
In general, it would be better to make distinctions between users of the system and whether individuals are in their last year of living. This would create a better representation of the total health care system. We only used average numbers, which results in an average reflection of the health care system.

6.2 IPL

In Chapter 5, we clarified the input parameters for the model of Alho and Vanne (2006). The parameters for the economic variables are independent of the type of social security system that is been computed. Therefore, the formulas for the health care system look the same as that of the AOW system, shown in Equations 5.4a and 5.4b. The main values for $V(x, z, u)$ are still the same, since this is the population forecast. The difference lies in the composition of $\hat{T}(x, z)$ and $\hat{S}(x, z)$. We first examine the composition of $\hat{T}(x, z)$ and $\hat{S}(x, z)$ before we give an indication of the primary balance, distribution of health care expenditures and the forecast results.

6.2.1 T(x,z)

In Section 3.5, we already indicated which part of the population is paying for the health care system. Eventually, we have two types of incomes with different tax percentages. The first income is collected in the health insurance fund and is used for the Zvw. The Zvw is generated from the income-related taxes for which different percentages are applicable for different working positions. We choose to work with the average percentage since it is not exactly known what every individual is doing for a living. The average percentage is 6.33%. The other taxes are generated in the long-term care fund. This is a social security for which every individual pays 9.65% of her salary with a maximum chargeable salary of €33791. The tax incomes are based on the average salary per individual. The distribution of incomes is almost the same as in Figure 5.2, but the age of the paying populating continues until 99^{+}. This distribution is based on the weighted average income derived from CBS. We notice that the growth in incomes does not continue, but starts decreasing for the eldest part of the population. The distribution of average incomes for male and female are given in Figure 6.1.



(a) Health Care Distribution of Incomes for Males.

(b) Health Care Distribution of Incomes for Females.

Figure 6.1: Health Care Distribution of Incomes for Males and Females

The distribution of incomes is used to compute the percentage of taxes that are paid for the Zwv and Wlz for every age. These quantities are normalised with the current total government incomes, as given in Table 3.3.

6.2.2 S(x,z)

The most complex part in the set up of the IPL for the health care system, is the composition of $\hat{S}(x, z)$. The Dutch government works with a variety of cost items, and it is unknown which age group takes the most advantage of those items. We already made some assumptions in Section 3.5. In this section, we will further explain how we distributed the costs per age group by giving some insights in each cost element.

Zwv

The Zwv is the largest cost element, mainly because of the costs for medical specialists. If we look at the general distribution of the costs in the Zvw, which we derived from Vektis, we see a very high peak at the age of zero. This is in coherence with the idea that more costs are made to keep a person alive in the younger years of living. Besides a birth is costly medical procedure, even in the case everything goes well. In Figure 6.2, we see the total Zvw expenditures per person for males and females. We already notice that females make more costs, partly due to the increased costs around the age of motherhood, and partly due to higher costs at the eldest ages.

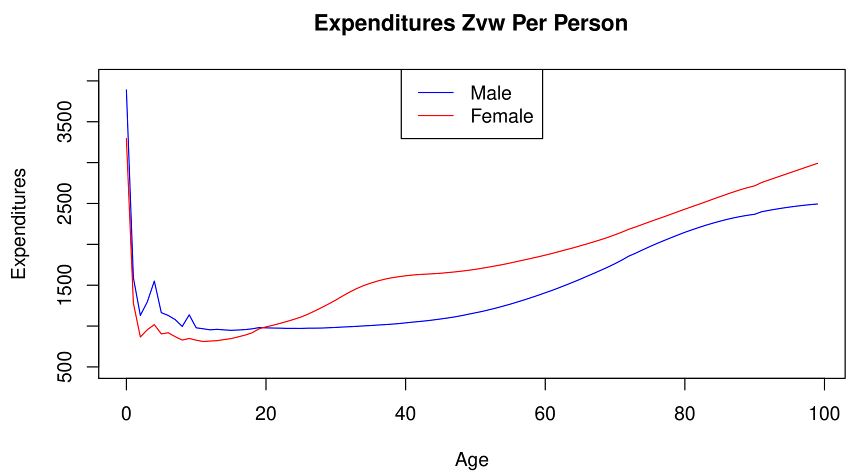


Figure 6.2: Expenditures for Zvw Per Person.

We have shown in Figure 6.3 the cost section 'medical specialists' to investigate the assumption that hospital care is the main cost driver of the Zvw. We can say with certainty that our assumption is correct. The course of hospital care is almost the same as the overall course of the Zvw expenditures, especially for the younger ages. We conclude that this factor has a big influence on the Zvw. Most of the other cost sections have a very low fee. The influence of age on the different cost sections is further explained in the section about Wlz.

As stated in Section 2.4, the 'red herring' theory is more often seen as correct measure of assigning health care expenditures. Even RIVM (2008) noticed this idea by a thorough investigation of the health care expenditures in the Netherlands. They used the civil registration together with health care data to investigate the Dutch health care system. They also used data from the civil registration for the time to death approach. We do not have this type of data, but assume that the study of RIVM (2008) is sufficient to take over their findings related to the last year of living. They found that for a female, the costs in her last year of living are approximately 14 times higher for a 65 years old and 'only' 5 times higher for a 85 years old. We used these data as benchmark. The difference in these factors is the course of gradual reduction in costs in the last year of living with an increasing age. We assume that with a younger age, it is even more appreciated to survive and the costs of a last year of living will be even higher in comparison to a healthy person. Therefore, we assumed that the last year of living for a newborn is 25 times higher than of a surviving baby. From this point, we did a gradual reduction until the factor 14 times of a 65 years old.

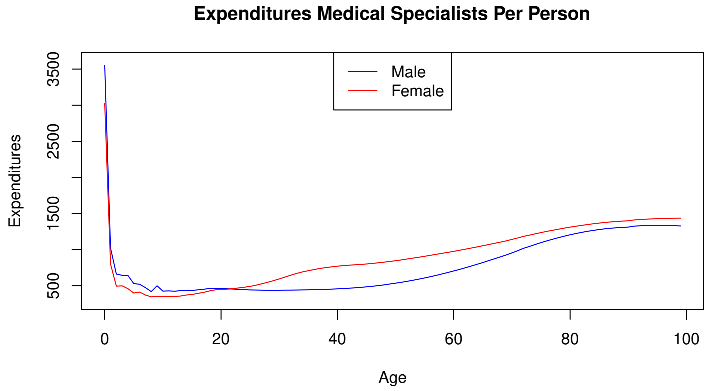
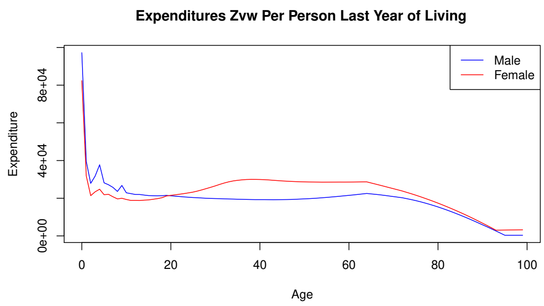
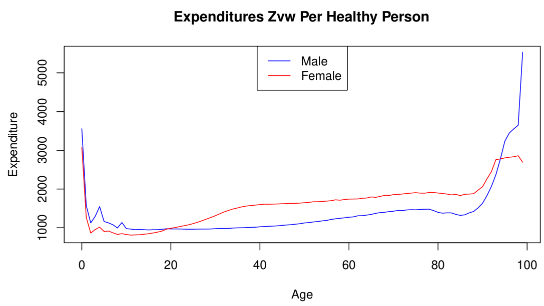


Figure 6.3: Expenditures for Medical Specialists Per Person.

We used the mortality and population data of the year 2017 to produce a surviving population set for a certain age and a population set that is in their last year of living. The cost factor for the last year of living is multiplied by the average costs of the Zvw and divided by the population set that is assumed to pass away in 2017. The remaining total costs are assigned to the healthy population. This results in much higher costs for the unhealthy part of the population per person. The results are shown in Figure 6.4 for male and females. The expenditures in the last year of living confirm the 'red herring' theory. The costs per person increase around the age of 35 years old and decrease around the age of 65 years old. The theory of steepening is present in case of the healthy part of the population. The costs do increase with age, with the exception of the newborns.



(a) Expenditures in the Last Year of Living Per Person.



(b) Expenditures in a Healthy Year Per Person

Figure 6.4: Expenditures for a Person in his Last Year of Living and a Healthy Person.

Wlz

The distribution of the Wlz expenditures is derived from the Vektis data set by using a correlation coefficient. We chose to use Spearman's rank correlation coefficient. We can not assume that the data are linear and the usage of Pearson's product-moment correlation coefficient would result in wrong conclusions. The data is mostly monotonic, with the exception of the newborns. We already noticed that a full regression analysis probably conduct better results, but the idea of correlation is sufficient. Spearman's method is preferred above the Kendall rank correlation coefficient since the present of ties in the data are likely.

In Table 6.1, the cost sections that have a correlation coefficient of $\rho \geqslant 0.7$ are shown. We notice a difference between male and females. Overall, the correlation coefficient for the cost sections that males and females have in common, are higher for females. We suspect this attributes with the fact that females live longer, and most of the time alone, and need more care. The fact that pharmacy has a very high correlation, is in accordance with the theory of comorbidities.

Male	ρ	**Female**	ρ
Medical specialists	0.74	Medical specialists	0.91
Pharmacy	0.94	Pharmacy	0.97
General practitioner consult	0.78	General practitioner consult	0.98
General practitioner multidisciplinary care	0.97	General practitioner multidisciplinary care	0.97
		Appliances	0.95
Seated patient transport	0.77	Seated patient transport	0.88
Lying patient transport	0.84	Lying patient transport	0.90
Basic mental care	0.71		
		Long-term mental care	0.97
Cross-border care	0.90	Cross-border care	0.89
Geriatric rehabilitation care	0.99	Geriatric rehabilitation care	0.99

Table 6.1: Cost Section for which $\rho \geqslant 0.7$, for Males and Females.

The medical specialists cost section is an important driver for the expenditures, but it also derives a lot of weight on the newborns. This is not in accordance with the general idea of the Wlz, since most of the functions, as described in Section 1.3.1 are used by the more elderly part of the population. Therefore, we use the distribution of the costs based on the correlation coefficient analysis, but will assign 60% of the expenditures to the part of the population that is 55 years and older. The distribution is normalised with the known Wlz expenditures. Eventually, the distribution of the Wlz expenditures is given in Figure 6.5. We notice a high increase around the age of 65 years old. This is caused by our assumption that more elderly people will use a higher percentage of the total Wlz expenditures. Besides, the increase of Wlz expenditures was already noticeable before we made a new cost distribution.

Figure 6.5: Expenditures Wlz Per Person.

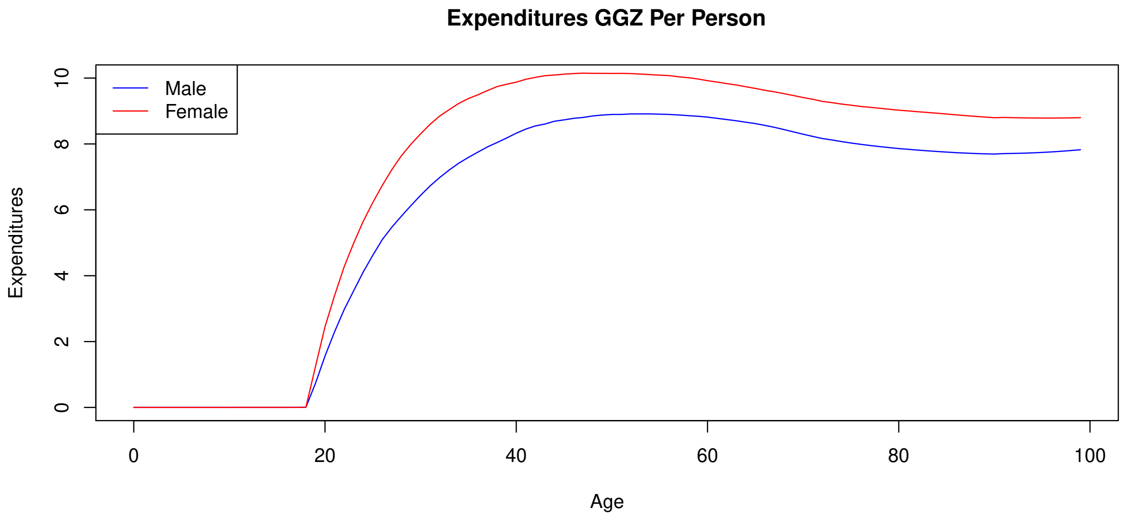


Figure 6.6: Expenditures GGZ Per Person.

GGZ

The distribution of the GGZ expenditures is based on the GGZ cost sections of the Vektis database. This results in three cost sections, namely specialised mental care, basic mental care and long-term mental care. The distribution is normalised with the known GGZ expenditures. In Figure 6.6 the distribution of the GGZ is given for males and females.

Contribution Education

The contribution of education is an expenditure that meets the accessibility contribution given in Figure 1.7. These are expenditures that cannot be assigned to one individual in general. Therefore, we divided the expenditures equally for each individual, which means a payment of €41.21 per person in the year 2017.

Health Care Providers

For the distribution of the health care providers, we used the Zvw distribution. We have chosen for this assumption since the health care providers are not only used for the eldest part of the population. Think about physiotherapists, dentists, etc.

