

Societal Aging and Health Care Systems:

A model-based policy analysis across OECD countries

by

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Preface

After this great journey of writing my thesis, I would like to thank everybody who helped me with this thesis. This project started in February 2018 and finished in September 2018. Erik Pruyt was my first supervisor and I would like to thank him for his continuous support during this journey. I appreciate his patience and insightful, helpful remarks about this thesis. Second, I would like to thank my friends and family for supporting me throughout this thesis journey over the past months. In particular, I would like to thank my parents for their unconditional support during my studies. Furthermore, I would like to thank all my colleagues at KPMG who made the time I spent here during my internship joyful. Especially, my supervisor at KPMG, Stein Samsom for bringing me the focus and great insights while writing my thesis.

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Contents

1	Introduction of the research	3
2	Problem investigation	5
2.1	Introduction to the problem.	5
2.2	The problem	5
2.3	What has been already done on health care systems and societal aging in the literature?	6
2.4	Research goal and research questions	7
2.5	Expected outcome	8
3	Research approach & design	9
3.1	What is needed to perform this research?	9
3.2	Research design - Preparation	9
3.3	Formulation	10
3.3.1	System dynamics modeling approach.	10
3.3.2	Entity-based modeling approach	10
3.4	Execution	11
3.4.1	Model-based policy analysis in EMA	11
3.4.2	Ethical reflection	11
4	Systems model	13
4.1	Stakeholders involved in the decision making process	13
4.2	Interrelation of the variables used in the conceptual model	14
4.3	Implemented policies.	17
4.4	The system dynamics model.	18
4.4.1	Main assumptions of the model	18
4.4.2	Societal aging model	19
4.4.3	Labour force model.	21
4.4.4	Demand for health care/cure.	21
4.4.5	Health care/cure supply	23
4.4.6	Financial model.	24
4.5	Database construction	25
4.5.1	Additional data sources	25
4.5.2	Data for the population model	25
4.5.3	Data life expectancy	26
4.5.4	Labor force	26
4.5.5	Supply health care/cure	26
4.5.6	Demand for health care/cure.	27
4.5.7	Financial data.	27
4.6	Outcome of interests	27
5	Results	29
5.1	The base case results	29
5.1.1	Results of the implementation of the technological advancement policies	30
5.1.2	Results of the implementation of additional-students-policy	30
5.1.3	Results of the euthanasia-policy.	32
5.2	Results of exploratory research	32
6	Conclusions and policy strategies	49
6.1	Overall conclusions.	49
6.1.1	Effect of societal aging on health care systems.	49
6.1.2	Conclusions regarding to the research problem	49
6.1.3	The impact of the results on the stakeholders involved.	50

6.2	Policy strategies	50
6.2.1	Australia	50
6.2.2	Austria	51
6.2.3	Belgium	51
6.2.4	Canada	51
6.2.5	Czech Republic	51
6.2.6	Denmark	51
6.2.7	Estonia	51
6.2.8	Finland	51
6.2.9	France	52
6.2.10	Germany	52
6.2.11	Greece	52
6.2.12	Hungary	52
6.2.13	Iceland	52
6.2.14	Ireland	52
6.2.15	Italy	52
6.2.16	Japan	52
6.2.17	Latvia	53
6.2.18	Luxembourg	53
6.2.19	Netherlands	53
6.2.20	New Zealand	53
6.2.21	Norway	53
6.2.22	Poland	53
6.2.23	Portugal	53
6.2.24	Slovak Republic	53
6.2.25	Slovenia	54
6.2.26	Spain	54
6.2.27	Sweden	54
6.2.28	Switzerland	54
6.2.29	United Kingdom	54
6.2.30	United States	54
7	Ethics and societal aging	55
7.1	Dilemma 1: Affordability of community versus common health	55
7.2	Dilemma 2: Affordability as an individual versus right to live	55
7.3	Dilemma 3: Affordability of community versus living through as an individual with dementia	56
8	Discussion & future research	57
8.1	Discussion	57
8.1.1	Results	57
8.1.2	Reflection of the model	57
8.1.3	Data	57
8.2	Future research	57
8.2.1	Model recommendations	57
8.2.2	Data handling	58
8.2.3	Policy recommendations	58
9	Future research	61
9.1	Model recommendations	61
9.1.1	Population model	61
9.1.2	Health demand model	61
9.1.3	Health supply model	61
9.1.4	Data handling	61
9.1.5	Policy recommendations	62

Appendices	69
A Python code of open exploration	69
A.1 Python code of open exploration for needed nurses	69
A.2 Python code of open exploration for costs	76

Executive summary

Personnel shortage will become a major public health problem in many countries in the near future, and one of the main causes of this problem is societal aging (Burke et al., 2013). The goal of this study is to discover the effect and the future affordability of societal aging on health care systems across the OECD, to investigate which policies are needed to overcome this problem and to shed new light on new debates of new policies. A model-based policy analysis using a multi-region dynamic modeling method has been performed to reach this goal.

In this research, a stakeholder analysis is executed to examine which stakeholders are involved in the decision making process concerning societal aging. Furthermore, a system dynamics model is built which represents the health care systems across the OECD. Within this model, four policies have been tested to examine which policies are suited to be implemented to close the future gap between the health supply and the health demand. The first policy is the automation-policy, which decreases the administrative tasks of nurses, through technological advancements. The second policy that is tested is the eHealth-policy, which supports health care institutions to make use of eHealth applications. The third policy is the additional-students-policy, which calculates the inflow of nursing students using the gap of needed nurses. The last policy is the euthanasia-policy, which helps people suffering from dementia to commit euthanasia.

The results of the research show a decrease in the gap between the demand for health care and the health care supply when the policies are implemented. The implementation of the additional-students-policy performs best in terms of closing the gap, but the costs of this implementation are high. Therefore governments should make trade-offs between the costs and the quality of health care. However, these trade-offs may include ethical dilemmas like the example of the committing-euthanasia-policy.

Introduction of the research

'Large staff shortage in healthcare: more than 120,000 vacancies'

The above quote was in the front page of one of the largest Dutch newspaper earlier this year (ANP/Redactie, 2018). Personnel shortage will become a growing public health problem, and one of the main causes of this problem societal aging (Burke et al., 2013). Three main reasons for societal aging are according to OECD, Trends Shaping Education (2008):

- Fewer children are and will be born across the OECD.
- The life expectancy increases
- The number of elderly people increases and the share of elderly people to younger people in the population increases.

The so-called 'double societal aging' will result in problems in terms of national health care budgets, expected pension costs and the pressure on personnel in the Dutch health care system (Auping et al., 2015). However, societal aging is not only a problem in the Netherlands, but societal aging is a problem present across OECD countries (OECD, 2017b)¹.

It is known that societal aging happens and that societal aging will cause problems in the future, but research done on the effect and the future affordability of societal aging on health care systems across the OECD using a multi-region modeling approach has not been investigated yet. Therefore this research offers a model-based policy analysis to assess the impact of different policies on the effect and the future affordability of societal aging on the different health systems in the OECD.

The first practical contribution of this research is the use of entity-based System Dynamics (SD) ² modeling in the scope of societal aging across the OECD. Entity-based modeling allows researchers to do research across different entities using generic model. The generic model uses the values of the different countries (OECD-countries) to show the results of the outcomes of interest for each country. Furthermore, system dynamics modeling allows policymakers to show the forecasted behavior of societal aging over time with and without the intervention of public policies. An extensive explanation of these methods is presented in chapter 3.

The second practical contribution is the ethical reflection reflecting the proposed policy strategies. Policy strategies will be proposed, based on the model-based policy analysis.

¹The OECD (Organisation for Economic Co-operation and Development) is an institution of countries with "the mission to promote policies that will improve the economic and social well-being of people around the world" (OECD, 2018)

²The abbreviation SD refers to System dynamics

However the model-based policy analysis does not incorporate the ethical issues in these policy strategies. Therefore an ethical reflection is needed to consider whether these proposed policy strategies are feasible and desirable in the real world.

The aim of this study is to investigate the effect and the future affordability of societal aging on health care systems in each OECD-country, to investigate which specific policies are needed to overcome this problem in each OECD-country and to shed light on new debates through evaluating these new proposed policies. This research seeks opportunities for governments across the OECD to virtually test possible policies and to consider implementing these policies in the real world.

The overall structure of the study takes the form of nine chapters, including this introductory chapter. Chapter 2 deals with an extensive problem investigation. It includes the problem statement, the scientific gap, the research objective with the research questions and the expected outcomes. The research design is explained in chapter 3. The research design describes the type of research and the methodology. In chapter 4 the model is explained, including the different sub models. Chapter 5 shows the results of the behavior of the model. The conclusions are drawn in chapter 6. Chapter 7 outlines ethical reflections, followed by discussion in chapter 8. The last chapter contains a discussion of recommendations for future research.

2

Problem investigation

2.1. Introduction to the problem

In the Netherlands, there is already a shortage of about 120,000 health professionals (ANP/Redactie, 2018). Not only in the Netherlands are there personnel shortages in health care, but also in other OECD-countries (Simoens et al., 2005). OECD, Trends Shaping Education (2008) shows trends that less children are being born across OECD, that life expectancy increases and that the distribution of age groups changes in the population. Due to the increase of the share of elderly people in the populations, OECD-countries are urgently in need for care in the long run (Francesca et al., 2011). The expected costs of the increased share of elderly people will add pressure on the financing of the health care systems in these countries. The following section addresses the problem of societal aging in more detail.

2.2. The problem

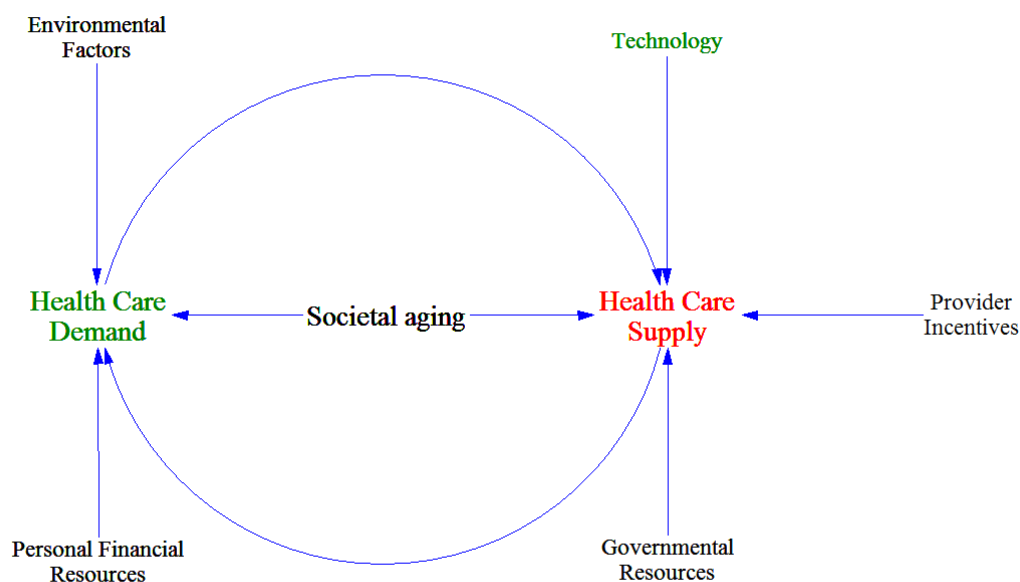


Figure 2.1: Aggregated model

To introduce the problem of societal aging, a highly aggregated model is shown of a standard health care system within the scope of societal aging in figure 2.1. Figure 2.1 shows the two important pillars of this model, which are the demand for health care and the health

care supply. As can be seen the demand for health care is affected by societal aging, environmental factors and personal financial resources.

- **Societal aging** increases the number of elderly diseases (arthritis, heart disease, cancer, Alzheimer's disease and osteoporosis), because the number of elderly people increases (Niccoli and Partridge, 2012). A higher number of elderly diseases causes an increase in the demand for health care.
- **External factors** such as, policies, social factors, spiritual factors and work related factors influence the demand for health care (Marmot, 2005).
- **Personal financial resources** impacts the health demand. Financial resources of persons are determined by health insurances and the coverage of health. The demand for health care is calculated based on these financial resources.

The health care supply is affected by societal aging, technology, provider incentives and governmental resources.

- **Societal aging** increases the demand of persons working in the health care, because the need for nurses and doctors is increasing. The ratio of elderly people to the population increases, so the pool of people working in health care decreases.
- **Technology** influences the health care supply. Emerging technological advances could increase health supply by using, for example, robots to support elderly people or people with chronic diseases. Another technological advancement is the automation of administration of the nurses and doctors to increase the utilization of the effective work.
- **Insurance incentives** influence the health care supply. In exceptional cases, health insurers choose not to cover specific treatments in other countries. Therefore, health care supply could be limited through the choices of the health insurers.
- **Governmental resources** strengthen the health workforce through financing the health care supply; Governmental bodies are responsible to arrange goods and services to the population, such as health care and education (OECD, 2017a).

The main problem of societal aging is the increasing demand for care, due the increase of elderly people. The work force in health care ages and the inflow of newly employed people into the health care supply decreases, because the fewer number of new borns. As a result the resulting gap between the health supply and health demand increases. Governments need to implement additional policies to close this gap.

2.3. What has been already done on health care systems and societal aging in the literature?

In this section the theoretical gap is explained as a reflection on existing studies done within health care systems, societal aging and system dynamics.

A large and growing body of literature has investigated the existence of societal aging. Large organisations, such as the World Health Organisation, the United Nations and The Organisation for Economic Co-operation and Development (OECD), already investigated this emerging problem (World Health Organization, 2015; Rosenberg et al., 2013; OECD, 2017b; Melorose et al., 2015; United Nations, 2017a). The World Health Organization (2015) addresses the challenges to health policies for aging populations and investigates how to provide these policies using different case studies of policy implementations in different countries. Furthermore, the Population Division of the department of Economic and Social Affairs of the United Nations provides accessible data of the world population and their analysis of trends (United Nations, 2017a) and investigates population trends in societies.

Bloom et al. (2011) focused on the new challenges societal aging raises. They argued that societal aging does not only have negative impacts, but brings also opportunities to people. Furthermore, they state that problems to societal aging need to be adopted on all levels, which

is on an individual, organizational and societal level (Bloom et al., 2011). Not only societal aging affects population and governments, but the changes of an aging population show an increase of chronic diseases in the population (OECD, 2011). The increase of incidence of chronic diseases in the population could press significantly on the financial affordability of health systems across the countries. According to Angelis et al. (2017), decision makers in the financial decision-making process should set efficiency rules and should implement innovative policy implementations in order to establish the affordability and sustainability of health care systems. Furthermore, Harper (2014) shows that a number of countries should think about their pension and health care expenditures, because otherwise countries will end up with a health expenditure of 40% of all government spending in the future. Furthermore, Pammolli et al. (2012) described the stability of European health care systems. With the growing number of health expenditures as a fraction of the GDP, they propose that European Governments should think about how to balance their expenditures equally across the needs of the countries.

In the field of societal aging, health care systems and system dynamics, two studies have looked at the impact of societal aging in the Netherlands, through the use of exploratory dynamics modeling (Pruyt et al., 2012) and through a robust system dynamics approach (Auping et al., 2015). The key message of the paper of (Pruyt et al., 2012) is that there is a need of an increase in the labour capacity in health care. Furthermore, increasing the retirement age will have a positive effect on solving the problems of societal aging. Auping et al. (2015) examined in their study that expensive societal aging costs are for the most part created by the decline of the work capacity and the increase of life expectancy. To keep up the current social security level in the Netherlands a constant growth of work capacity is needed. A mathematical approach to model a health care system is done by Grigoroudis and Phillis (2013). They made a framework for modeling health care systems and constructed strategies that could improve the health status of a population using a system-of-systems approach.

2.4. Research goal and research questions

Collectively, these studies outline a critical role for assessing problems of health care systems, in particular, the impact of societal aging. However, no previous study has investigated the dynamics of the effects and the future affordability of societal aging on the health care systems across all OECD countries using an entity-based modeling approach. Therefore, the objective of this research is to conduct a dynamic model and perform a model-based policy analysis across all OECD countries to answer the following main research question:

What is the effect and the future affordability of societal aging on the health care systems within OECD countries?

The following sub questions need to be answered to answer the main research question:

1. Who are the stakeholders involved in the decision-making process?
2. What is the level of interest and the power of the stakeholders involved in the decision-making process?
3. Which policies can governments implement to address problems of societal aging?
4. What are the most important variables to include and what are the interdependencies between these variables in the model?
5. How will data be collected and stored?
6. What are key structures of health care systems in OECD-countries?
7. Which key performance indicators are important to determine the impact of societal aging on health care systems?
8. What kind of simulations must be performed in order to answer the main research question and how can these simulations be interpreted?

9. What are the short-term and the long-term risks of societal aging?
10. How will unanticipated ethical issues be identified and addressed?
11. How will these ethical issues be addressed after the research?