Care Allowance

The care allowance is a contribution of the government to civilians that have a lower income to compensate for the healthcare expenditures. Since the payment of the care allowance is in relation to the income of an individual, the distribution of the amount of care allowance is dependent on the level of income given in Figure 6.1. The part of the population with a lower income, receives a higher part of the care allowance. Eventually, the distribution is a mirrored representation of the income distribution.

Eventually, the distribution of the total expenditures is given in Figure 6.7. We see an increase around the age of 65, this is caused by the Wlz expenditures. The costs of the newborns are still high, mainly due to the high costs of medical specialists. The health care expenditures are an average, meaning that the costs for the last year of living are divided over the total population. We believe this will not give any problems for the forecast of the predictive IPL, but the difference in users of the system is not taken into account.

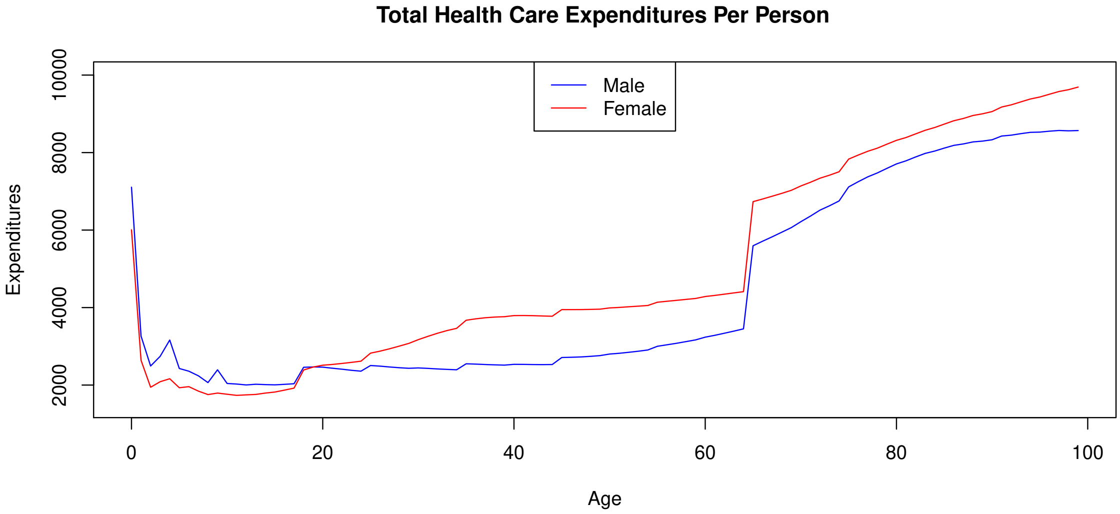


Figure 6.7: Total Health Care Expenditures Per Person, Normalised.

6.3 Indication

Before showing the results of the health care system, we first want to give an indication of the current and historical situation, by showing the primary balance and the distribution of health care payments. We give the summation of the total expenditures and revenues instead of each element separately. This is done for 2006 until 2017, since this is the moment that the health insurance fund was introduced.

6.3.1 Primary Balance

The primary balance is an indication of the growth in public wealth, or in our case, the growth in public wealth based on the health care system. In Figure 6.8, the historical primary balance for the health care system is given. We notice a negative primary balance, which means that there is a decline in public wealth. However, during the last years, the primary balance improved a little bit.

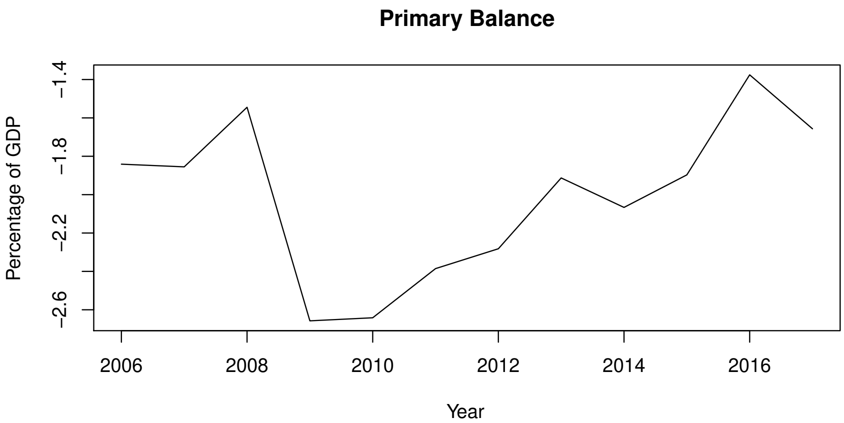


Figure 6.8: Historical Primary Balance for the Health Care System.

6.3.2 Distribution Health Care Expenditures

The distribution of the health care expenditures as percentage of GDP is given in Figure 6.9. We notice two trends. First of all, we see an increase in the health care payments as percentage of GDP. This means that the health care system in general has a depressing effect on the total GDP, which results that more money is used in the health care system. On the other hand, the government payments have decreased the past years, which is in accordance with the course of the primary balance.

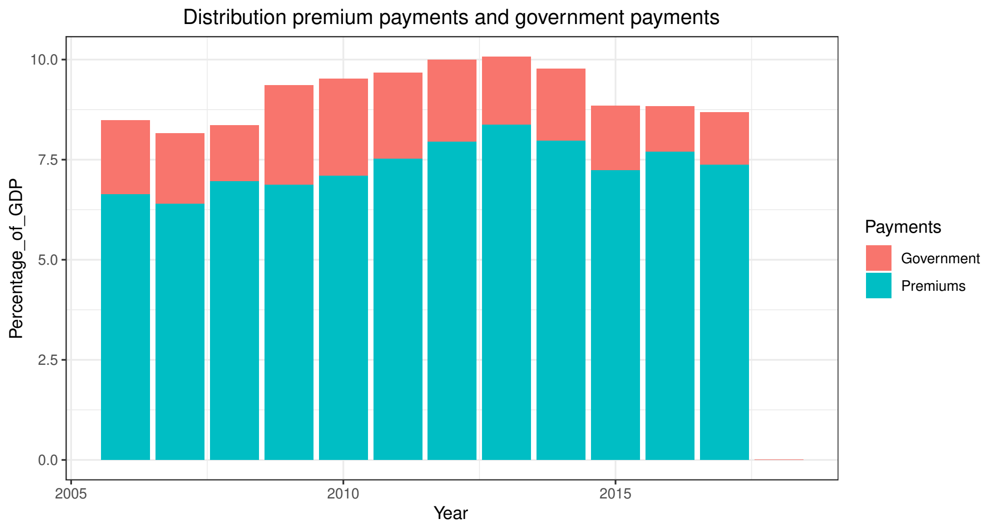


Figure 6.9: Historical Distribution of Health Care Payments.

6.4 Forecast Results

In this section, we first show the forecast of the primary balance and the distribution of the health care expenditures before the predictive IPL is given. As already mentioned in Section 3.3, we use 2017 as a benchmark year. This means that both the S and T are given as percentage of the GDP in 2017 for every year. This makes it more practical to compare the different years with each other and for see the course of the different forecasts. S and T are established by making different assumptions for different cost elements. This means that we deal with the average health care expenditures and incomes, which will give us no indication of the different users in the system.

6.4.1 Primary Balance and Distribution Health Care Expenditures

The first thing we notice, is a stable primary balance the next thirty years. We see that the primary balance is slightly declining, which is in accordance with the slight increase in governance payments, shown in Figure 6.11. We also see the same trend as for the primary balance of the AOW system. The graph is less steep, but still we see that from the year 2037 and onward the primary balance is improving. This corresponds with the fact that the baby-boom generation is passing away.

In Figure 6.11, we notice an overall decline of the health care expenditures. This seems rather odd, since the health care expenditures show an increasing trend, as given in Figure 1.4. We also notice that the percentage paid by the government is increasing the next thirty years, which makes the system more unstable. We believe that the decrease in overall expenditures is an indication that the ageing population is not a leading parameter of the increase in health care expenditures. We know that most of the expenditures are made by hospital care, especially in the last year of living. And most of these expenditures are related to people with the age between 20 and 60 years old.

We did not include an increase of expenditures in this model. We known that the health care expenditures do increase over time, due to improved technology, better medicines and increasing employment expenditures. This is different than for the AOW system, since entitlement payments stay the same over the years and we clearly saw the influence of the ageing population on the total expenditures. We expect that if we include the missing increase in expenditures, the overall health care expenditures must increase. This is also stated in a report of RIVM (2018). They concluded that only one third of the health care expenditures is explained by demography, and two third by other cost items such as technology and medicines. This is an important factor to take into account and should be incorporated in an improved model of the model that we used. Besides, we also would make a difference between costs in the last year of living and in a healthy year. This would improve the visibility of the overall health care expenditures system.

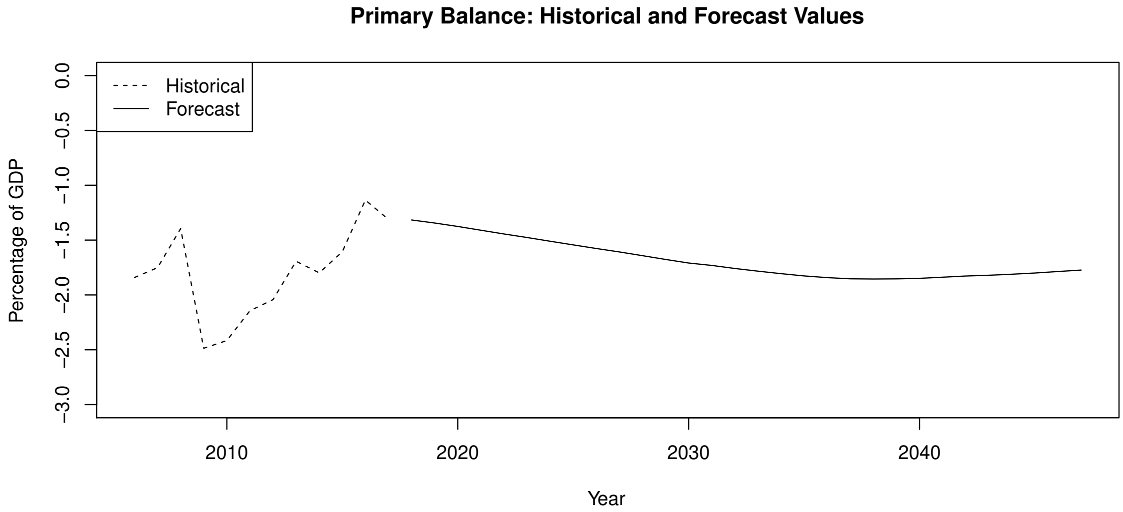


Figure 6.10: Historical and Forecast Primary Balance for Health Care System.

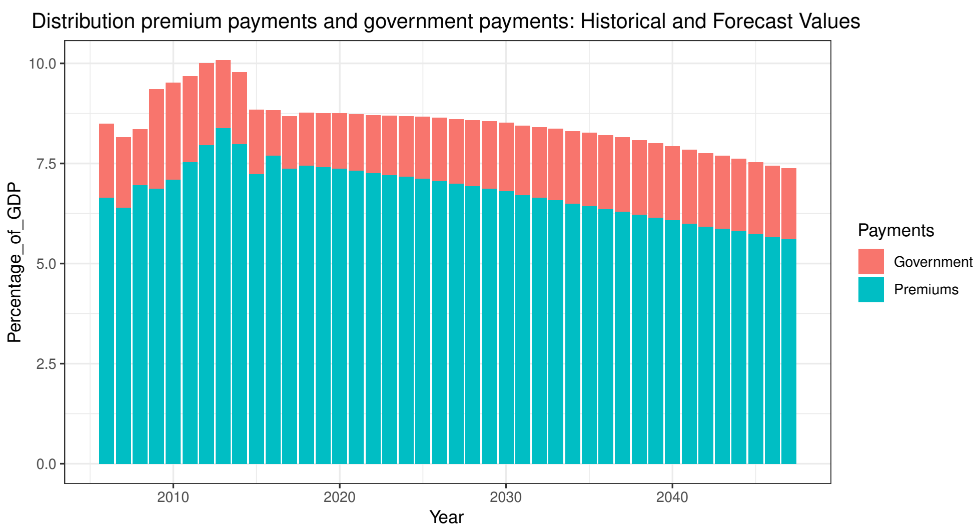


Figure 6.11: Historical and Forecast Distribution Health Care Payments.

6.4.2 Forecast IPL

The IPL is in line with the trends given in Figures 6.10 and 6.11. The ratio is positive, which means that the health care system is creating a negative wealth. In thirty years from now, the increase in entitlements is 0.5 times the GDP as health care liability. The analysis of variance shows that most of the variance in the future is explained by the demography. The variance explained by the uncertainty in taxes and entitlements is decreasing from the year 2035 and on wards. This has probably to do with a large decrease in the baby-boom generation.

Even though the overall health care expenditures do decrease, the IPL is further increasing. This is a result of the increasing percentage of government payments.