2.5. Expected outcome

The expected outcomes of this research are divided into two categories: The first category reflects the expected outcomes of societal aging on the current health care systems in the OECD without the implemented policies. The second category reflects the expected outcomes of the different policy implementations.

The expected outcome of the first category is that the number of elderly people will increase as a result of the increasing life expectancy. Therefore the ratio of elderly people and young people increases which results in a decrease of the health work supply. At the end societal aging will create a big gap between health demand and health supply.

The policies that are tested in the model are explained in section 4.3. The expected outcome of the four implemented policies is:

1. When the technological-advancement-policy is implemented the health supply will increase, because a part of the activities of the health supply will be replaced through new technologies.
2. When the eHealth-policy is implemented the doctor supply will increase, because part of the activities of the doctors will be replaced through new eHealth technologies.
3. The expected outcome of the additional-students-policy is that the policy will close the gap between the nurse demand and the nurse supply. However, the costs of the salaries of the 'extra' nurses needed will increase for every country across the OECD. This could have consequences for other government expenditures or on the amount of taxes in a country.
4. On the other side, the expectation is that the euthanasia-policy will reduce the costs of many countries. However, it will remain many questions regarding to the ethical issues of the implementation of this policy.

Research approach & design

3.1. What is needed to perform this research?

Societal aging can be specified as a societal challenge due its complex and multidisciplinary nature (George et al., 2016). There is no general agreement on the characteristics of the system, the current state of the system, the future behavior of the system and there is no true of correct problem formulation with a closed definition or single solution to solve the future problems of societal aging. A method to address the problems around societal aging is a model-based policy analysis. A model-based policy analysis uses a computational model in order to show the impact of the implementation of different policies under different scenarios (Bankes, 1993). Under the umbrella of a model-based policy analysis the techniques of system dynamics (SD) modeling and Exploratory Modeling & Analysis (EMA) are used in this research. The SD-modeling approach is used to construct the model and the EMA-workbench is used to run the model under different scenarios. A detailed explanation of these techniques are given further on in this chapter.

3.2. Research design - Preparation

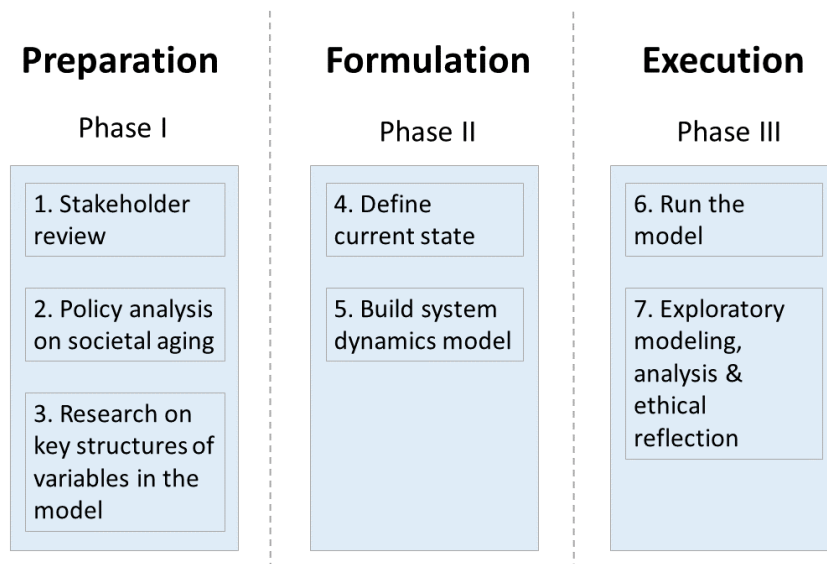


Figure 3.1: Research design

The research is executed in three different phases. The first phase is designed to study the policy landscape of societal aging and to study the landscape of the impact of societal aging

on the future affordability of health care systems. This phase creates a better understanding of the current situation of societal aging in the OECD-countries. First, a stakeholder review is executed to discover the stakeholders with their power and level of interest within the decision-making process. Second, a policy analysis of the different policies is executed to discover the already existing policies. Third, a literature review of the fundamental structures of the model is performed.

Based on the literature review, the development of the model is conducted in phase two. The current state of all the OECD-countries will be first determined. Second, the system dynamics model is built in the modeling software program called Vensim.

3.3. Formulation

The system dynamics model that is used in this research is conducted in this phase. The system dynamics model is built using an entity-based modeling approach. The system dynamics method is first explained followed with the explanation of the entity-based modeling approach.

3.3.1. System dynamics modeling approach

System Dynamics (SD) modeling is a method to model the dynamics of systems using differential equations (Forrester, 1997). System Dynamics models are defined using stock, flows and auxiliary variables and the purpose of system dynamics modeling is to evaluate the future and the impact of future policies (Forrester, 1997). System dynamics modeling is therefore an useful modeling approach to show the future problems of societal aging and to show the possible policy implementations to solve the problems of societal aging.

3.3.2. Entity-based modeling approach

In order to show the impact of societal aging on the countries across the OECD, an entity-based modeling approach is executed. An entity-based model considers the OECD-countries as separate entities, where the overall behavior is defined by the properties of the system dynamics model (Benenson et al., 2002).

Figure 4.15 shows an aggregated representation of the data stream in this research. The data of the countries is gathered from different databases and stored in the excel-file. The SD-model uses therefore the data from the excel to perform the simulations for each country.

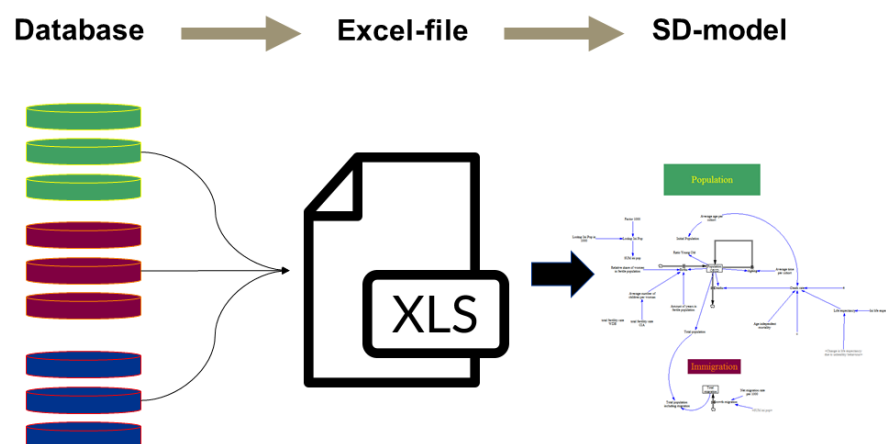


Figure 3.2: Data stream

3.4. Execution

The execution of the analysis is performed in this phase. In order to generate useful results and write conclusions to answer the main research question, a model-based policy analysis is performed in the EMA-workbench.

3.4.1. Model-based policy analysis in EMA

A model-based analysis is a method that analyzes policy implementations based on the results of the SD-model. The technique to perform the model-based policy analysis is Exploratory Modeling and Analysis (EMA) in the EMA-workbench (Bankes, 1993). The EMA-workbench "aims at providing support for performing exploratory modeling with models developed in various modeling packages and environments" (Kwakkel, 2018).

Therefore due to the fact of the uncertain outcome of this research, an exploratory research is conducted (Shields and Rangarajan, 2013). The exploratory research simulates the system dynamics over different scenarios. Not all the variables in the system dynamics model have a constant value over time. The uncertainty of these variables is not set on a constant value, but is set in a range between two values. The EMA-workbench uses the system dynamics model to perform scenarios with different values of the 'uncertain' variables in the model.

The ambition of this exploratory research design is not to provide a final answer to the main research question, but to test policies across uncertain futures, which allows governments to identify and evaluate the robustness of different policy options.

3.4.2. Ethical reflection

The exploratory research does not take the ethical aspects of the policy strategies into account. Therefore, an ethical reflection on the feasibility and the desirability of the policy strategies is performed.

Systems model

In this section a systems analysis of the research is performed. First, a stakeholder analysis is made to show the different stakeholders within the decision-making process. Second, the system demarcation is performed using a causal loop diagram. Third, the implemented policies in the model are explained. Fourth, the system dynamics model is described. Fifth, the data collection of the initial values of the variables is explained.

4.1. Stakeholders involved in the decision making process

A stakeholder analysis is the method of evaluating the impact of decisions to the decision-making process between the stakeholders involved (Jensen et al., 2014).

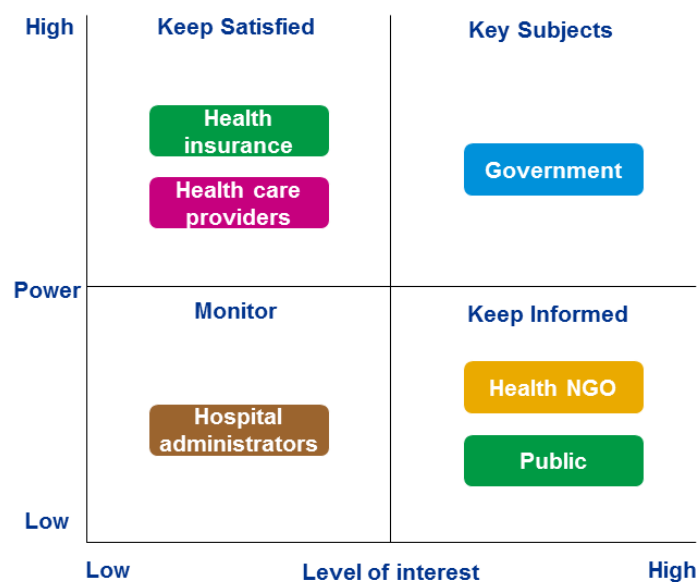


Figure 4.1: Stakeholder map

The stakeholder map in figure 4.1 shows the level of interest of each stakeholder over the power of each stakeholder. Monitors of the decision-making process are categorized in

the first quadrant. Monitors are stakeholders with a low level of interest and a low power in the decision-making process. The monitors of the decision-making process are the hospital administrators. The hospital administrators are the central point of control within hospitals. In general there are two types of administrators: generalists and specialists (Health Careers Center, 2018). Generalists are usually the managers of an entire facility/hospital and specialists are the administrators that are usually responsible for specific operations and/or departments. Hospital administrators have a low level of interest, because they do not benefit directly from societal aging policies. Furthermore, their power to the decision-making process is also low, because they do not have the power to decide which policies should be implemented.

Stakeholders in the second quadrant need to stay informed. Stakeholders in this quadrant have a high level of interest and a low level of power. Stakeholders in this quadrant are NGOs and the public. An example of a NGO is the HelpAge International. The mission of HelpAge is to endorse the well-being and inclusion of elderly people, and to reduce poverty and discrimination in later life (HelpAge International, 2018). Another NGO within the decision-making process could be the Alzheimer's Disease International organization. This organization benefits from the different societal aging policies. Another NGO is the International Federation on Aging, their goal is to provide a platform for experts working with societal aging related subjects to influence age-related policies (IFA, 2018). NGOs have a high interest and a low power in the decision-making process. The implemented policies of the governments affect the public directly. The public benefits from the policies the government implement and pays for it. Therefore, the public has a high level of interest in the decision-making process, but have no power to make the policies.

Stakeholders with a low level of interest and a high power are classified in the keep satisfied quadrant. Stakeholders belonging to this quadrant are the health insurances and health care providers. In most of the OECD countries the health expenditures of individuals are partly or fully covered by health insurances (Colombo and Tapay, 2004). Therefore, when policies do not align with health insurances, they do not take part in the decision-making process to solve the problem. The same holds for health care providers. When doctors, nurses and the medical supportive staff find out these policies are not satisfied, the implementation of those policies will be problematically.

The key subjects in the stakeholder map have high power and a high level of interest in the decision-making process. Governments belong to this key subject quadrant. Governments have three main responsibilities (OECD, 2017a):

- To arrange goods and services to the population. Goods and services include health care and education.
- To manage the cooperation between society and the economy
- To redistribute income

In the context of the effect of societal aging on the future affordability of health care systems, the first responsibility of governments is most important. OECD populations are aging and current health care systems are not sustainable for these new situations (OECD, Trends Shaping Education, 2008). For that reason, there is a need to craft or to redesign the current health care policies to meet the increasing demand in the health care systems.

An assessment of the roles of the stakeholders within the decision-making process will be carried out in the ethical reflection based on the proposed policy strategies.

4.2. Interrelation of the variables used in the conceptual model

The problem statement in chapter 2 shows the problem of the effect of societal aging on the future affordability of the health care systems within the OECD. The causal loop diagram of the system is shown in figure 4.2. The stakeholder map of 4.1 is superimposed on top of the causal loop diagram in order to show the interdependencies of between the stakeholders in the conceptual model.

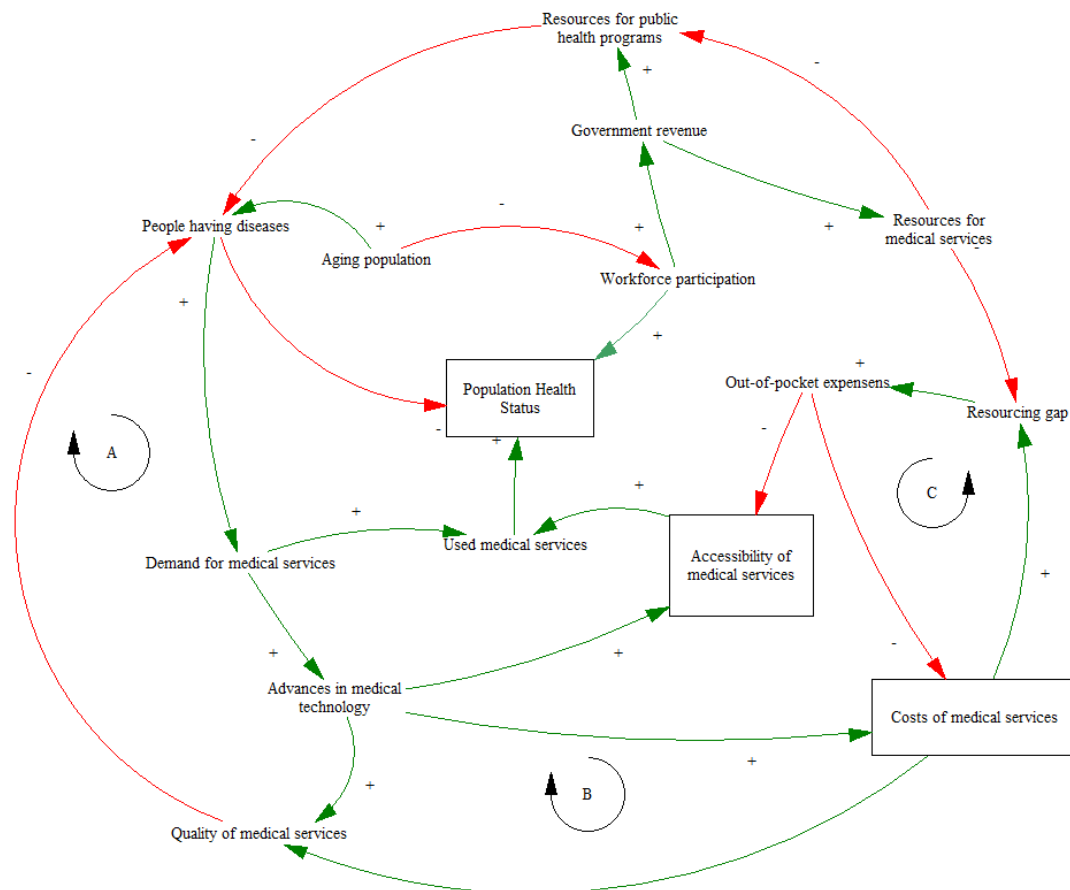


Figure 4.2: Causal loop diagram of the health care system

The **population health status** is dependent on the number of people having diseases, the workforce participation and the medical services used. When the number of diseases increases, the population health status decreases, because the health of the population is decreasing. Furthermore, when the number of medical services increases, the population health status increases due to a high availability of health services available. Furthermore, when the workforce participation decreases, due societal aging, the health status of a country decreases, because less people are able to work in the health care. The governments have a major influence on the population health status. Due policy implementations, governments have the power to influence the workforce participation in the health care. On the other side, the governments should be aware of the fact that the demand of health care providers is not infinite. When the demand is too high for health care, health care providers should work harder then when the demand is met. This could result in an increase of the work pressure and a decreasing productivity. When the workforce participation decrease, the population health decrease as well, so the public becomes more unhealthy. Therefore the health insurances have to pay more for the ill people.

People having diseases depends on the quality of medical services, resources for public health programs and the aging population. If the quality of the medical services decreases, the number of people having diseases increases. When the resources for public health programs decrease, the number of diseases increases. When the aging population increases the number of people with medical problems also increases. If the number of medical problems increases, the demand of medical services also increases. Therefore, the importance of keeping the public healthy is increasing, because when the resources for public health programs increases, people having diseases decreases. The governments have a big influence

on the resources for public health programs, because the governments are the financiers of the health programs. Furthermore, health insurances insist on these expenses by the government, otherwise they have to pay too much for the ill people. Health care providers have to work harder when more people are getting ill, which results in a decreasing quality of medical services. Therefore the Health NGOs will put pressure on the governments to take action.

Technological advancement influences the costs of health supply, demand for the health supply and the quality of health supply. The costs of health supply increases when technological advancement in health care increases (Sorenson et al., 2013). When technological advancement in health care increases, the demand for health supply increases, because the use of smart wearables makes the threshold to see a doctor lower and increases the demand for health care. Furthermore, technological advancement in health care also increases the quality of medical health supply. The public will eventually benefit from the technological advancements, because it will lower the costs at the long run. The same holds for the health care providers, because due the increasing health demand, the technological advancements will substitute a part of the work, which results in lower health costs. Furthermore, the health insurances will benefit from the implementation of technological advancements, because the costs of doctors will decrease. On the other side, governments should invest in the technological advancements and they have to make the trade-off either to invest in technological advancements and invest less in regular health care or to invest more in health care in total and cut the costs of other expenses.

Used medical services are dependent on the demand for health supply and the accessibility of medical services. If the demand for medical services increases, the use of medical services increases. The same holds if the accessibility of medical services increases, the use of medical services also increases. The used medical services are dependent on the number of ill people. However when the health supply does not cover the health demand, the health care providers should work harder or some people won't get the health care they need. Therefore the government should care about the health care supply and should take action to solve the problems of societal aging.

Out-of-pocket-expenses influence the costs of medical services as well the accessibility of medical services. If out-of-pocket-expenses increase, the costs of medical services decrease as well for the accessibility of medical services. When out-of-pocket-expenses increase, the accessibility of medical services decreases, because increasing the out-of-pocket expenses make it less attractive to use health care for people with a lower income. If the resourcing gap increases, as a consequence the out-of-pocket expenses increase as well. The problem with the out-of-pocket-expenses to the stakeholders involved in the decision-making process is that when the health care costs will increase, the out-of-pocket-expenses for the people will increase as well. And if the costs of health care increase due societal aging, the rich people are capable to pay for it.

The **resourcing gap** decreases if resources for medical services increase. The resources for medical services are dependent on the government revenue. When the government revenue decreases the resources for medical services decrease. The government is responsible for the resourcing gap. When the resources for medical services decrease, because the government revenues decrease the resourcing gap increases. This results in higher out-of-pocket expenses, which results in a lower accessibility for the medical services, used medical services and at the end a lower population health status. Therefore health insurances insist to the government to invest in health care, otherwise they will not pay the price for societal aging.

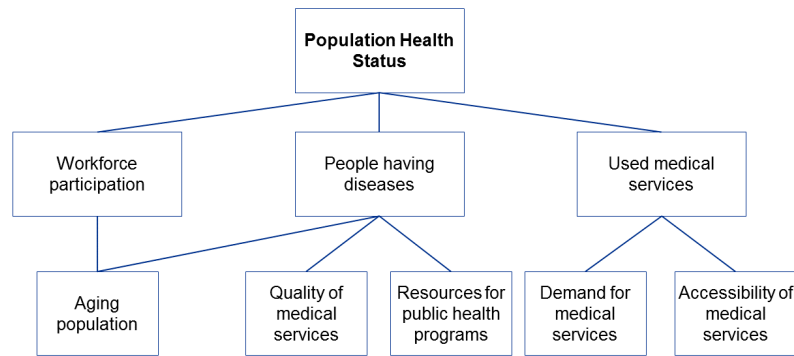


Figure 4.3: Cause tree of the causal loop diagram

The cause tree of the CLD is represented in figure 4.3. The root cause is the population health status. The population health status is determined with the workforce participation, the number of people have diseases and the used medical services in a country. The workforce participation is determined by the aging population, the number of diseases is determined by to the aging population, the resources for public health programs and the quality of medical services. The accessibility of medical services and the demand for medical services determines the medical services used.

4.3. Implemented policies

In this research four policies are tested to examine the impact of the policies on health care systems of the OECD-countries.

- The first two implemented policies are the 'technological-advancement'-policies. In this case the governments will not implement a fixed protocol, but will implement a procedure to support health care with technology advancements.
 - The first technological advancement is the automation of administrative tasks of medical personnel. Automation of administrative tasks in the form of an electronic patient record saves a lot of time for the executive nurses. Based on the study of Nursestation (2018), nurses spent between 39 % and 49 % of their time on administrative tasks.
 - The second technological advancement is the implementation of eHealth. eHealth refers to the use of digital applications in health care. Patients and doctors will be able to make diagnoses via the computer, communicate results and exchange information via the Internet. In the future this may save on average 40 % of the time of doctors and nurses.
- The third implemented policy is the additional-students-policy. This policy entails that the inflow of health students is determined based on the gap between the demand for health and the health supply. The additional inflow of these students will eventually affect the workforce in the health care.
- The fourth implemented policy is the euthanasia-policy. This policy forces people having dementia to commit euthanasia. Costs of dementia are high (Alzheimer's Association, 2018). The reason behind this policy is to cut health care costs in a country to increase the future affordability of health care systems. This policy is set to cover the potential increasing costs of the implementation of the additional-students-policy.

4.4. The system dynamics model

The model is subdivided in the societal aging model, labour force model, the education model, the model for demand for health care/cure, the health care/cure supply model and the financial model. The aggregated relation between the models is showed in figure 4.4. The purple boxes represent the policies, which influence the gap between the health supply, the demand on the health supply and the financial model.

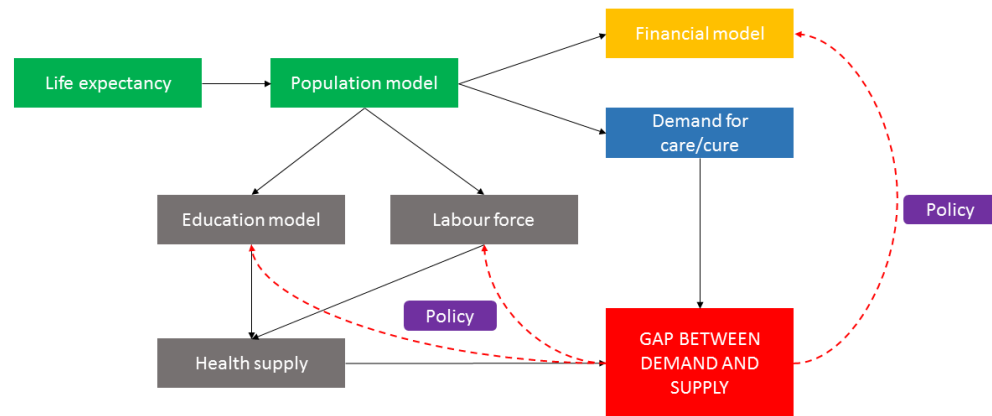


Figure 4.4: Model overview

In this research an important distinction is made between the health care and the health cure. Health care refers to the care needed by elderly people, whereas the health cure refers to the activities performed in a hospital. The countries of the OECD that are studied in this research are showed in figure 4.5.

Countries OECD			
Australia	France	Latvia	Slovenia
Austria	Germany	Luxembourg	Spain
Belgium	Greece	Netherlands	Sweden
Canada	Hungary	New Zealand	Switzerland
Czech Republic	Iceland	Norway	United Kingdom
Denmark	Ireland	Poland	United States
Estonia	Italy	Portugal	
Finland	Japan	Slovak Republic	

Figure 4.5: OECD countries

4.4.1. Main assumptions of the model

In the system dynamics model several assumptions have been made:

- The average number of children per woman, the relative share of women in fertile population and the number of years in fertile population remains constant.
- The Gompertz-function is used to calculate the death rate of a country. However, the death rate only differs due the different predictions in life expectancies. The age independent mortality, the a and the c in the Gompertz-function remains constant.
- The net migration rate remains constant.

- The fraction of people in extramural care is the same for each age group.
- The GDP is calculated based on the work force, average relative productivity and tech productivity. The technology growth rate is based on the ICT added value collected from the OECD-database (OECD Data, 2018e).
- 35% of the nurses in health care work in the extramural care and 65% work in the intramural care.

4.4.2. Societal aging model

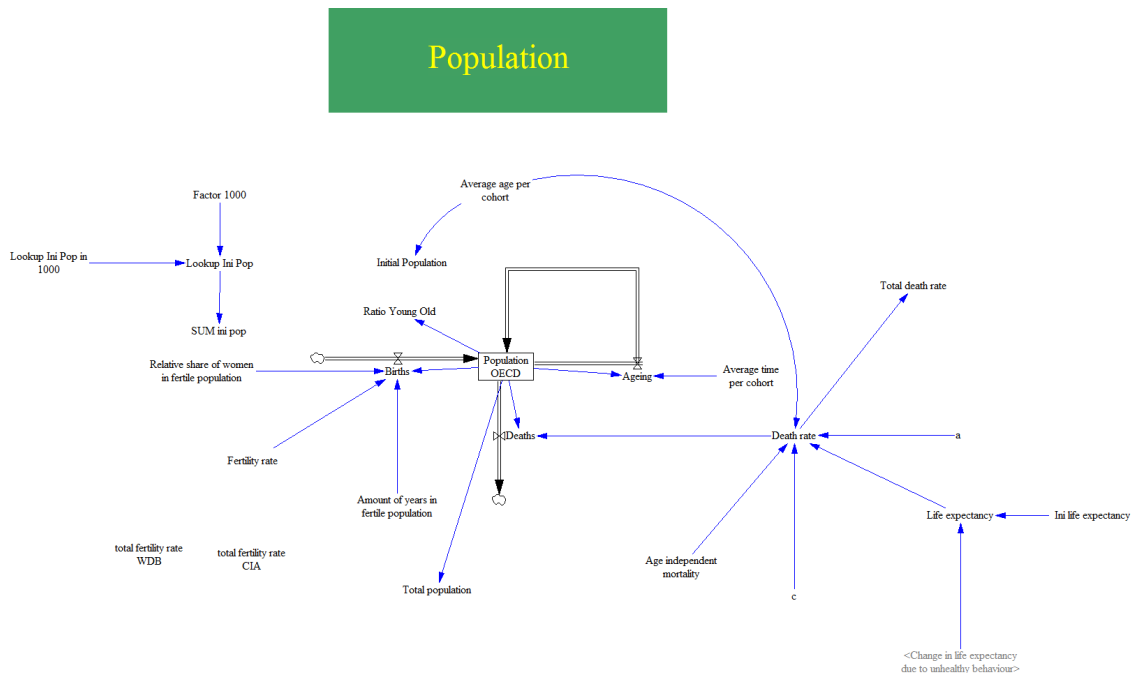


Figure 4.6: Population model in Vensim

The population model is shown in figure 4.6. The population of each country is divided in 21 age groups. Each age group has a range of five years and the highest age group is the AgeGroupPlus100. The data of each age group is available in the database of the United Nations (United Nations, 2018).

The number of births flows in the model is based on the relative share of women in fertile population, the average number of children per women and the number of years in fertile population. The relative share of women is 0.5 in this research. The number of years in the fertile population is set to 30 years: women are fertile from age 15 to 45.

The death rate of each country is calculated using the Gompertz function. Gompertz (1833) showed that the mortality rate tended to increase exponentially with age. The Gompertz function uses a mathematical model over time, using a $s(x)$ as the likelihood that a baby will achieve a certain age x (Kenney and Keeping, 1962). It helps the model to calculate the increase of the death rate when persons in the model get older.

The total population of the different countries is calculated over time. However, migration is not incorporated within the age cohorts, therefore a function is added with a constant of the net migration rate per 1000 inhabitants of a country. The net migration rate is the number of people coming to a country minus the people leaving the country over the year.

Life expectancy

The model to calculate the added life expectancy is showed in figure 4.7. In the societal aging model the death rate of a country depends on the life expectancy of a country. The initial life expectancy is retrieved from the CIA Factbook, where the future modeled life expectancy is

4.4.3. Labour force model

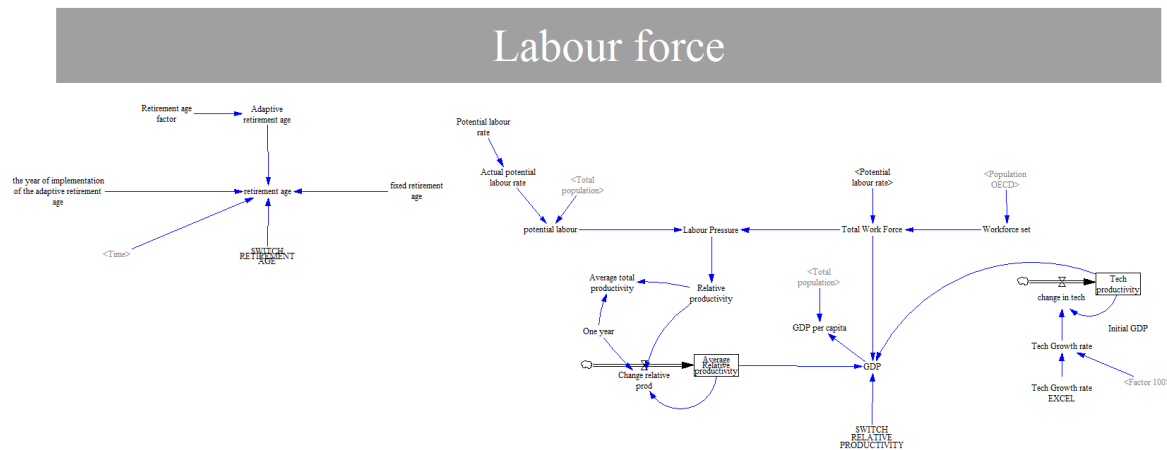


Figure 4.8: Labour force model

The labour force model computes the total work force of all the OECD-countries. The labour force is calculated using the potential labor rate times the total population. Based on the actual labour rate, the productivity is calculated. GDP is calculated using the tech productivity, the total work force and the inproductivity.

4.4.4. Demand for health care/cure

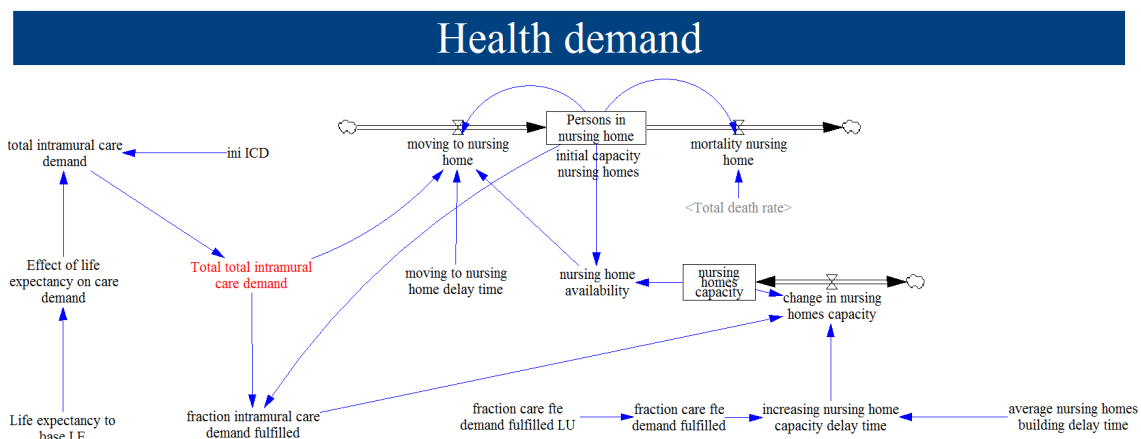


Figure 4.9: Health demand in nursing homes

The model to compute the number of persons in nursing homes is presented in figure 4.9. The total intramural demand for care is based on the average fraction of people needing care per age group. People moving to nursing homes is dependent on the total intramural demand for care, the nursing home availability and the moving to nursing home delay time. The nursing home availability is calculated with the persons in nursing homes and the nursing homes capacity. The nursing homes capacity is dependent on the change in nursing homes capacity. The change in nursing homes capacity is therefore dependent on the fulfilled demand of intramural care and the increasing nursing home capacity delay time.