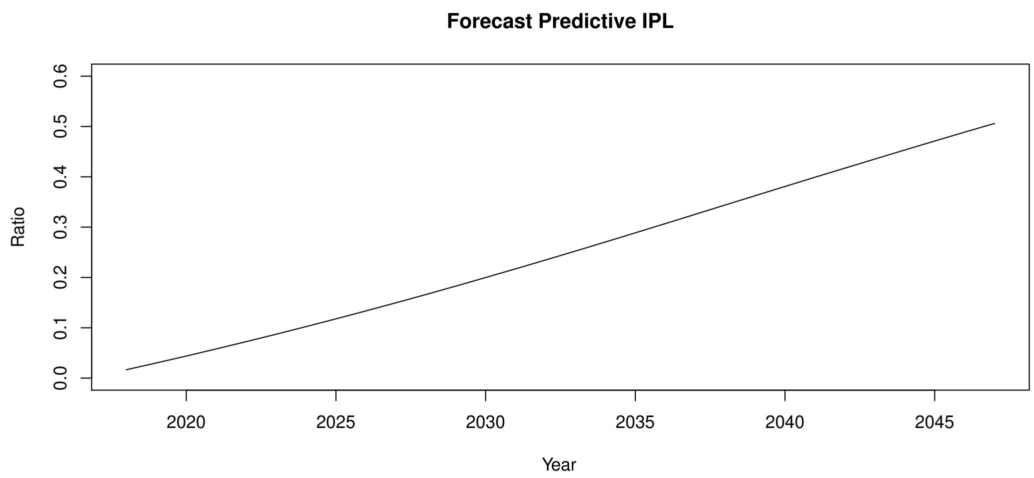


Figure 6.12: Forecast Predicted IPL for Health Care System.

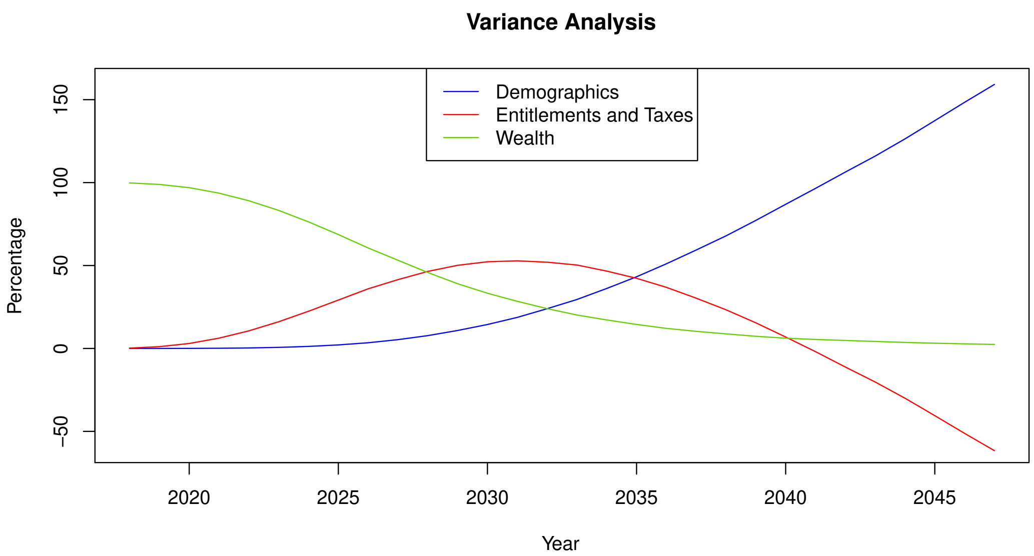


Figure 6.13: Variance Analysis of Health Care System

6.4.3 Forecast of Wlz Expenditures

The analysis of the overall health care system showed that an ageing population has no influence on the course of the health care expenditures. This could be different if we analyse the Wlz system, since most of the expenditures in the Wlz system are related to the elderly population. We first will show the current situation and secondly the forecast situation.

Current Situation

By looking at Figures 6.16 and 6.17, we see a major drop in overall payments at 2015. This is caused by the transition of the AWBZ to Wlz. Some elements of the AWBZ where transferred to the Wmo, and we do not take the Wmo into account in our analysis. This drop is also noticeable in the overall health care system. We also see that the percentage paid by the government is decreasing, which is a good development for the sustainability of the Wlz system.

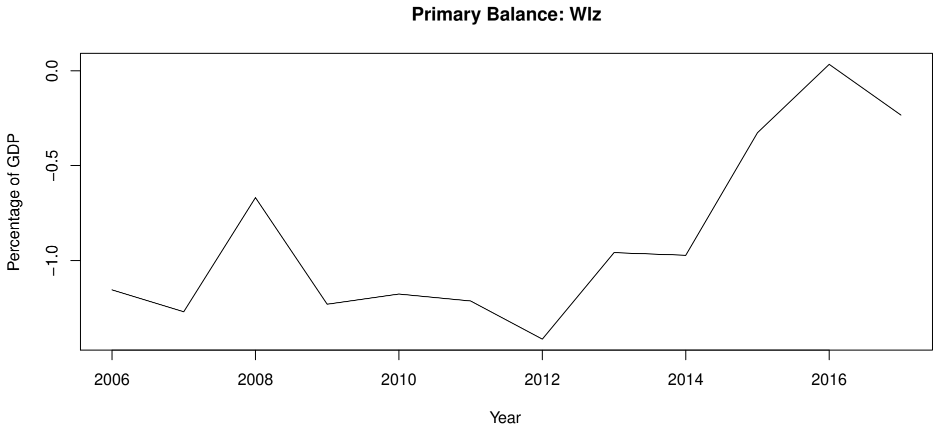


Figure 6.14: Historical Primary Balance for Wlz System.

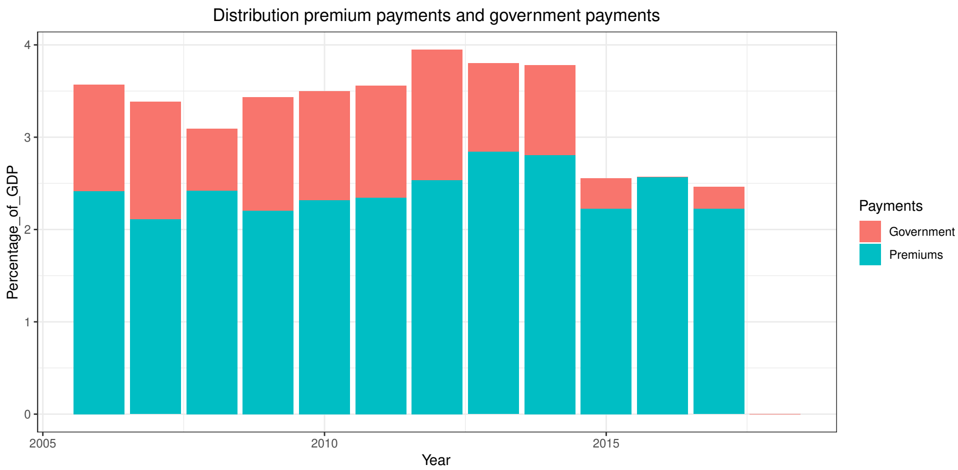


Figure 6.15: Historical Distribution Wlz Payments.

Forecast Situation

In Figure 6.16, we notice the same development as for the total health care system. The impact of the baby-boom generation is clearly visible, since in 2037, the primary balance is slightly improving. We also notice a difference in the course of the expenditures. In Figure 6.17, we notice that the ageing population has an impact on the course of the expenditures. We see that the expenditures are slightly increasing until 2037, for which that is not the case in the total health care system. Still, we do not include the increase in costs, which is still the case for the Wlz system. For example, the increase in employment salary is not taken into account, which should certainly be the case since the Wlz is used for individuals that need care 24 hours a day. This means that there will always be personnel as supervision, for example in nursing homes.

The difference in sustainability of the health care system and Wlz system is shown in Figure 6.18. Both are not sustainable, since the government is paying for the extra expenditures. The impact of the Wlz system is less severe, which is shown by a lower positive IPL value. This is caused by a lower percentage of GDP paid by the government in the Wlz system. For both IPL's, we expect that the values will be higher, since the cost development of improved technology, better medicines and increasing employee salaries is not taken into account.

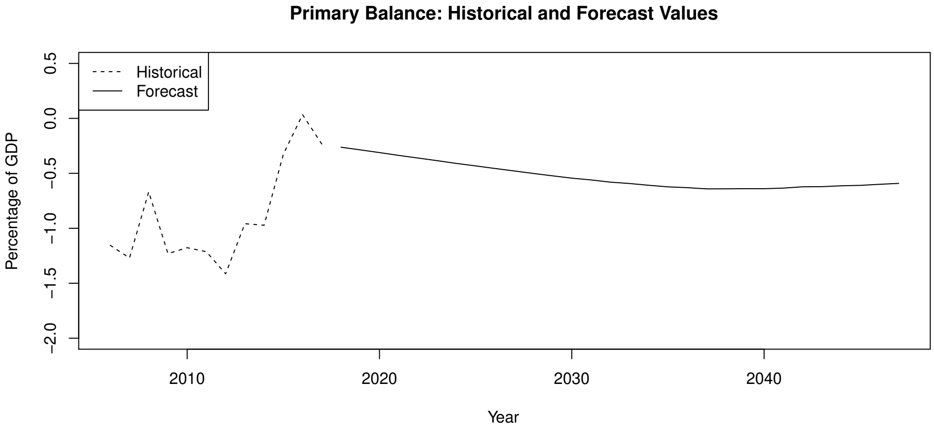


Figure 6.16: Historical and Forecast Primary Balance for Wlz System.

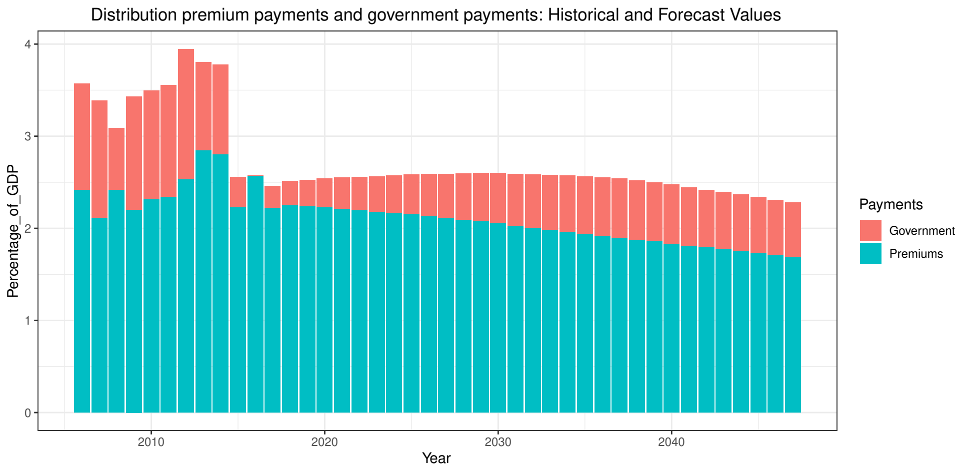


Figure 6.17: Historical and Forecast Distribution Wlz Payments.

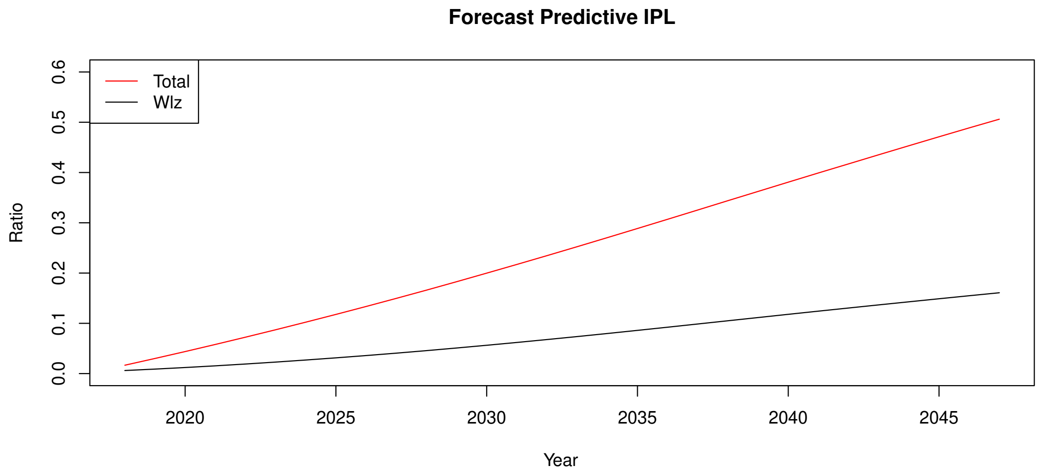


Figure 6.18: Forecast Predicted IPL for Total Health Care System and Wlz System.

6.5 Conclusion

In this chapter we gave an outline of the sustainability of the health care system. We first needed to make assumptions of the distribution of the health care expenditures and revenues. This corresponds with the following research question:

What are the current health care expenditures per age cohort in absolute value for the Dutch system?

For this questions, we relied on the data set of Vektis. By using these data, we already knew the average distribution of the Zvw. We noticed that the newborns are responsible for most of the expenditures per person. We also noticed a steady increase in health care expenditures with an increasing age. By dividing the expenditures per person in the categories last year of living and surviving individuals, we noticed two different types of distributions. In case of the last year of living, we see a confirmation in the 'red herring' theory. The most expenditures are still made by newborns, but the expenditures do decrease with an increasing age. This is mainly caused by the idea that individuals, doctors and family members make the decision how profitable the curing process might be. In case of surviving individuals, we still see an increase in expenditures with an increasing age. This corresponds with the theory of steepening.

Besides the expenditures for the Zvw, we also wanted to know the expenditures for the Wlz. We decided to use Spearman's rank correlation coefficient as indicator of the health care expenditures in the Zvw that have a positive correlation with age. This corresponds with the additional research question:

How is the development in demographic composition correlated with the types of health care expenditures?

The cost sections of the Zvw that have a correlation coefficient of $\rho \geqslant 0.7$ are used as input for the distribution of the Wlz. The cost sections that we used as input are shown in Table 6.1. Besides this distribution, we assign more weight to the elderly part of the population. So, 60% of the expenditures are assigned to the population that is 55 years and older. This is also shown in Figure 6.5 by a steep increase around the age of 65 years old, both for males and females.

Other health care expenditures that we considered are the GGZ, the contribution of medical education, health care providers and care allowance. The GGZ is based on the cost sections of GGZ in the Vektis data set, the contribution of medical education is equally divided per person, the health care providers follow the same distribution as the Zwv and the care allowance is dependent on the level of income of an individual. By combining all the distributions, we see that the eldest part of the population is having the highest health care expenditures per person.

For every health care expenditure, it would be preferable if we knew the detailed distribution per age and what type of cost sections are used. This correspond with the research question:

What are the current types of health care expenditures per age cohort in absolute value for the Dutch system?

For the Zvw, we have an indication of the different types of expenditures. We noticed that the section 'medical specialist' is the main cost driver of the health care expenditures. Besides, we see an increase in the costs for pharmacy and general practitioner consults. This corresponds with the theory of comorbidities as cost driver. Unfortunately, we do not know for certain which type of health care expenditures are present in the Wlz. Knowing a more detailed cost division would result in a better allocation of the health care expenditures, and a better forecast. This leads us to the last research question:

How could we model the health care expenditures and tax revenues for the coming 30 years?

The usage of the model of Alho and Vanne (2006) resulted in a positive prediction of the predictive IPL for the total health care system, which means a negative course of the health care expenditures. We notice a decrease in the health care expenditures as percentage of GDP. This seems unlikely, but it indicates that the development of the health care expenditures is not channelled by the ageing population. We only used the demography as changing variable for the next thirty years. It would be better to take the increasing costs of improving technology, better medicines and employee salaries into account. Two-thirds of the increase of total health care expenditures is caused by these elements and only one-thirds is caused by a changing demography, as stated by a research of RIVM (2018). We believe this is the case as well, since most of the total health care expenditures is made by hospital care and the last year of living, and the ageing population is not a leading factor in increasing costs related to the last year of living.

The Wlz system is not sustainable either. We still see a slightly decrease in expenditures over time, but we also see that the ageing population has an impact on the expenditures. This makes sense, since the Wlz is mostly used by the elderly part of the population. Even though, we did not implement the development of the increase in health care expenditures caused by improved technology or increased employee salaries. Therefore, the health care expenditures are lower than expected.

Chapter 7

Conclusions & Discussion

Contents

7.1 Conclusions

In this thesis, we created a framework using multiple models to assess the sustainability of the Dutch social care system. We first answer the main research question before we will look at the different models separately with the corresponding conclusions. We will start with the demography, followed by the AOW system and finally the health care system.

7.1.1 General Conclusion

After investigating different models for the demography and the forecast of the social security system, we can finally reflect on our main research question:

To what extent is the current AOW entitlement age sustainable relating to future AOW expenditures and health care expenditures, in the Dutch pay-as-you-go system?

Looking at the AOW system, we conclude that the system is not sustainable at the moment. We then only looked at the scenario's for which the entitlement age is increased. An increase of five years would result in a sustainable system, so from the current 66 years and 4 months to 71 years old. This is in line with the development of the life expectancy. By the introduction of the AOW in 1957, the average life expectancy for both males and females was 15.14 years. In 2017, this had increased to 20.30 years, so an increase of more than five years.

The health care system is not sustainable either, for both the total health care system as for the Wlz system. We expect that this will further be the case if the costs of new medicines, improved technology and increasing employee salaries are taken into account.

The percentage of expenditures paid by the government is lower in the health care system, both in the historical situation as in the forecast situation. And this is where we notice a big difference. The AOW system is a pay-as-you-go system, which is not working in an ageing society where all the AOW expenditures are made by the elderly part of the population. In the health care system, every individual pays taxes, even if an individual is 95 years old. This has a major effect on the cost reduction, since more people pay taxes after the AOW entitlement age. We highly question the usage of the pay-as-you-go system in an elderly population in general.

We have a few options to improve the sustainability of the social care system. We start with the AOW system. An increase of five years would result in a sustainable system, but only if the entitlement age is connected with the life expectancy. We expect that the increase in entitlement age could be lower if the AOW payments are reduced and/or the AOW tax percentage is increased. Both options should be investigated further. The pay-as-you-go system in general could work if we except that we would receive AOW at a later age, or if we adapt the amount of expenditures and revenues.

We expect that the costs of the health care system can be reduced if we would increase the taxable percentages on an individuals income. Or if a bigger part of the costs is paid as an individual contribution. For example, an increase in the amount of individual risk.

Overall, we conclude that both the AOW system and health care system are not sustainable. Of course, the 'extra' expenditures are covered by the government, but this should not be the case. By covering the shortage for an unstable system, less money is available for other systems, such as education, employment or climate change. We also acknowledge that a solution for the sustainability of both the AOW and health care system comes with a lot of difficulties. An immediate increase in the AOW entitlement age would result in protests by the part of the population that is almost entitled to receive AOW, but an increase in tax payments for the working part of the population also results in social discontent. The same applies for the health care expenditures. Increasing the amount of own risk could lead to a de-levelling effect on society. The complexity of resolving the sustainability of the social care system is huge.

7.1.2 Demography

The first model that we used was the demography model. We used three input parameters, mortality, fertility and net-migration, to create a population forecast. Even though, the forecast of the population deals with uncertainty, the forecast is accurate for the elderly part of the population. Most of the uncertainty is related to the younger parts of the population, since most of the uncertainty is caused by fertility and net-migration rates. First we explain the overall population forecast in general. Secondly, we explain each input parameter separately.

The forecast of the three input parameters results in the population forecast. The historical demography shows the development of the baby-boom generation. By looking at the demography of 2017, we see an increase in the population between the ages of 48 and 70 years old, which is the baby-boom generation. Looking into the future, we notice that in 2037, a part of this generation has passed away, but not entirely. If we look at the population forecast of 2047, we see that even a bigger part has passed away, but due to improved life expectencies and the size of the baby-boom generation, the fraction of the elderly part of the population and the working part of the population has increased, which is shown in the old-age dependency ratio. The idea of the pay-as-you-go system is that the working part of the population is pays for the elderly part of the population. The corresponding shape of the population is a pyramid, since the fraction of elderly could be compensated by the working part of the population. In 30 years, this will not be the case. The population is evenly divided, with the exception of the part that is 80 years or older, since a decrease in population is noticeable. Nevertheless, future demography suggest that the division of population is not suitable for the affordability of the pay-as-you-go-system.

The mortality rates are the most stable rates. They have a steady decline over the years and the confidence intervals are quite narrow. This indicates that the model is able to forecast the mortality rates with great certainty. As a result of this, the model is also able to forecast the life expectancy quite accurately. We see that the life expectancy is increasing, but the difference between males and females is declining.

The fertility rates went trough a major transformation between 1950 and 2017. First of all, we see a decrease in the fertility rates, which is mainly caused by the introduction of the anti-conception pill. The decrease in fertility rates is also noticeable in the child dependency ratio. Between 1960 and 1985, there is a major drop in this ratio, which stabilises after 1990. Besides the decrease in fertility rates, we see that the age of mothers is increasing. Or differently stated, the fertility rates are more centralised around the age of 30 years. Due to the drastic changes in the fertility rates, the model faces difficulties predicting the future fertility rates. The confidence intervals are very wide, indicating the uncertainty in the forecast. Besides, the net-migration rates also have an influence on the fertility rates.

The net-migration rates transformed from a negative rate to a positive rate between 1950 and 2017. A negative migration rate means a higher emigration rate than immigration rate. In 1950, this higher emigration rate was caused as a result of the second world war, where a part of the population wanted to built a new life in other parts of the world, such as Canada or Australia. From 1965 and onward, the Netherlands had a positive net-migration rate. The first positive migration rates were caused by working immigrants. The most recent positive net-migration rate is caused by refugee flows. Most immigrants have an age between 20 and 40 years, for which there is almost no difference between males and females. The forecast of the net-migration rates is quite uncertain. The confidence intervals are very wide, especially around the ages where most of the immigration takes place. The forecast still shows a positive net-migration rate, which has implications for the fertility rate as well. The increase in immigrants, causes higher fertility rates, which is also shown in the Birth Replacement Ratio. We notice that the BRR is lower than two, due to high immigration rates, but the BRR is increasing in the future, which is caused by a decrease in net-migration rates. The forecast model smooths the peaks in the historical net-migration.

7.1.3 AOW system

Before we tested the sustainability of the AOW system, we validated the outcomes with the actual situation. In general, more females are entitled to receive AOW, which makes sense since females have a higher life expectancy than males. If we look at the difference between cohabitation and single individuals, we see that most males have a partner to live with, and most females live alone. This is a result of the higher life expectancy of females. They live longer and therefore will 'outlive' their spouses. Single individuals receive higher AOW payments than individuals that are living together. Most females are not only living longer than males, but are also making higher costs than males due to the fact that they become single at some point in their lives. This indicates that females are responsible of a larger part for the AOW expenditures than males.

We did not include the life expectancy in the forecast, but we could imagine that by doing so, we found a model that ensures a sustainable AOW system for the next years. We see a decrease in the old age dependency ratio from 2037 and onward, meaning that fraction of elderly population in comparison with the working part of the population is decreasing. In 20 years from now, a new forecast should be made to conclude if this trend is proceeding and if the model should be adjusted to make the AOW system sustainable again.

The current situation of the AOW system is given by the primary balance and the distribution of AOW payments. The primary balance shows a steady decline from 1995 until 2017, indicating that over the years, increasing expenditures were made. The distribution of AOW payments shows this as well. Not only are the overall AOW payments as percentage of GDP increasing, the percentage of expenditures paid by the governments are increasing as well. This already indicates that the system is not sustainable. The pay-as-you-go-system is sustainable if the tax revenues cover all the AOW payments. This is clearly not the case for the current situation, since the government pays extra to cover the shortage in AOW payments.

After looking into the historical situation, we forecast the AOW system for three different scenarios, namely an entitlement age of 65, 68 and 71 years old. For every situation, the entitlement age is set as a fixed value and is not connected to the life expectancy. By setting the entitlement age to 65 years old, we notice an even further decrease of the primary balance and a higher percentage of AOW expenditures paid by the government. Besides, we forecast the predictive IPL. The IPL does not only take the future tax revenues and payments into account, but also the productivity and wealth of the government. Including these parameters result in a discounted value of the AOW system. A negative IPL shows that more revenues are generated and results in a surplus of the system. On the other hand, a positive IPL shows that more expenditures are generated and results in a shortage of the system. Sustainable means that the IPL has a value of zero. A positive value would indicate that we have too much expenditures and a negative value would indicate that we pay too much taxes.

The IPL of the AOW system with an entitlement age of 65 years old is rapidly increasing in the next thirty years. The AOW system pressures the GDP by a factor of 0.8 and more than half of the AOW expenditures is paid by the government. We can predict that lowering the AOW entitlement age to 65 years is a very unstable option. If we increase the entitlement age to 68 years old, we see a drop in the expenditures one year from now and an increase in the primary balance. This corresponds with the effect of receiving more taxes and paying less AOW. However, the trend of the expenditures stays the same, and from the first forecast year onward, the system is not sustainable. This indicates that even with a direct increase of the AOW entitlement age to 68 years old, the system is still not sustainable. On the other hand, in this system at all times, most of the AOW expenditures are paid by tax revenues.

In the end, we increased the AOW entitlement age to 71 years old. That is an increase of five years in comparison to the current system. We notice that the system is sustainable for the first four years. After that, the system follows the same course of the previous scenarios, meaning that the expenditures do increase until 2037 and that the system is unstable again. However, we could say that an immediate increase of the AOW entitlement age to 71 years old works.

7.1.4 Health Care System

The health care system is much more complicated than the AOW system. We have more diversified tax revenues and more granular expenditures. For every type of expenditures, we made a distribution suited to the type of population the expenditure is designed for. For example, the distribution of the Wlz expenditures is mainly focused on the elderly. We noticed a couple of things in the distribution of the expenditures. First of all, expenditures in the Zvw are mainly driven by the costs of medical specialists and most of them are made by newborns. We also see an increase of expenditures for an increasing age. However, these results are based on averages. If we make a division between Zvw expenditures for an individual in the last year of living and in a healthy year, we notice a different distribution. First of all, the expenditures in a last year of living are much more than in a healthy year. Secondly, we notice that in a healthy year, the costs do increase with age, but this does not count for a last year of living. We see a decrease in the expenditures at the age of 65 years old and onward. This is caused by the fact that if you become sick at the age of 60, most individuals will do whatever it takes to get better, but if you are 80 years old, you may conclude that you had a healthy life and won't extend your life for a low quality life. everything to survive.