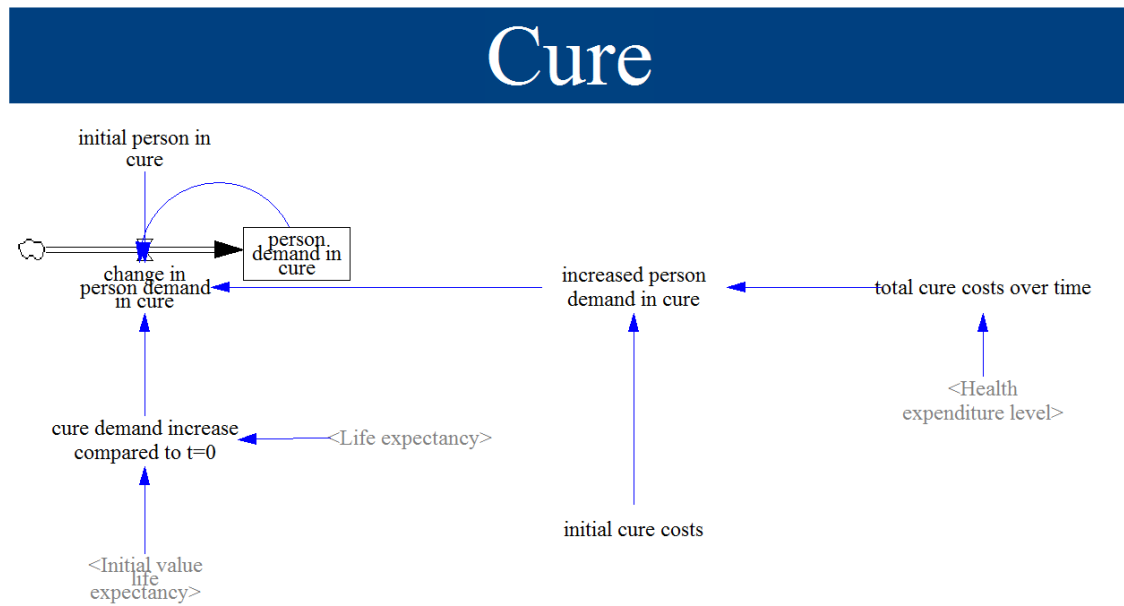


Figure 4.10: Demand for health cure

The model of the cure demand is presented in figure 4.10. The change in FTE demand in cure is calculated with the increased FTE demand in cure and the cure demand increase compared to $t=0$. The increased FTE demand in cure is based on the difference in the total cure costs over time. The cure demand increase compared to $t=0$ is calculated using the increase in life expectancy compared with the initial value of life expectancy.

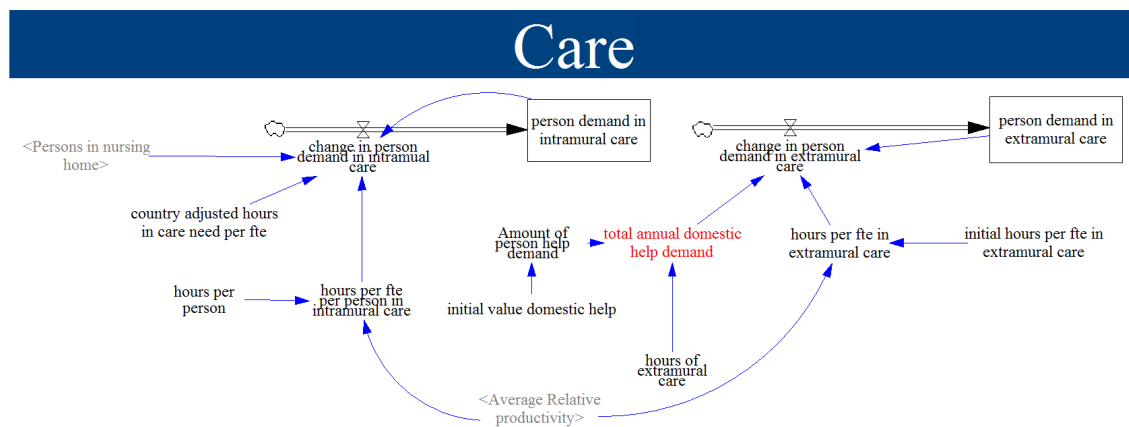


Figure 4.11: Demand for health care

A distinction is made between two types of health care in the health care model: the intramural care and the extramural care. Intramural care concerns the care received by clients during an uninterrupted stay in an institution (Ministerie van Volksgezondheid, Welzijn en Sport, 2018b). Extramural care concerns the care of clients who do not stay in an institution. It is care that the client receives from the care provider by appointment, or that the care provider delivers to the client at home (Ministerie van Volksgezondheid, Welzijn en Sport, 2018a).

FTE demand in **intramural care** is based on the change in FTE demand in intramural care. The change in FTE demand in intramural care is dependent on the number of persons in nursing homes, country adjusted hours in care demand per FTE and the average hours worked of a person on a yearly basis in a country and the average relative productivity in that particular country. Depending on the difference in the FTE demand the FTE demand in

FTE demand in **extramural care** is constructed in the same way using the change in FTE demand in extramural care. The change in FTE demand in extramural care is computed using the hours of FTE per nurse working in the extramural care with the total annual domestic help demand. The total annual domestic help demand is estimated using the fraction of the population needing extramural care.

4.4.5. Health care/cure supply

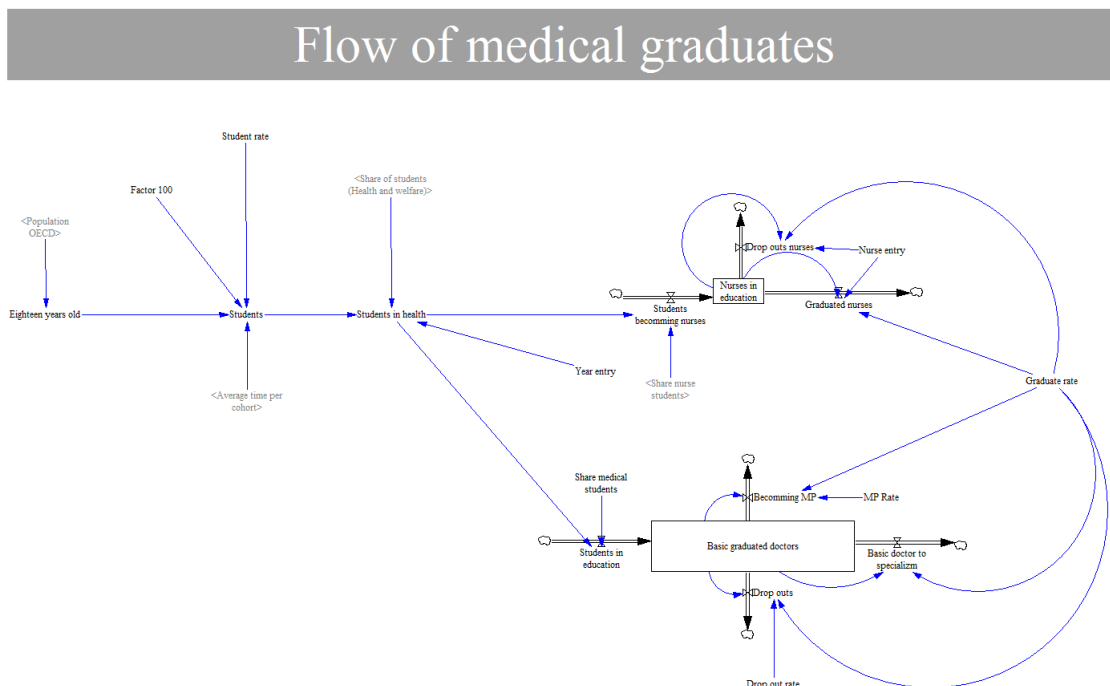


Figure 4.12: Model medical graduates

The model of computing the inflow of medical students is presented in 4.12. The total number of eighteen years old is summed based on the population model. The number of students after high school is calculated using the student rate times the number of people in the age cohort 15-19. The inflow of medical students between the doctors and the nurses is based on the ratio doctors/nurses in each country, which remains constant in the base case. The outflow of students is based on the average graduation rate of a country.

Health labour force/supply

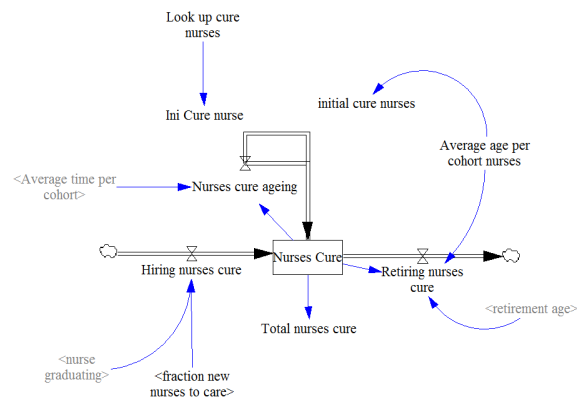


Figure 4.13: Model health care/cure supply

The health supply model of the nurses in cure is shown in figure 4.13. The model of the nurses in the health care has the same structure as nurses in cure. The inflow of the nurses are based on the graduates from the flow of medical graduates.

4.4.6. Financial model

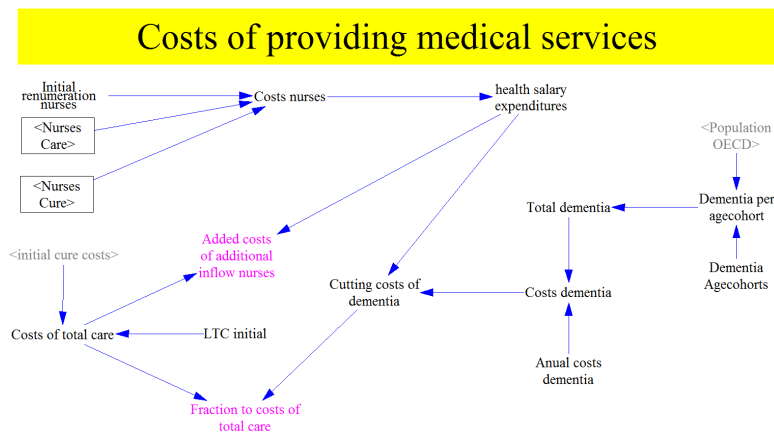


Figure 4.14: Financial model

The financial model is shown in figure 4.14. The variable health salary expenditures is computed with the variable total costs of nurses. The added costs of the additional inflow of nurses computes the fraction of costs of the additional inflow on the health expenditure. The total health expenditure is calculated with the current health cure expenditure and the long term costs. These two variables are computed using their initial value.

The dementia costs are estimated using the total sum of people having dementia times the average annual costs of dementia. The total sum of people having dementia is calculated using the average fraction of people having dementia per age cohort times the number of people in the age cohort.

The variable fraction to costs of total care shows the decrease of costs while implementing the euthanasia-policy.

4.5. Database construction

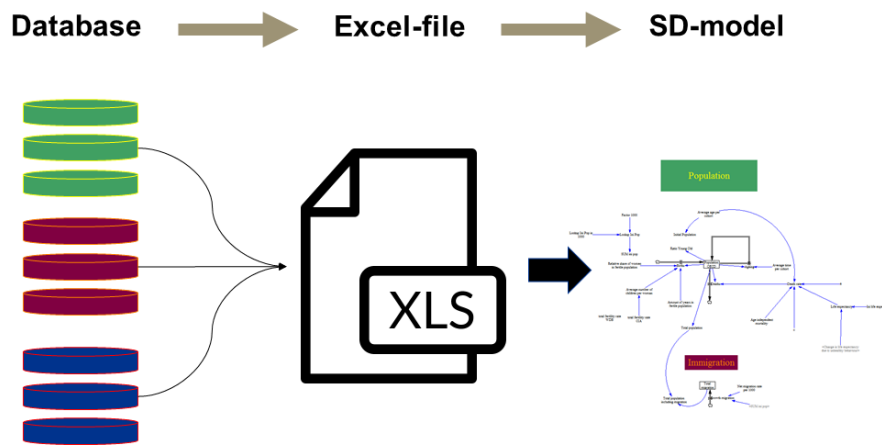


Figure 4.15: Data stream

Different initial values and look-up functioning are used in the system dynamics model. Data used in the model is gathered from the World Data Bank. The Data Bank of the World Data Bank is a database where data from National Statistics and from institutions are assembled. The data that is needed for the system dynamics model is stored in an Excel-file. In the SD-model, the function

$$GETXLSCONSTANTS('filename','tablename','firstcell')$$

is used to retrieve the data from the Excel-file to the Vensim model. A schematic representation of the data stream is shown in figure 4.15.

4.5.1. Additional data sources

Additional data sources used for data in the system dynamic model are the databases of the OECD and the United Nations. Data from these databases are processed manually, using the INDEX MATCH function of Excel. In this function the country specific data is stored in the same order of countries in the Excel-sheet.

4.5.2. Data for the population model

Initial population

The population in the system dynamics model is divided in age groups of five years. The population data is from the United Nations Population Division of the Department of the Economic and Social Affairs (United Nations, 2017b). The most recent age cohort population data of the OECD-countries is from the 1st of July 2017.

Total birth rate

The total birth rate of the OECD-countries is gathered from the World Data Bank as well from the World Factbook of Central Intelligence Agency (Central Intelligence Agency, 2018). The birth rate is the calculated average number of babies born per woman.

Initial value of life expectancy at birth

The data of the life expectancy at birth is generated from the CIA Factbook (Central Intelligence Agency, 2018). The most recent data is from the year 2017. Other life expectancy data is from the OECD statistics, which is data from the year 2015.

Net migration rate

The net migration rate is used as a constant for each country within the OECD. The net migration rate is gathered from the CIA Factbook (Central Intelligence Agency, 2018), however the year of the net migration rate is not known. In addition, the net migration rate is calculated per 1000 inhabitants.

4.5.3. Data life expectancy

Smoking people

The number of smoking people in a country is based on the percentage of the population aged 15+ who are daily smokers from the OECD-database. However, for the most countries in the OECD-database no recent data is available. In those cases the numbers of the missing countries are computed using older data of the countries.

Obese population

The data of obese population of the OECD-countries is retrieved from the OECD-database (OECD Data, 2018g).

Alcohol consumption

The alcohol consumption of the OECD-countries is retrieved from the OECD-database (OECD Data, 2018a).

4.5.4. Labor force

Fixed retirement age

The fixed retirement age is gathered from the *"Average effective age of retirement in 1970-2016 in OECD countries"*-file from the OECD database (OECD, 2016).

GDP

The initial value of the GDP is gathered from the Data Bank of the World Bank (World Bank, 2018).

4.5.5. Supply health care/cure

Total number of doctors

The total number of doctors is retrieved from the OECD-database (OECD Data, 2018b)

Total number of care nurses

The initial total number of nurses are retrieved from the OECD-countries (OECD Data, 2018f). The data from the database is the total number of nurses per 1000 persons. During the simulations, the share of nurses in the health care is computed using the demand for nurses between the health cure and the health care.

Total number of cure nurses

The initial total number of nurses works in the health cure (hospitals) is assumed to be 57% of the total number of nurses for all the countries (Eggink et al., 2010).

Graduation rates

The graduation rates are retrieved from the graduation rates and entry rates in the OECD-database (OECD Data, 2018c).

4.5.6. Demand for health care/cure

Fraction intramural demand for care

The fraction of intramural demand for care is based on the average cumulative percent distribution of personal health care spending in the United States (Schoenman and Chockley, 2017). The percentage of each age group needing care is computed, based on the long-term care recipients of the OECD (OECD Data, 2018h) and the average cumulative percent of personal health care spending

Fraction extramural demand for care

The extramural demand for care is calculated using the fraction of intramural demand for and the average difference of intramural care versus extramural care in the Netherlands in 2016 (Hussem et al., 2016).

4.5.7. Financial data

Health expenditure

Health expenditure is calculated using the percentage of the health expenditure of the GDP and the GDP itself (OECD Data, 2018d).

Long term costs

Long term costs are calculated using the public spending on long-term care as a percentage of GDP times the GDP (OECD, 2017b).

Dementia

The prevalence of dementia across all OECD countries by age group is found in the database of the OECD Data (2017). The costs of dementia are found at the website of the Alzheimer's Association (2018)

4.6. Outcome of interests

The following outcomes of interest are chosen to analyze the performance of the model. The outcomes of interests are the gap of nurses in care as a fraction of the total work force and the gap of nurses in health cure as a fraction of the total work force. In addition the costs of providing extra medical services to close the gap between the health supply and the demand for health will be used to provide a solution to the problems.

The 'gap' between the demand for health care/cure and supply of health care/cure is divided by the total work force of a country to normalize the outcomes.

5

Results

The results of the simulations of the model are presented in this section. Section 5.1 shows the results of the base case. The base case simulations show the results of **one** scenario. In this section, the first set of results shows the percentage of nurses needed in health care and health cure in a country as a fraction of the work force in the base case. The second set of results shows the results of the implementation of the eHealth-policy and the automation-policy. The third set of results shows the results of the implementation of additional-students-policy. The fourth set of results shows the costs of implementing the additional-students-policy and the impact of the implementation of the euthanasia-policy on the costs.

Section 5.2 shows the results of the exploratory research. In this section the results are shown of the **100** scenarios of each policy implementation.