For the prediction of the sustainability of the health care system, we only looked at the overall average expenditures, since it is not known for sure what the distribution of expenditures is in a last year of living and in a healthy year. We first looked at the current situation. We have a negative primary balance, indicating that more expenditures are made than revenues received. However, we see an increase in the primary balance, indicating that between the years 2009 and 2017, a reduction in expenditures has been made. There are two differences in the distribution of payments of the health care system and the AOW system. In the AOW system, the percentage of expenditures paid by the government is much higher than in the health care system, which indicates that the health care system is 'more' stable than the AOW system. This makes sense, since the eldest part of the population keeps paying taxes. On the other hand, the percentage of GDP for the health care system is higher than that of the AOW system. This means that in general, more money is spent for the health care system.

We predicted the IPL for the health care system in general and for the Wlz expenditures. The forecast of the overall health care system shows a couple of interesting trends. By looking at the distribution of payments and the IPL, we see an increase in the government payments. This suggests that further into the future, the health care system is getting more unstable. On the other hand, the costs as percentage of GDP do decrease. This means that the expenditures of the health care system are not driven by age. We conclude that the ageing population has no effect on the development of the health care expenditures. We expect that one of the main cost drivers is the increase in expenditures, due to costly medicines and new technologies, but this is not taken into account in this model.

If we only look at the expenditures made in the Wlz, the expenditures do increase. We see the same trend as for the AOW system, which means an increase in expenditures that starts decreasing around the year 2037 as a result of the baby-boom generation that starts passing away. The Wlz expenditures do depend on the ageing population. The percentage paid by the government is slightly increasing over the years, but will not be more than 30%. This indicates that still 30% of the total Wlz expenditures are not being paid by the tax revenues received with the Wlz system.

7.1.5 Social-Ethical Note

We would like to emphasise the important status of the social insurances in our society and the difficulties that come with changing its setup, both from a political and economic standpoint. The production of this master thesis is even based on the interest in the political movements in Dutch society regarding the AOW system. Currently, a part of the population feels betrayed by the recent increase in the entitlement age. They feel it is not fair that they should continue to work longer and do not receive what their parents used to get. They paid their fair part in the AOW system and are being 'punished' for doing what the state has asked them to do. These people cannot be blamed for feeling cheated. We should question the role of politics in this matter. By the introduction of the AOW system, the idea of matching the life expectancy to the entitlement age was already considered. For some reason, this has never been implemented and over the years, it only became more unpopular to do so, until the point that we finally concluded that the situation was not sustainable anymore.

Different people (not only politicians) have different opinions in solving this matter. Most of them feel that the entitlement age should be increased, but some think that this should not count for the entire population. They argue that people with physical jobs, which have a significant impact on the persons health, should not be forced to work till an even higher AOW age than they do now. A hardworking constructor should thus retire earlier than a person with an office job. Others argue that the richer part of the population should receive less AOW. We might question whether this complies with the original idea of a social security, which is that every individual is entitled to receive a fixed amount of money. Besides, the richer part of the population is already contributing more to the AOW system, by paing more taxes in higher tax brackets. These ideas also raise the question of where to draw the line? What jobs do we qualify as physical enough to retire earlier? And when are you earning too much money to lose your entitlement to AOW? These approaches only cause a lot of questions that make the system more difficult and ultimately are not solving the main problem, which is the increasingly elderly society that keeps getting older and older.

The usage of the social security system in the health care system can also be questioned. We know that most of the expenditures are made by a small part of the population. Do we think it that they should pay a larger part of the expenditures? And by looking at hospital care as the main cost driver, do we think it is still worth it to replace a knee of a 90 year old? And what about people that suffer from dementia, should we pay for nursing homes knowing that these people will never get better? From a humanitarian perspective, it is important to keep helping these people, which is in general the norm for people especially if the individual is closely related to the patient. Economically speaking, it is not worth it. Making the decision to stop paying for these treatments would take away a lot of pressure from the social security system in general. The idea of a healthy life expectancy is hereby considered. We know that we get older and older, but not always in a very healthy way. And by looking at the AOW system again, is it worthwhile to pay AOW each year to a person that is very sick? And who is responsible for making these decisions?

The goal of this master thesis is not to answer these ethical questions. We only want to allow the reader to take into account the complex context by outlining some ethical, but costly situations to think more thoroughly about the social care system. How far do we want to go to make this affordable? And if we choose to keep everybody alive as long as possible, what choices do we make to close the gap between the collected income and the expenditures. We think that our research contributes to the discussion by giving some necessary insights. It is clear that the system of the past cannot become the system of the future. When taking the original idea of the AOW system into account, the discussion about the AOW entitlement age is unnecessary, as we must match this with the life expectancy as the AOW system was supposed to be designed in the past. The question for now however, is how to control the current situation. Are we staying with the current system and pass the costs to the younger generations? Will we accept an increase in the entitlement age or a shortage in the monthly payouts? Or do we want to change the original concept of a social security and make distinctions between individuals? Most importantly, the perfect world where everything stays the same as in the present is not sustainable. Decisions have to be made which path we will follow, even though every decision will upset one group or the other, as there is no perfect solution. Politicians should make the necessary decision their predecessors refused to make, before it is too late.

7.2 Discussion & Further Research

This master thesis created a new methodology for the prediction of the Dutch social care system by combining existing forecast models for the demography and social care system. However, there is always room for improvement. We first outline the three main improvements of this thesis and should first be investigated. Than, we shortly suggest topics for further research for the different modelling steps.

The first drawback in this master thesis is the usage of a fixed entitlement age. By setting this age fixed, we could not investigate the effect of the link between the entitlement age and the life expectancy. Nowadays, the government has connect these two parameters, otherwise we would have the same problem again in the future. We suggest to implement the life expectancy in the model of Alho and Vanne (2006), to investigate the sustainability of the future AOW system. A second drawback is the assumption that the health care expenditures stay the same the next thirty years. We know that a large part of the expenditures is made by new technologies and increasing employee salaries. By looking at the development of these costs and taking these into account in the model, we expect a better forecasting model of the health care expenditures. A last main drawback is the usage of averages in every model. So average life expectancies, average incomes, and average expenditures. This results in a very general model. We suggest to investigate different education levels, since a higher education level results, in general, in a higher life expectancy and a higher income. The effect of this parameter could also have an impact on the overall AOW and health care system.

Other improvements for every model are given as follows:
Demography:

1. The uncertainty in fertility rates and net-migration rates are very high. This results in less accurate population forecasts. We suggest to investigate the possibilities in improving the forecasts of these demographic rates

2. The forecast is very dependent of the fitting procedure. We should test more thoroughly whether our fitting procedure is the best choice.

3. We used a mortality table in which every individual dies at the age of 99. This becomes very unrealistic with an increasing life expectancy. We suggest to use a more accurate life table as input.

Predictive IPL:

1. The productivity of the model of Alho and Vanne (2006) is connected with the growth in GDP series. This might be too short-sighted. We suggest to use more parameters for the productivity. For example, the difference in working and non-working part of the population.

2. We only looked at the AOW and health care system as social securities. The Dutch social care system has more securities, for example education. It might be interesting to look at this security as well, since the child dependency ratio starts to increase further into the future.

3. We suggest to do a scenario analysis on the AOW system where both the entitlement payment is reduced and the AOW tax percentage is increased.

4. In case of the health care system, it is very preferable to have more insights in the distribution of the expenditures. Especially if we know that last year of living and comorbidities have a high impact on the total costs.

5. For both the AOW and health care system, the distribution of incomes for different parts of the population is a more accurate parameter for the total revenues of the government.

Eventually, this research gives a good first indication of the social care system of the Netherlands. However, we should always take in mind that by using forecasts, an element of uncertainty is present. Therefore, the outcomes of this master thesis should be used as indication.

Bibliography

Ahlburg, D. and Land, K. (1992). Population forecasting: Guest editors' introduction. *International Journal of Forecasting*, 8:289–299.

Alders, M. and de Beer, J. (2019). *An Expert Knowledge Approach to Stochastic Mortality Forecasting in the Netherlands*. Demographic Research Monographs. Springer International Publishing, Cham, Switzerland, 1st edition. In: Bengtsson T., Keilman N. (eds) Old and New Perspectives on Mortality Forecasting.

Alho, J. and Vanne, R. (2006). On predictive distributions of public net liabilities. *International Journal of Forecasting*, 22:725–733.

Alho, J. M. (1990). Stochastic methods in population forecasting. *International Journal of Forecasting*, 6:521–530.

Auerbach, A., Kotlikoff, L., and Leibfritz, W. (1999). Generational accounting around the world. *National Bureau of Economic Research & University of Chicago*, pages 3–57.

Belastingdienst (n.d.a). Hoeveel moet u betalen? `https://www.belastingdienst.nl/wps/wcm/connect/bldcontentnl/belastingdienst/prive/werk_en_inkomen/sociale_verzekeringen/premies_volks_en_werknemersverzekeringen/volksverzekeringen/hoeveel_moet_u_betalen`. Accessed: 2019-04-18.

Belastingdienst (n.d.b). Werkgeversheffing Zvw of bijdrage Zvw? `https://www.belastingdienst.nl/wps/wcm/connect/bldcontentnl/belastingdienst/prive/werk_en_inkomen/zorgverzekeringswet/bijdrage_zorgverzekeringswet/tabel_werkgeversheffing_zvw_of_bijdrage_zvw/`. Accessed: 2019-06-04.

Booth, H. (2006). Demographic forecasting: 1980 to 2005 in review. *International Journal of Forecasting*, 22:547–581.

Booth, H., Hyndman, R. J., and Tickle, L. (2014). *Prospective life tables.* Chapman & Hall, CRC The R Series. CRC Press, Taylor & Francis group, Boca Raton, FL, USA, 1st edition. In: A. Charpentier (ed) Computational Actuarial Science with R.

Box, G. and Cox, D. (1964). An analysis of transformations. *Journal of the Royal Statistical Society. Series B (Methodological)*, 26:211–252.

Bukaçi, E., Korini, T., Periku, E., Allkja, S., and Sheperi, P. (2016). Number of iterations needed in monte carlo simulation using reliability analysis for tunnel supports. *Journal of Engineering Research and Applications*, 6:60–64.

Cambridge Dictionary (n.d.). fertility. `https://dictionary.cambridge.org/dictionary/english/fertility`. Accessed: 2019-07-22.

CBS (2018). Levensverwachting stijgt minder hard in nederland en eu. `https://www.cbs.nl/nl-nl/nieuws/2018/36/levensverwachting-stijgt-minder-hard-in-nederland-en-eu`. Accessed: 2019-08-20.

CBS (2019a). Bevolkingspiramide 2019. `https://www.cbs.nl/nl-nl/visualisaties/bevolkingspiramide`. Accessed: 2019-06-06.

CBS (2019b). Levensverwachting; geslacht, leeftijd (per jaar en periode van vijf jaren) . https://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=37360ned&D1=3&D2=1-2&D3=0&D4=17,29,41,53,65,77,89,l&HDR=G1,T&STB=G2,G3&CHARTTYPE=3&VW=T. Accessed: 2019-06-06.

CBS (2019c). Zorg; uitgaven en financiering vanaf 1972. https://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=83075NED. Accessed: 2019-04-18.

Craig, J. (1994). Replacement level fertility and future population growth. *Population Trends*, Winter:20–22.

Creedy, J. and Scobie, G. M. (2005). Population ageing and social expenditure in new zealand. *The Australian Economic Review*, 38:19–39.

Currie, I. D., Durban, M., and Eilers, P. H. C. (2004). Smoothing and forecasting mortality rates. *Statistical modelling*, 4:279–298.

Department of Economic and Social Affairs - Statistics Division (2004). *Handbook on the Collection of Fertility and Mortality Data*, volume 92 of *Series F*. United Nations, New York, NY, USA, 1st edition.

Geue, C., Briggs, A., Lewsey, J., and Lorgelly, P. (2014). Population ageing and healthcare expenditure projections: New evidence from a time to death approach. *The European Journal of Health Economics*, 15:885–896.

Gregersen, F. A. (2014). The impact of ageing on health care expenditures: a study of steepening. *The European Journal of Health Economics*, 15:979–989.

Harper, S. (2014). Economic and social implications of aging societies. *Science*, 346:587–591.

Hazra, N. C., Rudisill, C., and Gulliford, M. C. (2018). Determinants of health care costs in the senior elderly: Age, comorbidity, impairment, or proximity to death? *The European Journal of Health Economics*, 15:831–842.

Hyndman, R. J. (2019). *Package 'demography'*, 1.22 edition. https://cran.r-project.org/web/packages/demography/demography.pdf.

Hyndman, R. J. and Booth, H. (2008). Stochastic population forecasts using functional data models for mortality, fertility and migration. *International Journal of Forecasting*, 24:323–342.

Hyndman, R. J., Booth, H., and Yasmeen, F. (2013). Coherent mortality forecasting: The product-ratio method with functional time series models. *Demography*, 50:261–283.

Hyndman, R. J. and Khandakar, Y. (2008). Automatic time series forecasting: The forecast package for r. *Journal of Statistical Software*, 27:1–22.

Hyndman, R. J. and Ullah, M. S. (2007). Robust forecasting of mortality and fertility rates: A functional data approach. *Computational Statistics & Data Analysis*, 51:4942–4956.

Independer (n.d.). Ontwikkeling van het eigen risico sinds 2006. https://www.independer.nl/zorgverzekering/info/10-jaar-zorgstelsel/het-eigen-risico.aspx. Accessed: 2019-06-05.

Lee, R. D. and Carter, L. R. (1992). Modeling and forecasting u.s. mortality. *Journal of the American Statistical Association*, 87:659–671.

Lee, R. D. and Tuljapurkar, S. (1994). Stochastic population forecasts for the united states: Beyond high, medium, and low. *Journal of the American Statistical Association*, 89:1175–1189.

Lutz, W., Goldstein, J., and Prinz, C. (1996). *The Future Population of the World: What Can We Assume Today?* London: Earthscan, London, UK, revised edition. International Institute for Applied Systems Analysis.

Ministerie VWS (2016). Het nederlandse zorgstelsel. Technical report, Mnisterie van Volkgezondheid, Welzijn en Sport, Den Haag, NL.

Muszyńska, M. M. and Rau, R. (2012). The old-age healthy dependency ratio in europe. *Journal of Population Ageing*, 5:151–162.

O'Neill, C., Groom, L., Avery, A. J., Boot, D., and Thornhill, K. (2000). Age and proximity to death as predictors of gp care costs: Results from a study of nursing home patients. *Health Economics*, 9:733–738.

Ortega, J. A. (2006). Birth replacement ratios: New measures of period population replacement. Technical report, Universidad de Salamanca.

Polder, J. J., Barendregt, J. J., and van Oers, H. (2006). Health care costs in the last year of life - the dutch experience. *Social Science & Medicine*, 63:1720–1731.

PRB (2018). 2018 world population data. http://www.worldpopdata.org/. Accessed: 2019-17-07.

Puth, M.-T., Neuhauser, M., and Ruxton, G. D. (2015). Effective use of Spearman's and Kendall's correlation coefficients for association between two measured traits. *Animal Behaviour*, 102:77–84.

Ramsay, J. and Silverman, B. (2005). *Functional Data Analysis*. Springer Series in Statistics. Springer Science+Business Media, Inc., New York, NY, USA, 2nd edition.

Rau, R., Bohk-Ewald, C., Muszyńska, M. M., and Vaupel, J. W. (2017). *Visualizing Mortality Dynamics in the Lexis Diagram*, volume 44 of *Demographic Methods and Population Analysis*. Springer International Publishing, Cham, Switzerland.

Rijksoverheid (n.d.a). Financiering van de zorguitgaven. http://www.rijksbegroting.nl/2019/voorbereiding/begroting,kst248591_31.html. Accessed: 2019-06-05.

Rijksoverheid (n.d.b). Wat is het eigen risico van mijn zorgverzekering en wanneer betaal ik dit? https://www.rijksoverheid.nl/onderwerpen/zorgverzekering/vraag-en-antwoord/eigen-risico-zorgverzekering. Accessed: 2019-06-05.

RIVM (2008). Levensloop en zorgkosten - achtergrondrapport. Technical report, Rijksinstituut voor Volksgezondheid en Milieu, Bilthoven, NL.

RIVM (2018). Volksgezondheid toekomst verkenning 2018: Een gezond vooruitzicht. Technical report, Rijksinstituut voor Volksgezondheid an Milieu.

Shumway, R. H. and Stoffer, D. S. (2011). *Time Series Analysis and Its Applications - With R Examples*. Springer Texts in Statistics. Springer Science+Business Media, New York, NY, USA, 3rd edition.

Smallwood, S. and Chamberlain, J. (2005). Replacement fertility, what has it been and what does it mean? Technical report, Population and Demography Division - Office for National Statistics.

Smith, S. K., Tayman, J., and Swanson, D. A. (2013). *Overview of the Cohort-Component Method*, volume 37 of *Demographic Methods and Population Analysis*. Springer Netherlands, Dordrecht, NL, 1st edition. In: A Practitioner's Guide to State and Local Population Projections.

Stoeldraijer, L. and Harmsen, C. (2017). De levensverwachting meet de sterfte. Technical report, Centraal Bureau voor de Statistiek (CBS).

SVB (2015). AOW uitgaven. https://www.svb.nl/Images/Ontwikkeling%20AOW.pdf. Accessed: 2019-04-09.

SVB (n.d.a). AOW-bedragen. https://www.svb.nl/int/nl/aow/wat_is_de_aow/wie_krijgt_aow/. Accessed: 2019-05-24.

SVB (n.d.b). AOW-pensioen. https://www.svb.nl/int/nl/aow/hoogte_aow/bedragen/aow_bedragen_tabel.jsp. Accessed: 2019-05-24.

SVB (n.d.c). OBR. https://www.svb.nl/int/nl/obr/overbruggingsregeling/maximum_bedragen/index.jsp. Accessed: 2019-05-24.

The World Bank (n.d.). Real interest rate in %. https://data.worldbank.org/indicator/FR.INR.RINR?locations=NL&view=chart. Accessed: 2019-08-05.

van den Born, Karin and Andere Tijden (2001). De Spaanse Griep. https://anderetijden.nl/aflevering/620/De-Spaanse-Griep. Accessed: 2019-07-16.

van der Meulen, A. (2009). Overlevingstafels en longitudinale analyse: deelthema overlevingstafels. Technical report, Centraal Bureau voor de Statistiek (CBS).

Zweifel, P., Felder, S., and Meiers, M. (1999). Ageing of population and health care expenditure: a red herring? *Health Economics*, 8:485–496.

Glossary

Akw	Algemene kinderbijslag wet
Anw	Algemene nabestaanden wet
AOW	Algemene Ouderdomswet
BRR	Birth Replacement Ratio
CAK	Centraal Administratie Kantoor
CIZ	Centrum Indicatiestelling Zorg
NBRR	Net Birth Replacement Ratio
PGB	persoonsgebonden budget
RIVM	Rijksinstituut voor Volksgezondheid en Milieu
SVB	Sociale Verzekeringsbank
TFR	Total Fertility Rate
Wlz	Wet langdurig zorg
Wmo	Wet maatschappelijke ondersteuning
Zvw	Zorgverzekeringswet

Appendix A

Different tax percentages for Zvw

Situation	2019	2018	2017	2016	2015
• Child support after 01-01-2006 • AOW receiver • Foreign incomes from paid employment without compensation • Director of majority shareholder without employee insurance • Freelancer • Survivor pension • Entrepreneur • Opting-in • Pension • Welfare for early retirement (received after 01-01-2006) • Welfare for early retirement (received after 01-01-2006) and not insured for the health insurance fund in 2005 • Welfare from private disability benefit • Fisherman with his own boat	5,70%	5,65%	5,4%	5,5%	4,85%
• Child support after 01-01-2005	5,70%	5,65%	0%	0%	0%

• Welfare entitled individual trough municipality • Paid employment • Survivor that receives Anw • Welfare for early retirement (received after 01-01-2006) and insured for the health insurance fund in 2005 • Temporary unemployment welfare (in Dutch: WW'er) • Director of majority shareholder with employee insurance • Welfare from employment insurance fund for disability benefit (in Dutch: WIA)	6,95%	6,90%	6,65%	6,75%	6,95%
• Welfare entitled individual trough SVB	6,95%	6,90%	6,65%	5,50%	4,85%
• Fisherman	0%	0%	0%	0%	0%

Table A.1: Different tax percentages for different scenarios (Zvw premiums), Belastingdienst (ndb).

Appendix B

Algorithm Hyndman and Booth

B.1 Notation

$B_t(x)$: Births in calendar year t to females of age x
$D_t^S(x)$: Deaths in calendar year t of persons of age x on 31 December of sex S
$P_t^S(x)$: Population of age x at 1 January of year t of S
$E_t^S(x)$: Population of age x exposed to risk (30 June) in calendar t of sex S
$D_t^S(x, x+1)$: Cohort deaths in calendar year t of persons aged x at the beginning of year t of sex S
$D_t^S(B, 0)$: Cohort deaths in calendar year t of births during year t of sex S
$G_t^S(x, x+1)$: net-migration in calendar year t of persons aged x at the beginning of year t of sex S
$G_t^S(B, 0)$: net-migration in calendar year t of births during year t of sex S
$q_t^S(x)$: Central death rate for age x in year t of sex S
$f_t(x)$: Fertility rate for females of age x in year t
$r_t^S(x)$: Life table survivorship ratios for $x = 0, 1, 2, ..., p-2$, in year t for sex S
$r_t^S(B)$: Life table survivorship ratios for birth to age 0 in year t for sex S
$r_t^S(p-1^+)$: Life table survivorship ratios for $p = 1^+top^+$ in year t for sex S
$R_t^S(x)$: Population adjusted for the first half of migration in year t of sex S

where $t = 1, ..., n, x = 0, 1, 2, ..., p-1, p^+$, and p^+ denotes the open-ended age group p and above.

B.2 Algorithm

$R_t^S(x) = P_t^S(x) + G_t^S(x, x+1)/2 \qquad x = 0, ..., p-2$
$R_t^S(p-1) = P_t^S(p-1) + G_t^S(p-1^+, p^+)/4$
$R_t^S(p^+) = P_t^S(p^+) + G_t^S(p-1, p^+)/4$
$\overline{D}_t^S(x, x+1) = r_t^S(x) R_t^S(x) \qquad x = 0, ..., p-2$
$\overline{D}_t^S(p-1^+, p^+) = r_t^S(p-1^+)\big[R_t^S(p-1) + R_t^S(p^+)\big]$
$\overline{R}_{t+1}^S(x+1) = R_t^S(x) - \overline{D}_t^S(x, x+1) \qquad x = 0, ..., p-2$
$\overline{R}_{t+1}^S(p^+) = R_t^S(p-1) + R_t^S(p^+) - \overline{D}_t^S(p-1^+, p^+)$
$\overline{E}_t^S(x) = \big[R_t^S(x) + \overline{R}_{t+1}^S(x)\big]/2 \qquad x = 1, ..., p-1, p^+$
$\overline{D}_t^S(x) = q_t^S(x)\overline{E}_t^S(x) \qquad x = 1, ..., p-1, p^+$
$D_t^S(x) \sim Poisson\Big(\overline{D}_t^S(x)\Big) \qquad x = 1, ..., p-1, p^+$
$D_t^S(x, x+1) = \big[D_t^S(x) + D_t^S(x+1)\big]/2 \qquad x = 1, ..., p-2$
$D_t^S(p-1^+, p^+) = \big[D_t^S(p-1)/2 + D_t^S(p^+)\big]$
$R_{t+1}^S(x+1) = R_t^S(x) - D_t^S(x, x+1) \qquad x = 1, ..., p-2$
$R_{t+1}^S(p^+) = R_t^S(p-1) + R_t^S(p^+) - D_t^S(p-1^+, p^+)$
$B_t^S(x) \sim Poisson\big(f_t(x)\big[R_t^F(x) + R_{t+1}^F(x)\big]/2\big) \qquad x = 15, ..., 49$
$B_t^S = \sum_{x=15}^{49} B_t^S(x)$
$B_t^M \sim Binomial\big(B_t^S, \rho/(\rho+1)\big)$

$B_t^F = B_t^S - B_t^M$
$R_t^S(B) = B_t^S + G_T^S(B,0)/2$
$\overline{D}_t^S(B,0) = r_t^S(B)R_t^S(B)$
$\overline{R}_{t+1}^S(0) = R_t^S(B) - \overline{D}_t^S(B,0)$
$\overline{E}_t^S(0) = \left[R_t^S(0) + \overline{R}_{t+1}^S(0)\right]/2$
$\overline{D}_t^S(0) = q_t^S(0)\overline{E}_t^S(0)$
$D_t^S(0) \sim Poisson\left(\overline{D}_t^S(0)\right)$
$f_0 = \overline{D}_t^S(B,0)/\overline{D}_t^S(0)$
$D_t^S(B,0) = f_0 D_t^S(0)$
$D_t^S(0,1) = (1-f_0)D_t^S(0) + D_t^S(1)/2$
$R_{t+1}^S(0) = R_t^S(B) - D_t^S(B,0)$
$R_{t+1}^S(1) = R_t^S(0) - D_t^S(0,1)$
$P_{t+1}^S(0) = R_{t+1}^S(0) + G_t^S(B,0)/2$
$P_{t+1}^S(x+1) = R_{t+1}^S(x+1) + G_t^S(x,x+1)/2 \qquad x = 0, ..., p-1, p^+$

$\rho =$ male : female sex-ratio at birth: $B_t^F = \frac{1}{1+\rho}B_t$ and $B_t^M = \frac{\rho}{1+\rho}B_t$. $\overline{A}$ indicates an estimate of A.