5.1. The base case results

Countries	CARE	CURE	Total	Countries	CARE	CURE	Total
Switzerland	3.03%	1.81%	4.84%	Czech Republic	1.69%	1.03%	2.72%
Luxembourg	3.30%	1.42%	4.72%	Iceland	1.72%	0.98%	2.70%
Germany	2.85%	1.42%	4.27%	Ireland	1.79%	0.90%	2.69%
Finland	2.75%	1.48%	4.23%	Estonia	1.81%	0.72%	2.53%
Belgium	3.02%	1.12%	4.13%	Japan	1.43%	1.07%	2.50%
Greece	2.13%	1.78%	3.91%	Slovak Republic	1.79%	0.62%	2.41%
Austria	1.95%	1.86%	3.81%	France	1.50%	0.77%	2.27%
Norway	2.30%	1.23%	3.53%	New Zealand	1.48%	0.71%	2.19%
Denmark	2.10%	1.25%	3.34%	United Kingdom	1.42%	0.69%	2.12%
Netherlands	2.43%	0.90%	3.32%	Italy	1.35%	0.73%	2.09%
Slovenia	2.08%	1.02%	3.10%	United States	1.23%	0.83%	2.06%
Australia	2.08%	0.91%	2.99%	Poland	1.17%	0.60%	1.77%
Canada	2.00%	0.98%	2.98%	Spain	1.04%	0.56%	1.60%
Sweden	1.84%	0.95%	2.79%	Portugal	0.89%	0.62%	1.51%
Hungary	1.92%	0.87%	2.79%	Latvia	0.86%	0.54%	1.39%

Figure 5.1: Results of the gap in needed nurses as a fraction of the workforce when no policies are implemented

The results of the base case without policies are shown in figure 5.1. The results imply that Switzerland will face the highest total gap of needed nurses in 2050. The model results show that 4.8% of the total workforce of Switzerland should work in the health care to close the gap between the demand for health and the health supply. The highest gap of nurses in health *care* occurs in Luxembourg and the highest gap of nurses in *cure* occurs in Austria.

The lowest gap of nurses both in the health *care* and health *cure* occurs in Latvia. Latvia shows a gap of nurses of 1.4% of the total workforce.

5.1.1. Results of the implementation of the technological advancement policies

Countries	CARE	CURE	Total	Countries	CARE	CURE	Total
Luxembourg	3.11%	1.18%	4.29%	Iceland	1.43%	0.69%	2.12%
Switzerland	2.50%	1.47%	3.97%	Sweden	1.42%	0.70%	2.12%
Germany	2.51%	1.17%	3.68%	Ireland	1.43%	0.57%	2.00%
Finland	2.33%	1.26%	3.59%	Estonia	1.38%	0.44%	1.81%
Austria	1.77%	1.49%	3.26%	Japan	1.07%	0.69%	1.76%
Greece	1.85%	1.41%	3.25%	Slovak Republic	1.38%	0.37%	1.75%
Belgium	2.42%	0.84%	3.25%	United Kingdom	1.19%	0.54%	1.73%
Netherlands	2.11%	0.75%	2.85%	New Zealand	1.16%	0.51%	1.67%
Norway	1.79%	0.82%	2.61%	France	0.92%	0.52%	1.44%
Canada	1.63%	0.70%	2.34%	Poland	0.97%	0.39%	1.36%
Hungary	1.67%	0.65%	2.31%	United States	0.94%	0.40%	1.34%
Denmark	1.51%	0.77%	2.28%	Italy	0.80%	0.42%	1.21%
Australia	1.61%	0.65%	2.26%	Latvia	0.65%	0.35%	1.00%
Czech Republic	1.47%	0.78%	2.25%	Spain	0.66%	0.31%	0.98%
Slovenia	1.49%	0.73%	2.22%	Portugal	0.62%	0.35%	0.97%

Figure 5.2: Results of the gap in needed nurses as a fraction of the workforce when the technological-advancement-policies are implemented

The results in figure 5.2 show the results of the implementation of the eHealth-policy and the automation-policy. Luxembourg shows the highest gap of 4.3% of nurses needed of the total workforce. Switzerland, Germany and Finland show still a high gap of nurses above 3.5% of the workforce.

The impact of the eHealth-policy and the automation-policy on the gap of nurses is shown in figure 5.3. The highest impact of the implementation is in Denmark, Norway, Slovenia, Belgium, Italy and Switzerland. These countries show a difference of the gap in needed nurses of at least 0.8% as a fraction of the total workforce. Furthermore, the implementation of technological-advancement-policies has the least impact in the United Kingdom, Latvia, Poland and Luxembourg with a decrease of the difference of the gap in needed nurses with 0.4% as a fraction of the total workforce.

Countries	Difference CARE	Difference CURE	Difference	Countries	Difference CARE	Difference CURE	Difference
Denmark	0.48%	0.59%	1.06%	Canada	0.28%	0.37%	0.64%
Norway	0.41%	0.51%	0.92%	Finland	0.22%	0.42%	0.64%
Slovenia	0.29%	0.59%	0.88%	Spain	0.24%	0.38%	0.62%
Belgium	0.28%	0.60%	0.88%	Germany	0.25%	0.34%	0.59%
Italy	0.32%	0.56%	0.88%	Iceland	0.30%	0.28%	0.58%
Switzerland	0.34%	0.53%	0.87%	Austria	0.37%	0.19%	0.55%
France	0.25%	0.58%	0.84%	Portugal	0.28%	0.27%	0.55%
Japan	0.38%	0.36%	0.73%	New Zealand	0.20%	0.32%	0.52%
Australia	0.26%	0.47%	0.73%	Czech Republic	0.25%	0.22%	0.47%
United States	0.43%	0.30%	0.73%	Hungary	0.22%	0.25%	0.47%
Estonia	0.28%	0.43%	0.72%	Netherlands	0.15%	0.32%	0.47%
Ireland	0.33%	0.37%	0.69%	Luxembourg	0.24%	0.19%	0.43%
Sweden	0.25%	0.42%	0.68%	Poland	0.22%	0.20%	0.42%
Slovak Republic	0.25%	0.41%	0.66%	Latvia	0.19%	0.20%	0.39%
Greece	0.38%	0.28%	0.66%	United Kingdom	0.15%	0.23%	0.38%

Figure 5.3: Difference of the gap between no policies and the implementation of the eHealth-policy and the automation-policy

5.1.2. Results of the implementation of additional-students-policy

The results of the additional-students-policy are shown in figure 5.4. The results show that after the implementation Switzerland still has the highest gap of 0.4% as the fraction of the workforce, followed by Norway, Finland, Denmark, Japan and Germany. Italy and Latvia show the lowest gap of 0.04% as a fraction of the total workforce across all OECD countries. The gap for nurses in the health care will be closed entirely in Italy and in the health cure in Latvia.

Countries	Care	Cure	Total	Countries	Care	Cure	Total
Switzerland	0.24%	0.23%	0.47%	Austria	0.23%	0.03%	0.26%
Norway	0.27%	0.16%	0.43%	New Zealand	0.18%	0.07%	0.26%
Finland	0.14%	0.25%	0.38%	United Kingdom	0.14%	0.09%	0.23%
Denmark	0.20%	0.17%	0.37%	United States	0.17%	0.06%	0.22%
Japan	0.15%	0.21%	0.36%	Hungary	0.16%	0.06%	0.22%
Germany	0.11%	0.24%	0.36%	Iceland	0.21%	0.00%	0.21%
Slovenia	0.17%	0.16%	0.33%	France	0.11%	0.09%	0.20%
Australia	0.24%	0.09%	0.33%	Czech Republic	0.15%	0.06%	0.20%
Luxembourg	0.24%	0.09%	0.32%	Estonia	0.11%	0.09%	0.20%
Canada	0.23%	0.08%	0.31%	Slovak Republic	0.16%	0.01%	0.17%
Ireland	0.23%	0.08%	0.31%	Spain	0.11%	0.05%	0.16%
Greece	0.20%	0.10%	0.30%	Poland	0.12%	0.02%	0.14%
Belgium	0.15%	0.14%	0.29%	Portugal	0.07%	0.04%	0.11%
Netherlands	0.13%	0.14%	0.27%	Latvia	0.04%	0.00%	0.04%
Sweden	0.15%	0.12%	0.26%	Italy	0.00%	0.04%	0.04%

Figure 5.4: Results of the gap in needed nurses as a fraction of the workforce when the additional-students-policy is implemented

The difference of the decrease of the gap between the technological advancement policies and additional-students-policy is shown in figure 5.5. As can be seen the highest decrease occurs in Luxembourg with almost 4%. Switzerland, Germany, Finland and Austria show all a decrease of the gap above the 3%. The lowest decrease of the gap occurs in Spain, Portugal and Latvia. These countries experience a decrease of less than 1% as a fraction of their total workforce.

Countries	Difference CARE	Difference CURE	Total difference	Countries	Difference CARE	Difference CURE	Total difference
Luxembourg	2.88%	1.10%	3.97%	Slovenia	1.32%	0.57%	1.89%
Switzerland	2.26%	1.24%	3.50%	Sweden	1.28%	0.58%	1.85%
Germany	2.39%	0.93%	3.32%	Ireland	1.20%	0.49%	1.69%
Finland	2.20%	1.01%	3.21%	Estonia	1.27%	0.35%	1.61%
Austria	1.53%	1.46%	3.00%	Slovak Republic	1.22%	0.36%	1.58%
Belgium	2.27%	0.70%	2.96%	United Kingdom	1.06%	0.45%	1.50%
Greece	1.65%	1.30%	2.96%	New Zealand	0.98%	0.44%	1.42%
Netherlands	1.98%	0.61%	2.58%	Japan	0.92%	0.48%	1.40%
Norway	1.51%	0.66%	2.18%	France	0.81%	0.43%	1.23%
Hungary	1.51%	0.59%	2.10%	Poland	0.85%	0.36%	1.21%
Czech Republic	1.32%	0.72%	2.04%	Italy	0.80%	0.38%	1.18%
Canada	1.41%	0.62%	2.03%	United States	0.77%	0.34%	1.11%
Australia	1.37%	0.56%	1.93%	Latvia	0.61%	0.35%	0.96%
Denmark	1.31%	0.60%	1.91%	Portugal	0.55%	0.31%	0.86%
Iceland	1.22%	0.68%	1.91%	Spain	0.56%	0.26%	0.82%

Figure 5.5: Difference in decrease of gap between the technological advancement policies and the additional-students-policy

Results of the costs of additional-students-policy

The results of the costs of implementing the additional-students-policy is shown in figure 5.6. The costs are calculated using the costs of the 'extra' nurses as a fraction of the current health expenditures. Greece will experience an increase of 24% as a fraction of their current total health expenditures. The increase of nurse students will have the least impact on the health expenditures in Japan, Sweden, Switzerland and United States. When these countries will implement the additional-students-policy, their total health expenditures will increase up to 10% due the costs of the salaries in 2050.

Countries	Additional costs	Countries	Additional costs
Greece	24.09%	Denmark	15.77%
Slovenia	21.59%	Spain	14.48%
Estonia	21.36%	Canada	14.34%
Poland	20.34%	Germany	14.17%
Slovak Republic	19.61%	Latvia	12.73%
Luxembourg	19.45%	Norway	12.15%
Australia	18.75%	United Kingdom	11.54%
Belgium	18.65%	Italy	10.81%
Hungary	18.38%	Austria	10.45%
Iceland	17.67%	France	10.34%
Czech Republic	17.45%	Portugal	10.09%
New Zealand	17.40%	Japan	9.76%
Netherlands	17.09%	Sweden	9.27%
Finland	16.44%	Switzerland	7.82%
Ireland	16.38%	United States	7.58%

Figure 5.6: Results of the additional costs of the extra inflow of nurses in 2050

5.1.3. Results of the euthanasia-policy

The additional-students-policy shows an effective behavior in closing the gap between the health supply and the demand for health across the OECD countries, but the salary costs increase for all the countries as well. The euthanasia-policy could be an effective policy to reduce these costs. The euthanasia-policy entails that people having dementia are forced to commit euthanasia in order to cut the growing salary costs.

Countries	Costs of closing	After euthanasia	Difference	Countries	Costs of closing	After euthanasia	Difference
Poland	20.34%	-76.46%	96.80%	France	10.34%	-7.75%	18.09%
Latvia	12.73%	-78.17%	90.90%	Belgium	18.65%	0.83%	17.82%
Hungary	18.38%	-63.49%	81.87%	Canada	14.34%	-3.43%	17.77%
Slovak Republic	19.61%	-46.47%	66.08%	Austria	10.45%	-7.24%	17.69%
Estonia	21.36%	-43.04%	64.40%	Germany	14.17%	-3.30%	17.47%
Czech Republic	17.45%	-41.26%	58.71%	Netherlands	17.09%	0.83%	16.26%
Greece	24.09%	-31.25%	55.34%	Australia	18.75%	3.27%	15.48%
Portugal	10.09%	-35.11%	45.20%	Ireland	16.38%	1.49%	14.89%
Slovenia	21.59%	-21.86%	43.45%	Iceland	17.67%	3.73%	13.94%
Spain	14.48%	-19.40%	33.88%	Denmark	15.77%	2.13%	13.64%
Italy	10.81%	-19.53%	30.34%	Sweden	9.27%	-3.99%	13.26%
Japan	9.76%	-10.93%	20.69%	Luxembourg	19.45%	7.23%	12.22%
New Zealand	17.40%	-2.00%	19.40%	Norway	12.15%	1.51%	10.64%
Finland	16.44%	-2.69%	19.13%	Switzerland	7.82%	-0.71%	8.52%
United Kingdom	11.54%	-7.47%	19.01%	United States	7.58%	0.18%	7.40%

Figure 5.7: Decrease of closing the gap costs with a 'committing-euthanasia'-policy

Figure 5.7 shows the results of the costs when the euthanasia-policy will be implemented with the assumption that the inflow of supply is dependent on the gap between the demand for health and the health supply. When the additional-students-policy and the euthanasia-policy are implemented together, Poland shows an decrease of costs of almost 76.46% of their current total health expenditure. The United States will face the least cost decrease of 7.4% when both policies are implemented.

5.2. Results of exploratory research

Section 5.1 shows the results of **one** base case scenario, where only initial values are used. However, given the uncertain structure of the future, an exploratory research is performed using the EMA-workbench. Table 5.1 shows the variables that are uncertain in the model with their uncertainty range.

In this part the same policy implementations are used for all the three outcomes of interest. No policies, the technological policies and the student-inflow-policy are used for the gap of

the nurses in cure and care.

The students-inflow-policy and the euthanasia-policy are used to compute the costs of the students-inflow-policy. The number of scenarios is set on **100** for each policy implementation, which means that 300 experiments are performed for the needed nurses in cure and care and 200 experiments are performed for the costs.

Table 5.1: Model uncertainties

Uncertainty variable	Ranges	Default value
Growth rate alcohol	0.01 - 0.05	0.04
Increase rate obesity	0.01 - 0.02	0.0147
Graduation uncertainty factor	0.6 - 1.4	1.0
Influence of smoking on life expectancy	1.2 - 2.4	1.8
Influence of inactive population on life expectancy	0.2 - 0.6	0.4
Influence of obesity on life expectancy	0.2 - 0.8	0.5
Influence of heavy drinking on life expectancy	0.1 - 0.3	0.2
hours of extramural care	500 - 1000	730
Annual relative change due to eHealth policy	0.3 - 0.5	0.4
Annual relative change due to TECH ADV policy	0.3 - 0.5	0.4
Fertility rate uncertainty factor	0.6 - 1.4	1.0

Australia

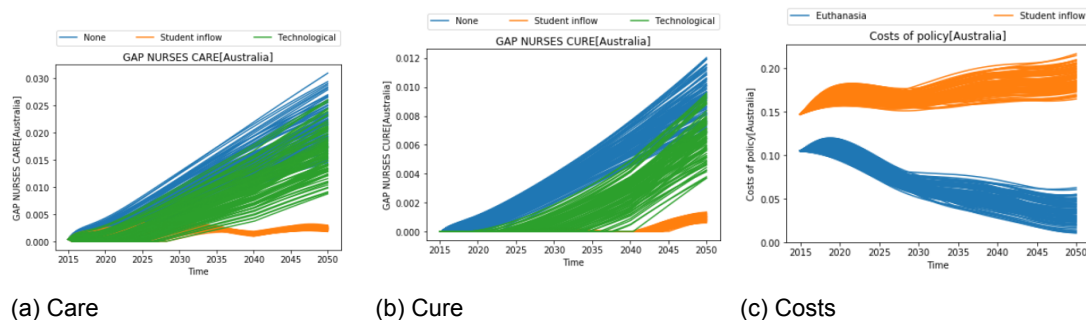


Figure 5.8: Results Australia

The implementation of the technological-policy shows a decrease of the gap with at least 0.5% (55850 vacancies) for the needed nurses in care and 0.2% (22340 vacancies) for the needed nurses in cure in Australia. The demand for nurses in cure is fixed until 2040. After this year the gap will increase with a maximum of 0.1% (111700 vacancies) as a fraction of the total working force.