Appendix C

ARIMA Output

Mortality:

```
-- Coefficient 1 --
Series: xx[, i]
ARIMA(1,1,0) with drift

Coefficients:
          ar1    drift
      -0.4912  -0.1682
s.e.   0.1065   0.0234

sigma^2 estimated as 0.08349:  log likelihood=-11.01
AIC=28.02   AICc=28.4   BIC=34.64

-- Coefficient 2 --
Series: xx[, i]
ARIMA(1,1,0)

Coefficients:
          ar1
      -0.5225
s.e.   0.1057

sigma^2 estimated as 0.02877:  log likelihood=24.15
AIC=-44.29   AICc=-44.1   BIC=-39.88

-- Coefficient 3 --
Series: xx[, i]
ARIMA(2,0,0) with zero mean

Coefficients:
         ar1    ar2
      0.4381  0.430
s.e.  0.1167  0.119

sigma^2 estimated as 0.03023:  log likelihood=22.83
AIC=-39.67   AICc=-39.29   BIC=-33.01

-- Coefficient 4 --
Series: xx[, i]
ARIMA(2,0,0) with zero mean

Coefficients:
         ar1     ar2
      0.5037  0.3135
s.e.  0.1186  0.1200

sigma^2 estimated as 0.01854:  log likelihood=39.63
AIC=-73.26   AICc=-72.89   BIC=-66.6

-- Coefficient 5 --
Series: xx[, i]
ARIMA(2,0,0) with zero mean

Coefficients:
         ar1     ar2
      0.2625  0.2322
s.e.  0.1247  0.1300

sigma^2 estimated as 0.02625:  log likelihood=28.17
AIC=-50.34   AICc=-49.96   BIC=-43.68

-- Coefficient 6 --
Series: xx[, i]
ARIMA(0,0,0) with zero mean

sigma^2 estimated as 0.01741:  log likelihood=41.23
AIC=-80.47   AICc=-80.41   BIC=-78.25
```

Fertility:

```
-- Coefficient 1 --
Series: xx[, i]
ARIMA(1,2,1)

Coefficients:
          ar1     ma1
      -0.7462  0.4194
s.e.   0.1813  0.2375

sigma^2 estimated as 0.1851:  log likelihood=-37.1
AIC=80.19   AICc=80.58   BIC=86.76

-- Coefficient 2 --
Series: xx[, i]
ARIMA(0,2,1)

Coefficients:
          ma1
      -0.2820
s.e.   0.1262

sigma^2 estimated as 0.04013:  log likelihood=12.93
AIC=-21.85   AICc=-21.66   BIC=-17.47

-- Coefficient 3 --
Series: xx[, i]
ARIMA(2,0,1) with zero mean

Coefficients:
         ar1      ar2      ma1
      1.8265  -0.8684  -0.3007
s.e.  0.0811   0.0817   0.1639

sigma^2 estimated as 0.03967:  log likelihood=12.4
AIC=-16.8   AICc=-16.16   BIC=-7.92

-- Coefficient 4 --
Series: xx[, i]
ARIMA(2,0,1) with zero mean

Coefficients:
         ar1      ar2      ma1
      1.8783  -0.9229  -0.8047
s.e.  0.0694   0.0614   0.1755

sigma^2 estimated as 0.04614:  log likelihood=8.11
AIC=-8.23   AICc=-7.59   BIC=0.65

-- Coefficient 5 --
Series: xx[, i]
ARIMA(1,0,0) with zero mean

Coefficients:
         ar1
      0.8657
s.e.  0.0588

sigma^2 estimated as 0.02575:  log likelihood=27.74
AIC=-51.48   AICc=-51.3   BIC=-47.04

-- Coefficient 6 --
Series: xx[, i]
ARIMA(0,0,3) with zero mean

Coefficients:
         ma1     ma2     ma3
      0.6480  0.5534  0.6337
s.e.  0.1054  0.1059  0.1116

sigma^2 estimated as 0.01397:  log likelihood=49.33
AIC=-90.66   AICc=-90.03   BIC=-81.78
```

Net-Migration:

```
-- Coefficient 1 --
Series: xx[, i]
ARIMA(2,1,1)

Coefficients:
         ar1      ar2      ma1
      0.9710  -0.4442  -0.7906
s.e.  0.1493   0.1169   0.1255

sigma^2 estimated as 849275:  log likelihood=-542.97
AIC=1093.95   AICc=1094.6   BIC=1102.7

-- Coefficient 2 --
Series: xx[, i]
ARIMA(2,0,0) with zero mean

Coefficients:
         ar1     ar2
      0.3531  0.2141
s.e.  0.1188  0.1195

sigma^2 estimated as 1404827:  log likelihood=-568.42
AIC=1142.84   AICc=1143.22   BIC=1149.45

-- Coefficient 3 --
Series: xx[, i]
ARIMA(1,1,3)

Coefficients:
          ar1     ma1      ma2      ma3
      -0.7835  1.2446  -0.0578  -0.4751
s.e.   0.1125  0.1605   0.2568   0.1590

sigma^2 estimated as 93406:  log likelihood=-470.25
AIC=950.49   AICc=951.49   BIC=961.44

-- Coefficient 4 --
Series: xx[, i]
ARIMA(1,0,1) with zero mean

Coefficients:
         ar1     ma1
      0.5003  0.9023
s.e.  0.1091  0.0744

sigma^2 estimated as 50193:  log likelihood=-458
AIC=922.01   AICc=922.39   BIC=928.62

-- Coefficient 5 --
Series: xx[, i]
ARIMA(1,0,1) with zero mean

Coefficients:
         ar1     ma1
      0.8818  0.7092
s.e.  0.0721  0.0945

sigma^2 estimated as 10187:  log likelihood=-404.81
AIC=815.61   AICc=815.99   BIC=822.23

-- Coefficient 6 --
Series: xx[, i]
ARIMA(1,0,1) with zero mean

Coefficients:
         ar1     ma1
      0.4952  0.7250
s.e.  0.1153  0.0913

sigma^2 estimated as 6498:  log likelihood=-388.98
AIC=783.95   AICc=784.33   BIC=790.57
```

Figure C.1: ARIMA Output for each Input Parameter.

Appendix D

Summary Output

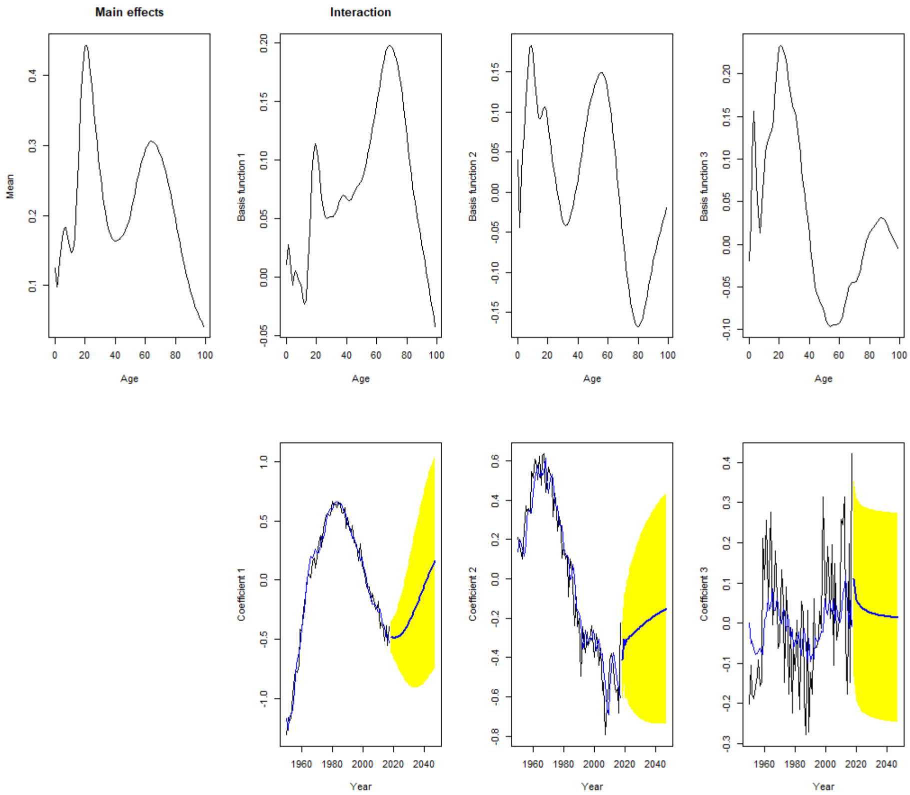


Figure D.1: Summary Male Mortality.

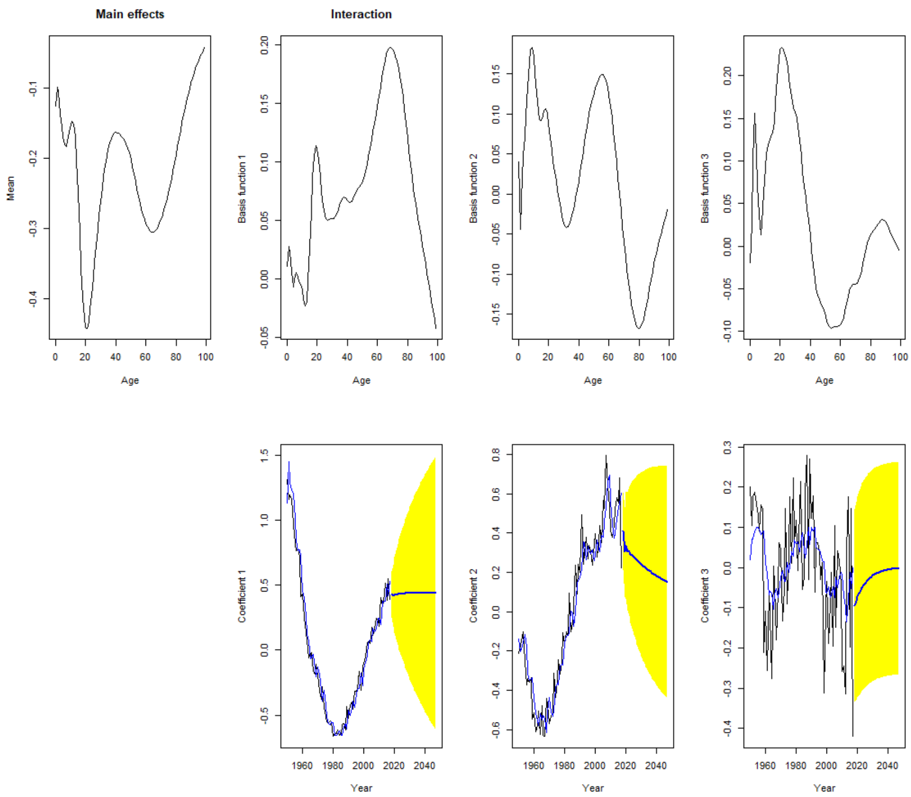


Figure D.2: Summary Female Mortality.

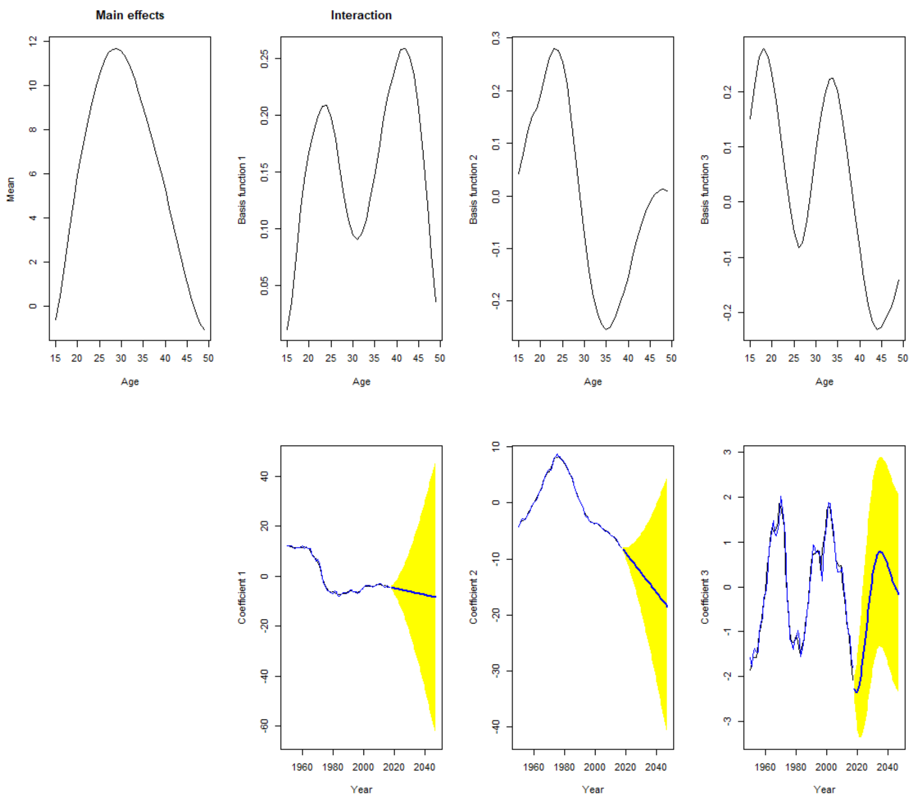


Figure D.3: Summary Fertility.

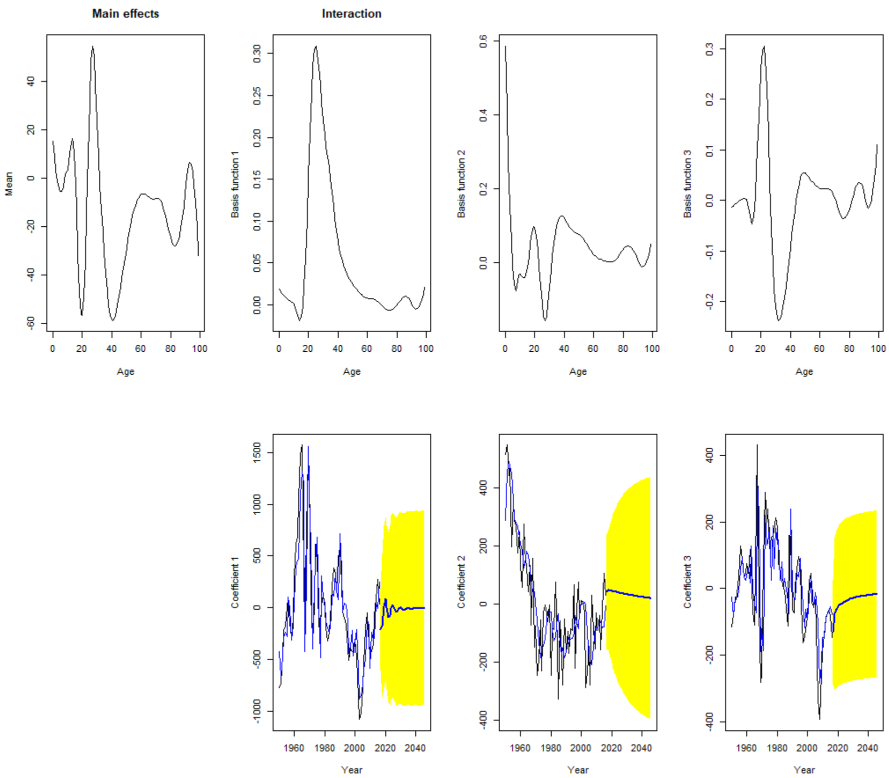


Figure D.4: Summary Male Net-Migration.

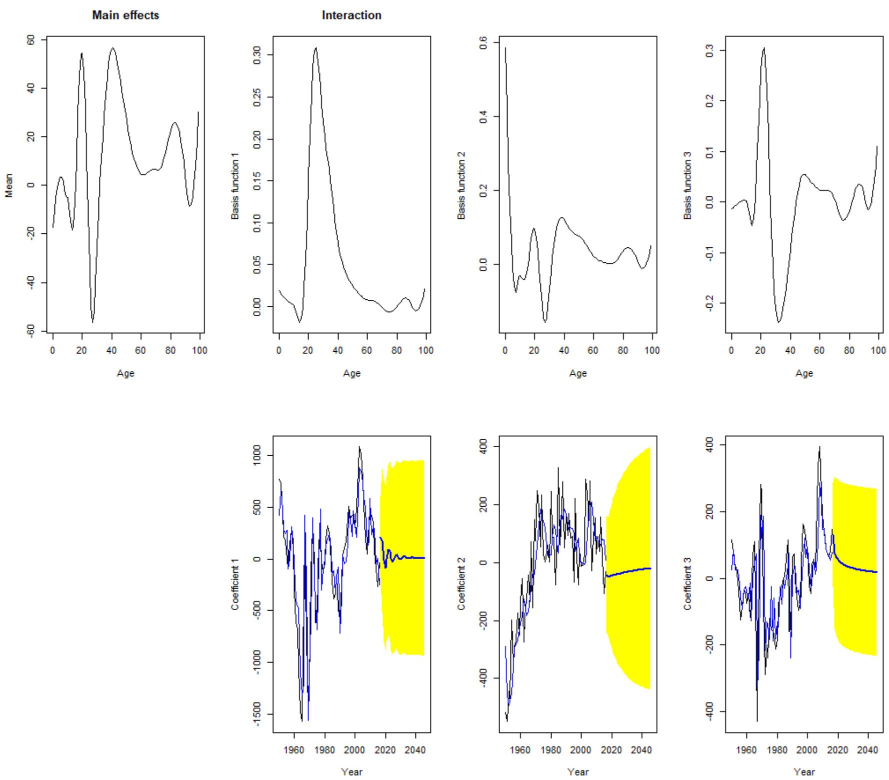


Figure D.5: Summary Female Net-Migration.

Appendix E

Simulation Computations for the IPL

Alho and Vanne (2006) use four simulation steps to compute the predictive distribution of the IPL, also known as L and given in Equation 2.34.

1. Stochastic population forecast
   N amount of stochastic population paths for a certain amount of years where generated using the program PEP and stored. Each path is a matrix of values $V(x, z, u)$ with rows corresponding to the future years u, and 202 columns corresponding to ages $x = 0, 1, 2, ..., 99, 100^+$, for males $z = M$ and females $z = F$.

2. Computation of W
   N values for X_1 were sampled from a normal distribution with mean zero and variance given by Equation 2.31c. In the same way, N values for X_2 were sampled from a normal distribution with mean zero and variance given by Equation 2.32c. Then W_1 and W_2 are computed using Equations 2.31a and 2.32a, and $W = W_1 + W_2$ is computed as well.

3. Computation of S and T
   N values of m_3 were sampled for a normal distribution with mean and variance derived from the MA(1) model, where $m_3 \sim N(\mu, \sigma^2_{m_3})$. S and T might become infinite if the productivity grows faster than the discount rate, therefore any value of $m_3 \geqslant E[m_1]$ is excluded. N sample path of the process $x_t = w_t + \theta_1 w_{t-1}$ were generated by generating the same amount of values as forecast years for $w_t \sim N(0, \sigma^2)$, where σ^2 is derived from the MA(1) model. w_0 is the last value estimated from the GDP data. By combining the results of step 1 with the simulated data of the productivity, Equations 2.33a and 2.33b were computed.

4. Computation of L
   Equation 2.34 was used to produce N values for L based on step 2 and 3.

Appendix F

Statistical Overview Social Security Systems

	Mean	Median	Q_1	Q_3	Standard Deviation
$S(1) - T(1)$	0.01724	0.01725	0.01714	0.01734	0.00017
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(1)$	0.02070	0.02071	-0.01622	0.02518	0.00668
$S(10) - T(10)$	0.2200	0.2201	0.2176	0.2225	0.00365
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(10)$	0.2234	0.2235	0.2183	0.2286	0.00759
$S(20) - T(20)$	0.5267	0.5269	0.5194	0.5343	0.01099
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(20)$	0.5302	0.5305	0.5216	0.5390	0.01291
$S(30) - T(30)$	0.8314	0.8316	0.8176	0.8454	0.02083
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(30)$	0.8348	0.8349	0.8205	0.8495	0.02189

Table F.1: Overview Statistics Model Predictive IPL, Entitlement Age of 65.

	Mean	Median	Q_1	Q_3	Standard Deviation
$S(1) - T(1)$	0.006765	0.006771	0.006676	0.006858	0.00015
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(1)$	0.01023	0.01025	0.00573	0.01470	0.00668
$S(10) - T(10)$	0.1137	0.1138	0.1115	0.1161	0.00335
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(10)$	0.1172	0.1172	0.1121	0.1222	0.00749
$S(20) - T(20)$	0.3167	0.3167	0.3099	0.3234	0.01006
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(20)$	0.3200	0.3200	0.3120	0.3282	0.01205
$S(30) - T(30)$	0.8314	0.8316	0.8176	0.8454	0.02083
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(30)$	0.5453	0.5455	0.5323	0.5585	0.01937

Table F.2: Overview Statistics Model Predictive IPL, Entitlement Age of 68.

	Mean	Median	Q_1	Q_3	Standard Deviation
$S(1)-T(1)$	-0.003457	-0.003460	-0.0035436	-0.003372	0.00014
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(1)$	3.886e-06	1.372e-05	-4.470e-03	4.484e-03	0.00668
$S(10)-T(10)$	0.0146	0.0146	0.0125	0.0167	0.00309
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(10)$	0.01806	0.01804	0.01304	0.02302	0.00749
$S(20)-T(20)$	0.1174	0.1174	0.1109	0.1238	0.00950
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(20)$	0.1208	0.1208	0.1128	0.1238	0.0117
$S(30)-T(30)$	0.2671	0.2674	0.2547	0.2798	0.01879
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(30)$	0.2706	0.2708	0.2573	0.2839	0.0200

Table F.3: Overview Statistics Model Predictive IPL, Entitlement Age of 71.

	Mean	Median	Q_1	Q_3	Standard Deviation
$S(1)-T(1)$	0.01317	0.01318	0.01299	0.01336	0.000309
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(1)$	0.01663	0.01664	0.01213	0.02113	0.00669
$S(10)-T(10)$	0.1461	0.1463	0.1420	0.1503	0.00622
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(10)$	0.1496	0.1495	0.1434	0.1558	0.00909
$S(20)-T(20)$	0.3220	0.3217	0.3090	0.3347	0.0191
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(20)$	0.3254	0.3253	0.3118	0.3388	0.0202
$S(30)-T(30)$	0.5027	0.5005	0.4729	0.5295	0.0426
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(30)$	0.5061	0.5040	0.4764	0.5335	0.0431

Table F.4: Overview Statistics Model Predictive IPL, Health Care Expenditures.

	Mean	Median	Q_1	Q_3	Standard Deviation
$S(1)-T(1)$	0.002624	0.0002627	0.002570	0.002679	9.2333e-05
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(1)$	0.006085	0.006116	0.001587	0.010569	0.00668
$S(10)-T(10)$	0.03718	0.03719	0.03598	0.03843	0.00183
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(10)$	0.04064	0.04065	0.03602	0.04527	0.00694
$S(20)-T(20)$	0.09522	0.09524	0.09172	0.09869	0.00511
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(20)$	0.09869	0.09871	0.09301	0.1045	0.00842
$S(30)-T(30)$	0.1573	0.1572	0.1508	0.1639	0.00974
W	-0.00346	-0.00349	-0.00793	0.00104	0.00668
$L(30)$	0.1608	0.1606	0.1530	0.1687	0.0117

Table F.5: Overview Statistics Model Predictive IPL, Expenditures Wlz.

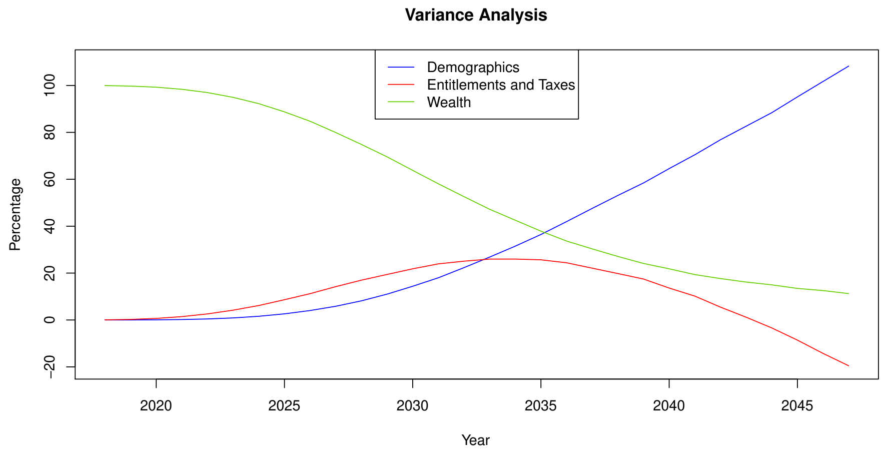


Figure F.1: Variance Analysis of AOW System with Entitlement age of 68.

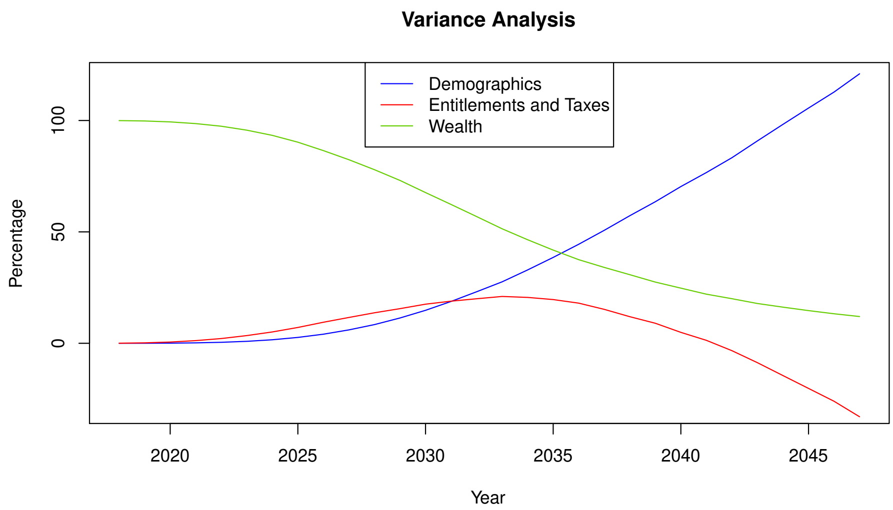


Figure F.2: Variance Analysis of AOW System with Entitlement age of 71.

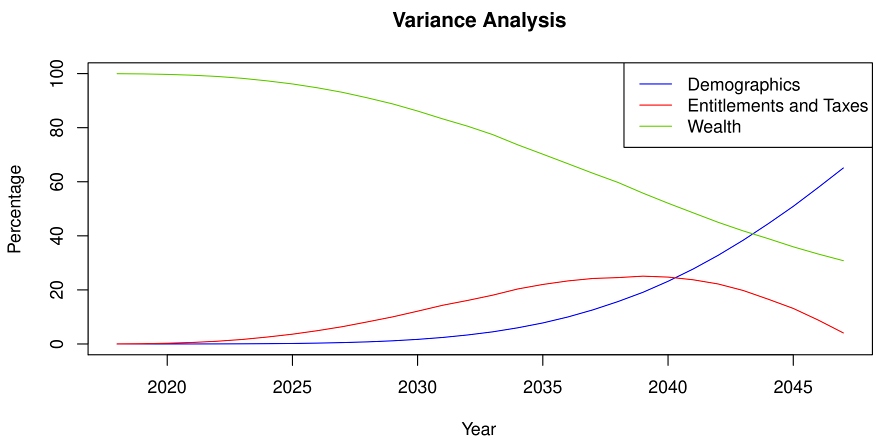


Figure F.3: Variance Analysis of Wlz System