The costs of the implementation of the additional students will increase between 16% to 21% of the current health expenditure in 2050, which is between the \$17.067.005.605 and \$23.893.807.847. However when the euthanasia-policy will be implemented, these costs will decrease between the 1% and 7% as a fraction of the current total health expenditure, which is between the \$1.137.800.374 and \$7.964.602.616

Austria

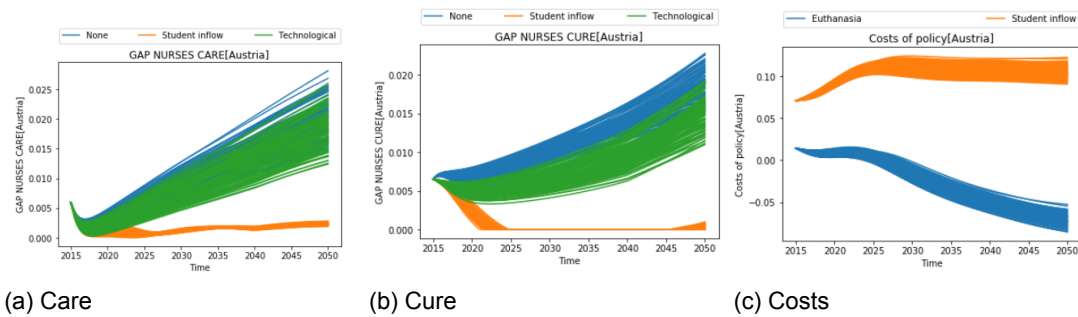


Figure 5.9: Results Austria

The results in Austria show both a decrease of the gap of nurses when the technological advancement policies are implemented. Furthermore, the additional-students-policy shows a minor gap over time in the gap of the nurses in care. The gap of the nurses in cure will be closed between 2021 and 2025 if the additional-students-policy will be implemented.

The costs of the implementation of the additional-students-policy will increase between the 9% and 12% of the current total health expenditure, which is between the \$3.589.100.195 and the \$4.785.466.927. These costs will be covered when the euthanasia-policy will be implemented, because the costs show a value under the 0%.

Belgium

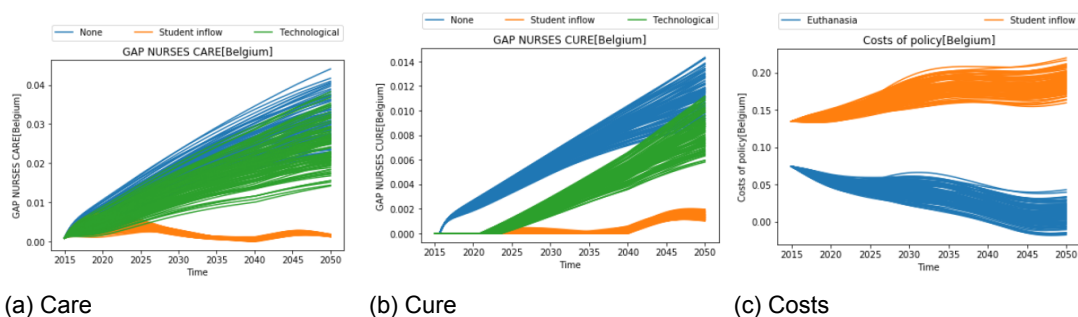


Figure 5.10: Results Belgium

The results of implementation of the technological-advancement-policies show a decrease of the gap of the nurses in care and cure. The gap in nurses is higher for the nurses in care compared to the nurses in cure. Furthermore, the overlap between no policies and the technological advancement policy is less for the the gap of nurses in the cure.

The costs of the additional-students-policy will shift between the 15% to 20% of the current total health expenditure, which is between the \$7.329.260.417 and the \$9.772.347.223. When the euthanasia-policy will be implemented, these costs will decrease from -0.1% of the current total health expenditure to \$2.443.086.806.

Canada

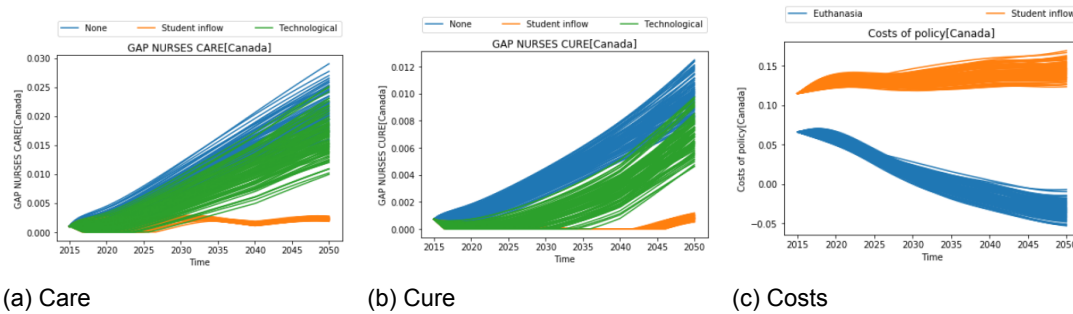


Figure 5.11: Results Canada

The gap of nurses in care when the technological advancements will be implemented is between the 1% (150700 vacancies) and the 2.2% (331540 vacancies) as the fraction of the total workforce. The gap of nurses in the cure will be between the 0.5% (75350 vacancies) and the 0.9% (135630 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will be between the 11% and the 17% in 2050, which is between the \$17.560.403.094 and \$27.138.804.782. Furthermore, when the euthanasia-policy will be implemented all the salary costs will be covered.

Czech Republic

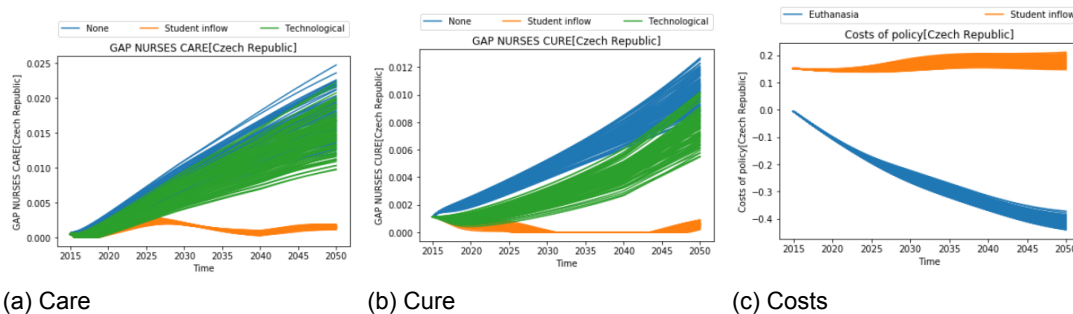


Figure 5.12: Results Czech Republic

The implementation of the technological-advancement-policy in the Czech Republic shows a minor difference compared to the implementation of no policies in the gap of the nurses in care. The gap when the technological-advancement-policy is implemented is lower for the needed nurses in cure.

The costs of the implementation of the additional-students-policy will be between 13% and 20% of the current total health expenditure, which is between the \$1.832.916.553 and \$2.819.871.621. However, if the euthanasia-policy will be implemented all the costs will be covered.

Denmark

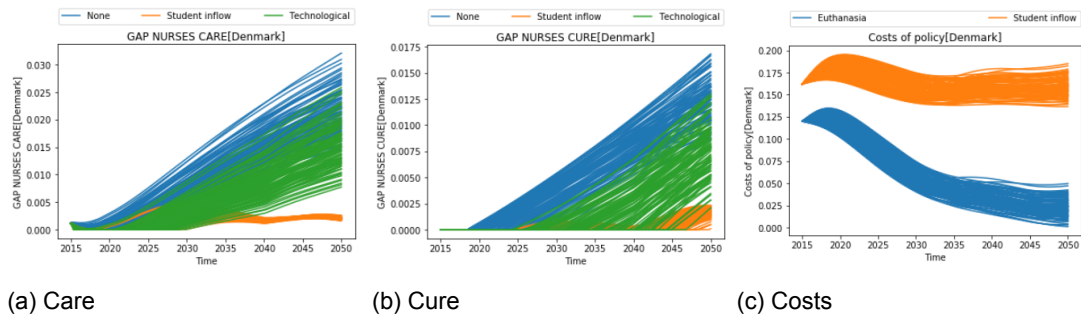


Figure 5.13: Results Denmark

Denmark shows a decrease in the gap of needed nurses in care when the technological-advancement-policies will be implemented. There is also a decrease of the gap in needed nurses in cure when the technological-advancement-polices will be implemented.

The costs of the implementation of the additional-students-policy differ between 15% and 18.5% of the current total health expenditure, which is between the \$4.741.943.017 and the \$5.848.396.388. When the euthanasia-policy will be implemented the costs will be reduced between the \$0 and the \$1.580.647.672.

Estonia

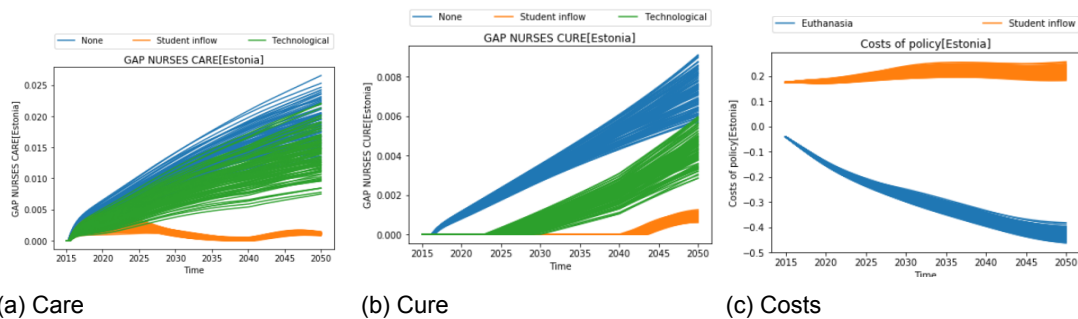


Figure 5.14: Results Estonia

The gap of needed nurses in care when the technological-advancement-policies is implemented is between the 0.8% (4200 vacancies) and 2% (10600 vacancies) as a fraction of the total workforce. The gap of needed nurses in cure is between the 0.3% (1590 vacancies) and the 0.6% (3200 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 19% and the 28% of the current total health care expenditures, which is between the \$286.290.005 and \$421.901.061. However, the implementation of the euthanasia-policy covers the salary costs entirely.

Finland

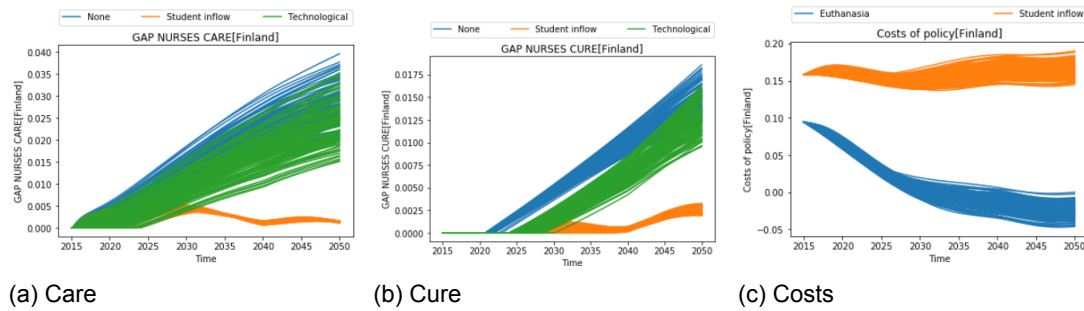


Figure 5.15: Results Finland

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 1% (22350 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.25% (5590 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 15% and the 18% of the current total health care expenditures, which is between the \$3.354.897.463 and the \$4.025.876.956. The implementation of the euthanasia-policy covers almost all the salary costs of the additional-students-policy.

France

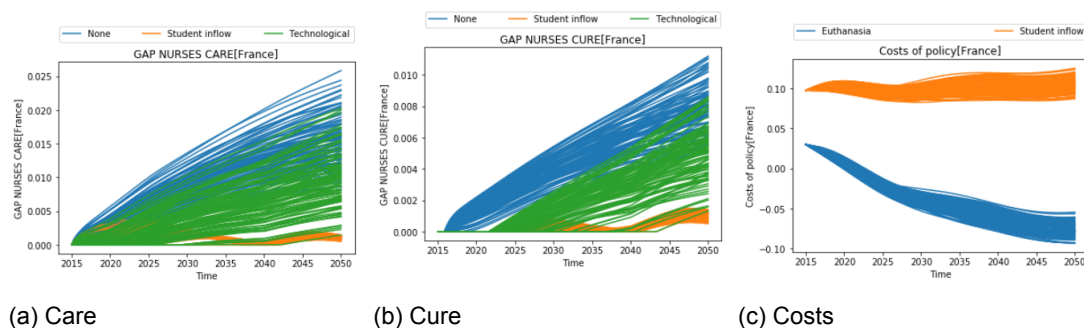


Figure 5.16: Results France

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.5% (137100 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.2% (54840 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 9% and the 14% of the current total health care expenditures, which is between the \$24.555.424.854 and the \$38.197.327.551. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Germany

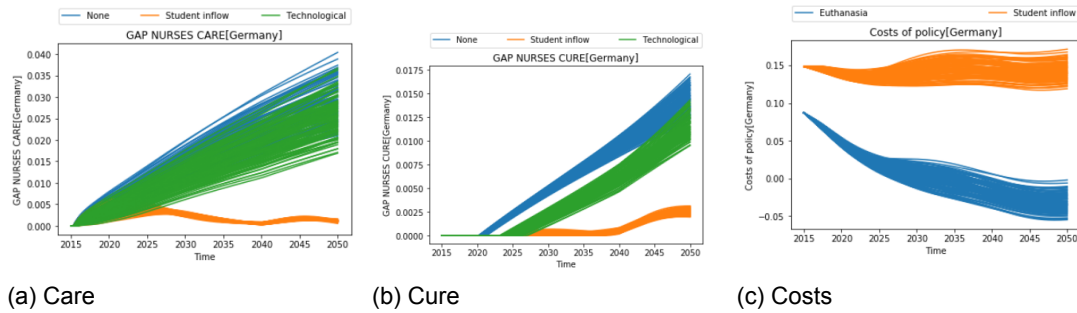


Figure 5.17: Results Germany

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.5% (141450 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.025% (70725 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 13% and the 17% of the current total health care expenditures, which is between the \$50.257.709.918 and the \$65.721.620.662. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Greece

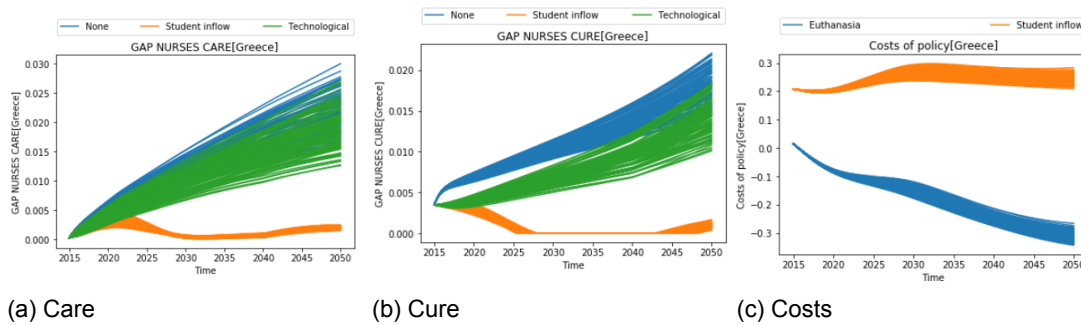


Figure 5.18: Results Greece

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.3% (10590 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.5% (17600 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 22% and the 29% of the current total health care expenditures, which is between the \$3.588.954.253 and the \$4.730.894.243. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Hungary

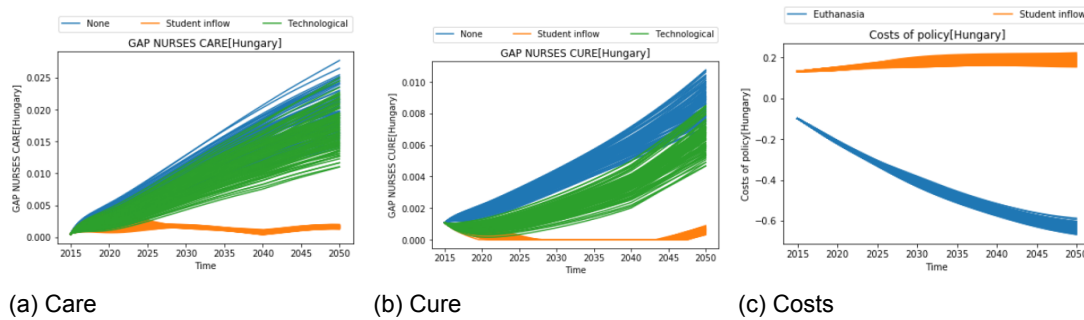


Figure 5.19: Results Hungary

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.3% (10100 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.2% (6800 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 15% and the 21% of the current total health care expenditures, which is between the \$1.349.643.227 and \$1.889.500.517. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Iceland

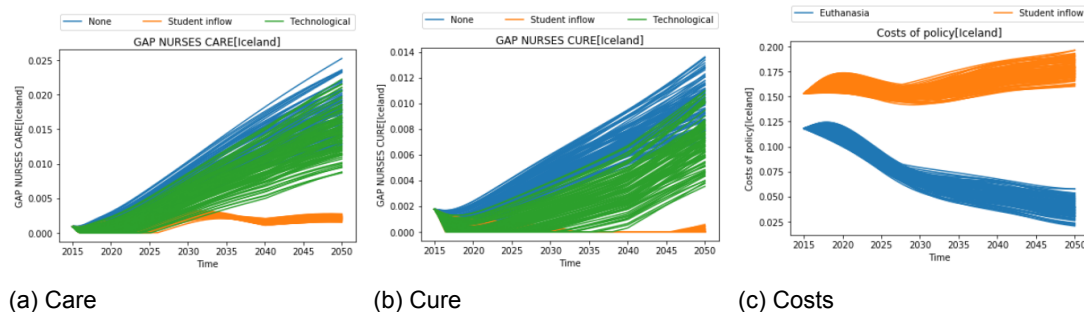


Figure 5.20: Results Iceland

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.3% (580 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.3% (580 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 15% and the 18% of the current total health care expenditures, which is between the \$258.886.766 and the \$310.664.119. The implementation of the euthanasia-policy covers almost all the salary costs of the additional-students-policy between 2.5% to 6% of the current total health expenditures, which is between the \$43.147.794 and the \$103.554.706.

Ireland

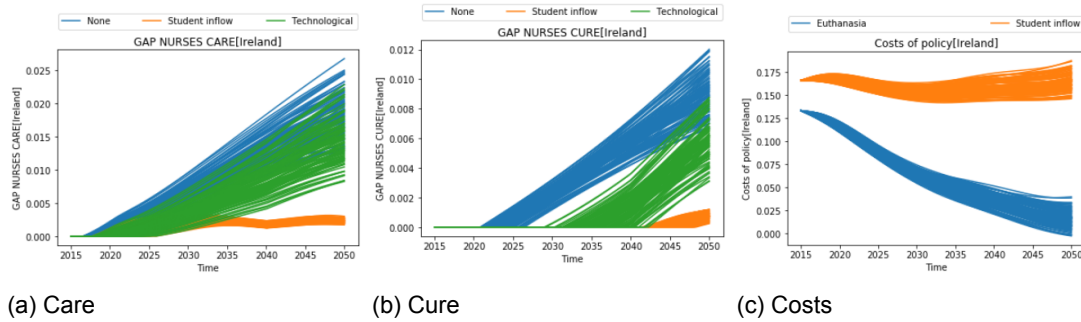


Figure 5.21: Results Ireland

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.2% (4400 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.4% (8800 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 15% and the 18% of the current total health care expenditures, which is between the \$3.423.419.958 and the \$4.108.103.949. The implementation of the euthanasia-policy covers almost all the salary costs of the additional-students-policy between 0% to 5% of the current total health expenditures, which is between the \$0 and the \$1.141.139.986.

Italy

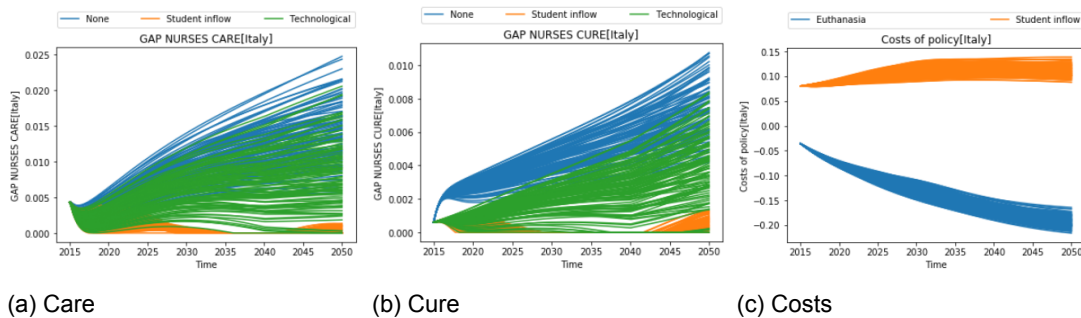


Figure 5.22: Results Italy

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.5% (83400 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.2% (33360 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 10% and the 14% of the current total health care expenditures, which is between the \$16.642.926.971 and the \$23.300.097.759. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Japan

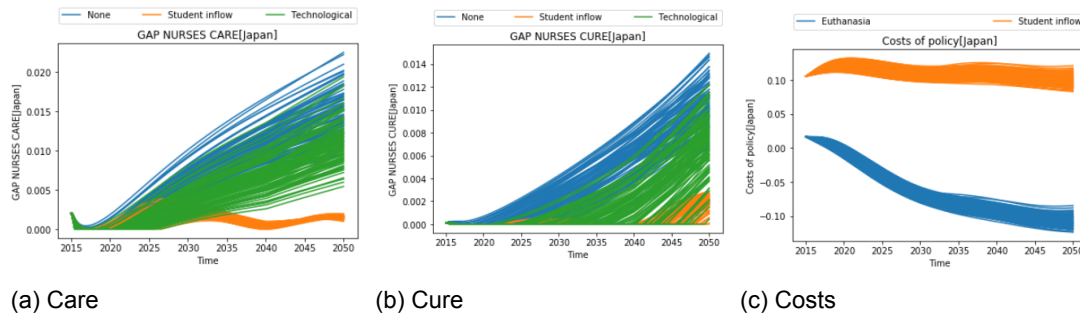


Figure 5.23: Results Japan

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.5% (207450 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.1% (41490 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 10% and the 14% of the current total health care expenditures, which is between the \$53.830.177.283 and the \$75.362.248.196. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Latvia

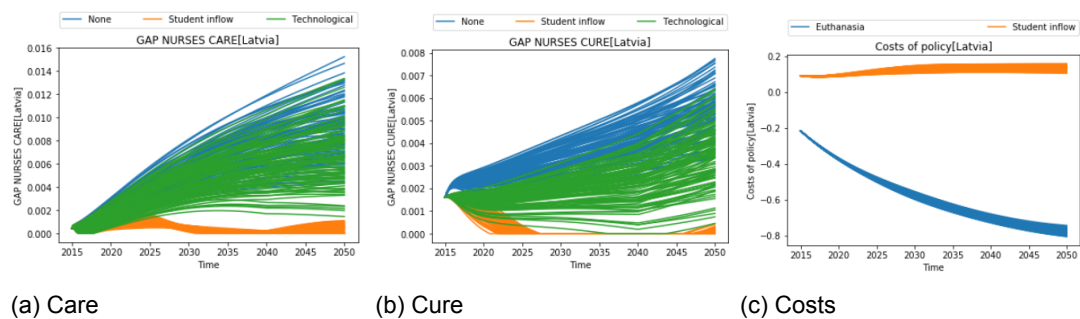


Figure 5.24: Results Latvia

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.1% (750 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.01% (75 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 12% and the 17% of the current total health care expenditures, which is between the \$191.326.017 and the \$271.045.190. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Luxembourg

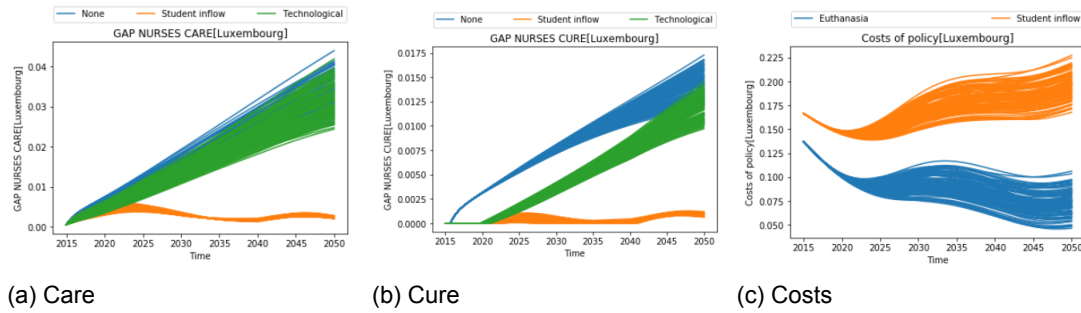


Figure 5.25: Results Luxembourg

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.4% (880 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.25% (550 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 16% and the 22.5% of the current total health care expenditures, which is between the \$580.077.938 and the \$815.734.600. The implementation of the euthanasia-policy covers almost all the salary costs of the additional-students-policy between 5% to 11% of the current total health expenditures, which is between the \$181.274.355 and the \$398.803.582.

Netherlands

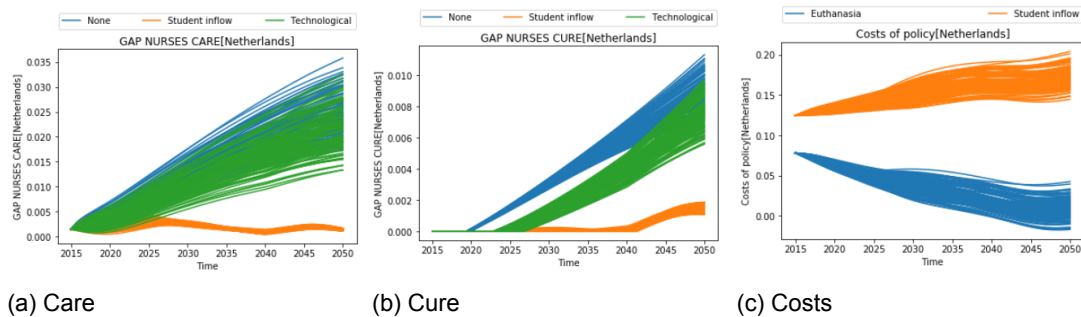


Figure 5.26: Results Netherlands

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.8% (58800 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.15% (11000 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 15% and the 20% of the current total health care expenditures, which is between the \$12.360.821.643 and the \$16.481.095.524. The implementation of the euthanasia-policy covers almost all the salary costs of the additional-students-policy between 0% to 5% of the current total health expenditures, which is between the \$0 and the \$4.120.273.881.

New Zealand

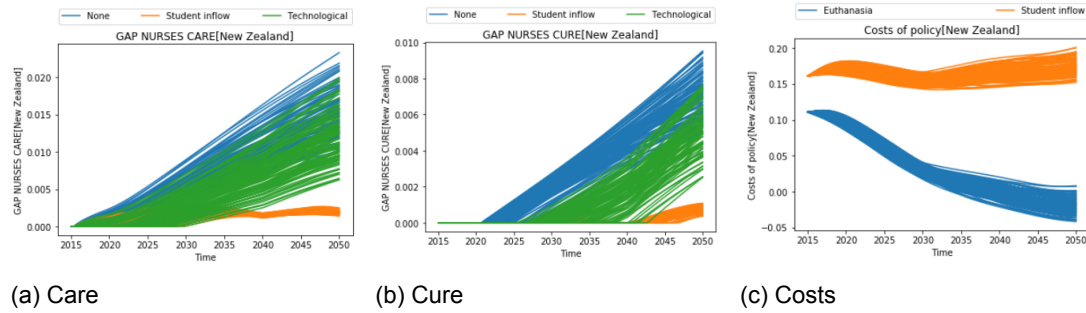


Figure 5.27: Results New Zealand

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.4% (9700 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.3% (7300 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 16% and the 20% of the current total health care expenditures, which is between the \$2.765.002.719 and the \$3.456.253.399. The implementation of the euthanasia-policy covers almost all the salary costs of the additional-students-policy between 0% to 2% of the current total health expenditures, which is between the \$0 and the \$345.625.339.

Norway

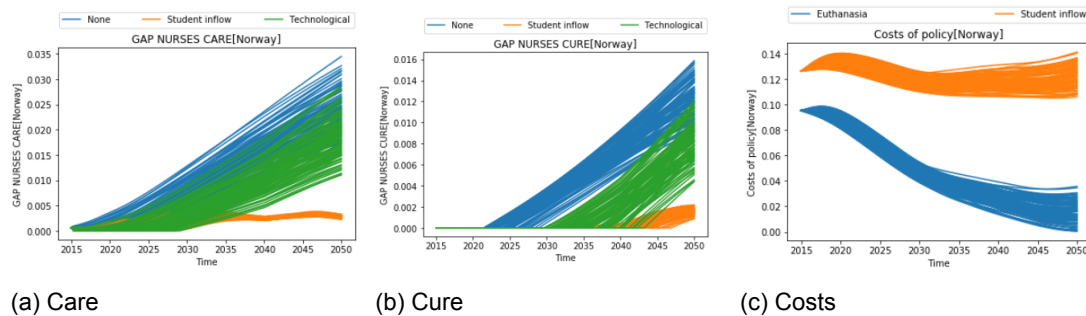


Figure 5.28: Results Norway

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.9% (21500 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.4% (9600 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 11% and the 14% of the current total health care expenditures, which is between the \$4.066.156.066 and \$5.175.107.721. The implementation of the euthanasia-policy covers almost all the salary costs of the additional-students-policy between 0% to 4% of the current total health expenditures, which is between the \$0 and the \$1.478.602.206.

Poland

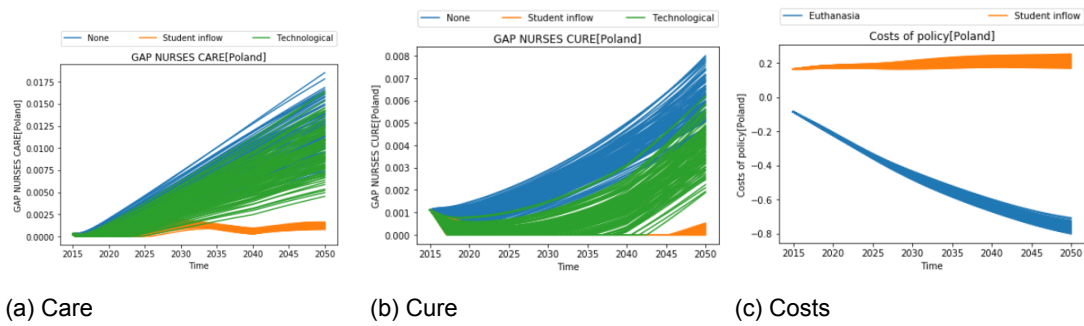


Figure 5.29: Results Poland

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.25% (33275 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.2% (26600 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 18% and the 21% of the current total health care expenditures, which is between the \$5.364.146.585 and the \$6.258.171.016. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Portugal

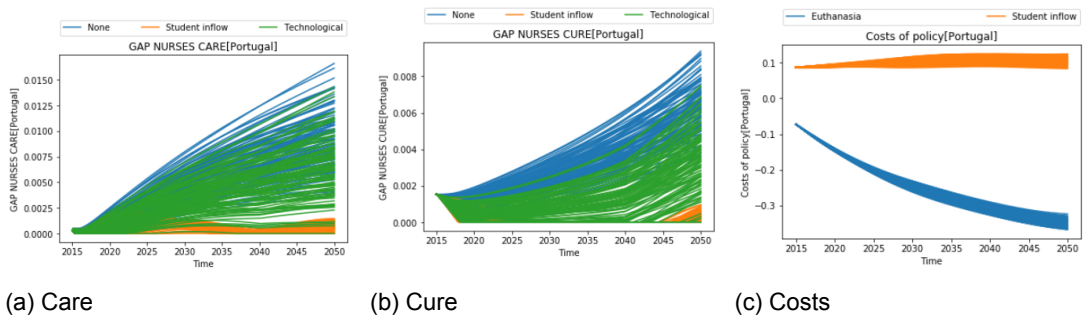


Figure 5.30: Results Portugal

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.25% (9060 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.2% (7250 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 9% and the 14% of the current total health care expenditures, which is between the \$1.651.888.191 and the \$2.569.603.853. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Slovak Republic

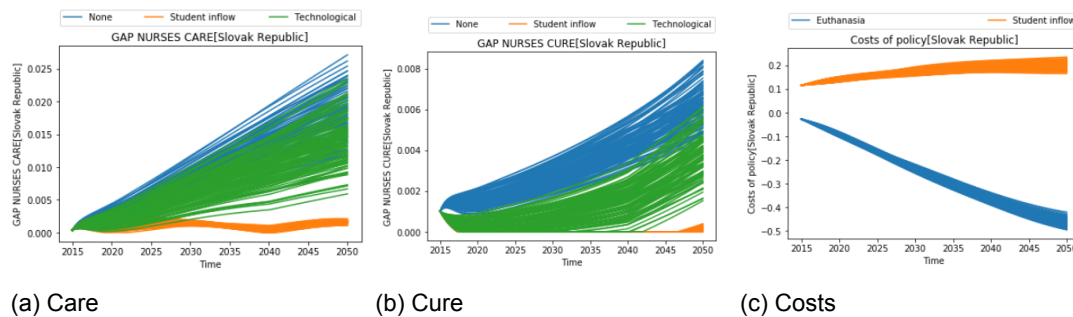


Figure 5.31: Results Slovak Republic

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.3% (6100 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.2% (4060 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 17% and the 22% of the current total health care expenditures, which is between the \$1.048.302.896 and the \$1.356.627.277. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Slovenia

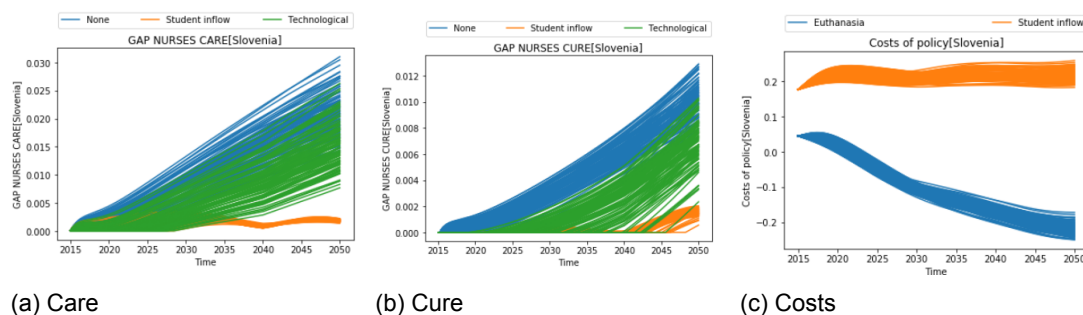


Figure 5.32: Results Slovenia

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.9% (6350 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.2% (1400 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 19% and the 24% of the current total health care expenditures, which is between the \$714.058.157 and the \$901.968.198. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Spain

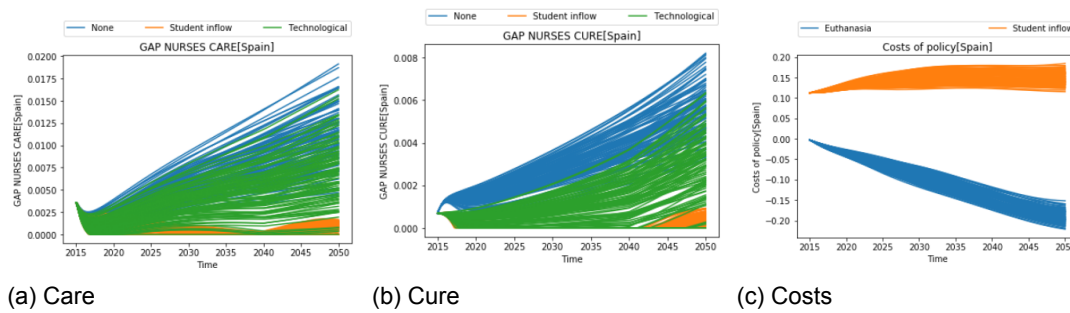


Figure 5.33: Results Spain

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.5% (81200 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.3% (48720 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 12.5% and the 17.5% of the current total health care expenditures, which is between the \$14.115.688.104 and the \$19.761.963.345. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Sweden

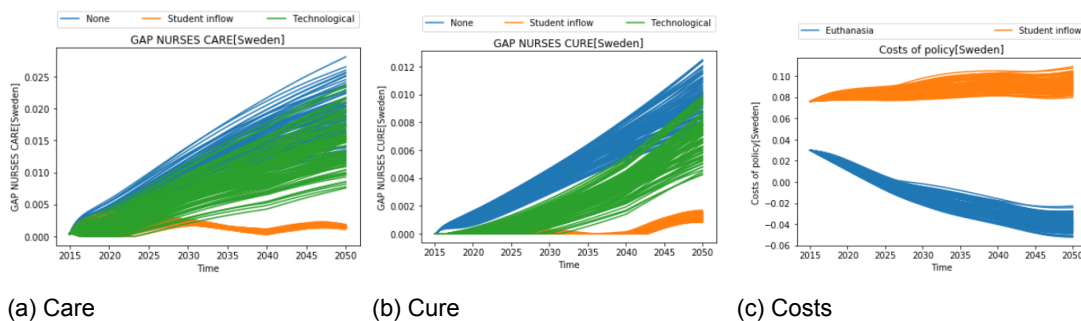


Figure 5.34: Results Sweden

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.4% (18300 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.2% (9150 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 8% and the 10% of the current total health care expenditures, which is between the \$4.501.732.530 and the \$5.627.165.663. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

Switzerland

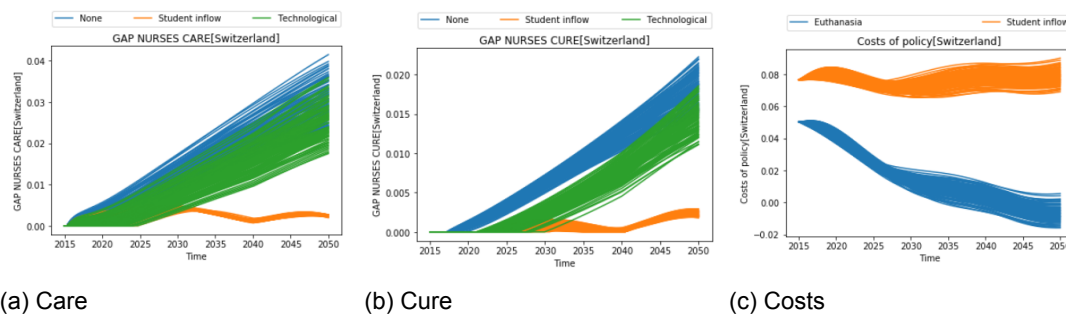


Figure 5.35: Results Switzerland

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.5% (17500 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.4% (14000 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 7% and the 9.5% of the current total health care expenditures, which is between the \$5.568.883.697 and the \$7.557.770.732. The implementation of the euthanasia-policy covers almost all the salary costs of the additional-students-policy between 0% to 1% of the current total health expenditures, which is between te \$0 and the \$795.554.813.

United Kingdom

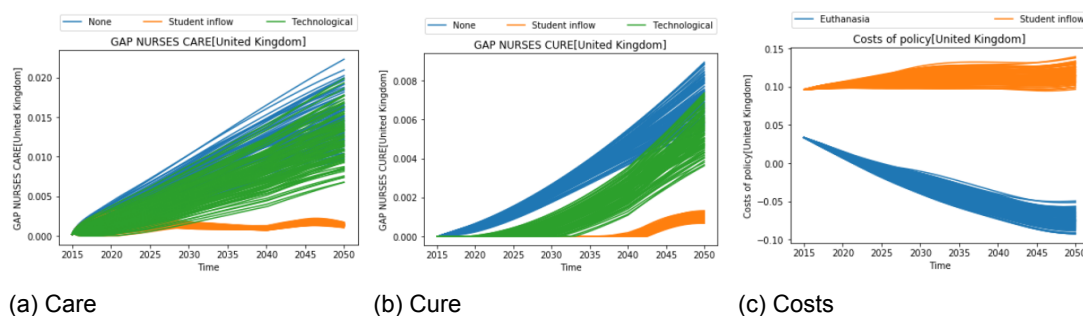


Figure 5.36: Results United Kingdom

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.2% (59280 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.1% (29640 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 10% and the 14% of the current total health care expenditures, which is between the \$25.866.137.162 and the \$36.212.592.027. The implementation of the euthanasia-policy covers all the salary costs of the additional-students-policy.

United States

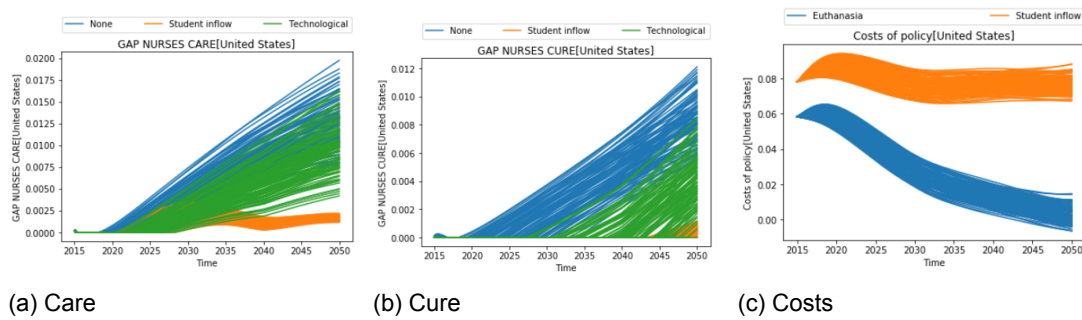


Figure 5.37: Results United States

The gap between no policies and the implementation of the technological-advancement-policy is for the needed nurses in care at least 0.5% (726500 vacancies) as a fraction of the total workforce and for the needed nurses in cure 0.4% (581200 vacancies) as a fraction of the total workforce.

The costs of the implementation of the additional-students-policy will increase between the 7% and the 9% of the current total health care expenditures, which is between the \$218.842.249.577 and the \$281.368.606.600. The implementation of the euthanasia-policy covers almost all the salary costs of the additional-students-policy between 0% to 2% of the current total health expenditures.

Conclusions and policy strategies

The conclusions based on the results of section 5 are presented in this chapter. The sub questions are answered in chapter 4, where after the model is built to answer the main research eventually.

6.1. Overall conclusions

The main research question was formulated as follows: *What is the effect and the future affordability of societal aging on the health care systems within OECD countries?*

6.1.1. Effect of societal aging on health care systems

The results of the base case imply that governments of the OECD-countries should take action to implement policies in order to solve the problems of societal aging. The results show that there will be a gap in **all** the countries of the OECD between the demand and the supply of nurses in care and cure. However, there is a major difference between the countries across the OECD.

The implementation of the eHealth-policy and the automation-policy shows a decrease of the gaps between the demand for health and the health supply, but these policies will **not** close the gap.

The implementation of the additional-students-policy is the most effective policy when governments want to close the gap between the health supply and the demand for health. All the countries across the OECD will decrease their gap under 0.5% of their total workforce. However, in order to fully close the gap of all the countries, the structure of the additional-students-policy should be changed.

The additional-students-policy decreases of the gap between the demand for health and the health supply, but it will increase the salary costs of **all** the countries across the OECD. Greece will face the highest salary costs of all the countries when the additional-students-policy is implemented as a fraction of the current total health expenditure. However, the implementation of the euthanasia-policy shows a major decline of the costs of the additional-students-policy.

6.1.2. Conclusions regarding to the research problem

The research problem is about the sustainability/affordability of health systems given the threat of societal aging. This research shows that **all** countries across the OECD are not sustainable regarding to the threat of societal aging. When the governments will not take action to solve the problems around societal aging, the health care systems are not able to supply health care to the people who will need it in the future. On the other hand, when the governments will invest to close the gap of nurses, the costs of health care will increase dramatically. All the countries will face a massive increase of the costs due the salaries of the 'extra' nurses. An **important** side note, the increase of the costs is only focused on the

salary costs, so other extra costs are not integrated. Overall, the costs of health care to solve the problems of societal aging will increase and countries are not able to afford these extra costs, because the increase of these costs are too big.

6.1.3. The impact of the results on the stakeholders involved

Public

The additional-students policy is an effective policy to solve the problems around societal aging. The impact of this policy will be severe on the public. People have to pay to cover the costs of this policy. It is possible that people will have to pay more taxes or that governments decide to cut other expenses, which will also affect the people.

Government

Governments have the difficult choice to determine what to do. On the one hand, they can choose to invest money and combat the problems surrounding societal aging. On the other hand, they can choose to invest less money and take the risk of lowering the quality of health care.

Health insurances

Health insurers have an advantage of implemented policies, because people stay healthy. Therefore health insurances have to spend less money to people in order to let them stay healthy.

Health care providers

The impact will be great for health care providers if the policies are implemented because people are needed to close the gap. As long as there are no people, because it is for example not attractive to work in health care, the work pressure will be high, which will lead to a reduction in productivity.

NGOs

The NGOs will benefit from the implementation of the policies, because these policies help to improve the lives of the elderly. They will encourage the government to implement these policies, so that the government will actually implement them.

Hospital administrators

Hospital administrators will look at what the future will bring, because they know that these policies require more people who are going to work in health care. If more people are needed, more space is needed to take care of these people. These possible problems were not included in this study.

6.2. Policy strategies

This section proposes the policy strategies for each country individually.

6.2.1. Australia

Almost 3% of the total work force should work extra in the health care and the health cure to close the gap of Australia. The implementation of the eHealth-policy and the automation-policy shows an decrease of the gap. The additional-students-policy will decrease the gap in Australia, however the additional costs of this implementation are high. The additional costs of this implementation will be around the 18% of the current total health expenditure. When the Australian government implement the euthanasia-policy, the costs will reduce with 15%. The first advice to the Australian government is to implement the technological advancements policies to increase the effective work of the nurses in Australia. Furthermore the Australian government should make trade-offs between the costs of health or the quality of health.

6.2.2. Austria

Austria shows a relative high total gap of the nurses compared to other OECD-countries, but shows a relative low decrease of the nurses in the health care when the technological advancement policies are implemented. Furthermore, the additional-students-policy shows an impressive decrease of the total gap and compared with the other countries, the additional costs of the policy will increase to around 10%, which is low compared to other countries. The euthanasia-policy will be effective in Austria, because the costs of the additional-students-policy is covered and the health expenditure will decrease to under 0% of the current total health expenditures. Therefore, based on these results, the advice is to implement the euthanasia-policy to cover the costs of the additional-students-policy.

6.2.3. Belgium

The implementation of the technological advancements policies have a relative high impact on the gap between the nurses in Belgium. It reduces the gap to almost 1% percent as a fraction of the total workforce. On the other hand the costs of health care will increase in Belgium to 15% to 20% of the current total health expenditure. The advice to the Belgium government is to first lower the salaries of the nurses or second to implement the euthanasia-policy, which reduces the costs. The government of Belgium should make the trade-offs between the quality of health and the costs of health care.

6.2.4. Canada

The government of Canada benefit when both policies will be implemented, but the costs will increase with almost 15% of the current total health expenditure. Therefore, the government of Canada should make the trade-offs between the quality of health and the costs of health care.

6.2.5. Czech Republic

The Czech Republic shows an average gap of their workforce compared to other countries. However the implementation of the technological advancement does not affect much. Therefore the first advice to the Czech Republican government to invest more in to eHealth and automation to affect the gap of nurses more. Furthermore, the additional-students-policy shows an decrease of the gap to 0.2% of the total workforce in Czech Republic, but the costs of the policy increases with around 20% of their current total health expenditure. The euthanasia-policy shows a perfect result, because their expenditure will decrease to under the 0% of their current total health expenditure.

6.2.6. Denmark

Denmark should focus on the implementation of the technological advancement policies, because the highest decrease of the gap when implementing this policy occurs in Denmark. Furthermore, Denmark should make the trade-off between the quality of health care and the costs of health care. The government of Denmark can implement the euthanasia-policy, but eventually it reduces the costs. So they can lower the remunerations of the nurses, they can increase the effectivity of the hospitals and elderly resident houses or they should implement robotics to replace the nurses.

6.2.7. Estonia

Estonia will face a high costs of health care when they implement the additional-students-policy, but when they implement the euthanasia-policy, the costs of health care will reduce. Therefore the euthanasia-policy is a highly effective policy to implement for Estonia.

6.2.8. Finland

The effect of the implementation of the technological advancement will decrease the gap in Finland and implementing the additional-students-policy shows another decrease of the gap in Finland. However the health care costs increase to almost between the 15% and 20% of their current total health expenditure. The euthanasia-policy will be effective, because it will

cover all the costs. The government should therefore make the trade off between the health care costs and the health quality.

6.2.9. France

The government of France benefits when the technological advancement policies will be implemented. Furthermore, the costs of implementation of the additional-students-policy will raise the health care expenditures dramatically. An option is to implement the euthanasia-policy, but it still shows an increase of the costs. Additional policies to lower the costs are needed in France to overcome the problems of societal aging.

6.2.10. Germany

The German government will face a high gap of the nurses when they will not implement policies to overcome the problems. Implementing the technological advancements policies are effective, but compared to other countries, they can increase the impact of these policies more. Furthermore, the German government should make the trade off between the costs of health care and the quality of health.

6.2.11. Greece

The implementation of the technological advancement policies are effective for the population in Greece. The gap of needed nurses decreases. Furthermore, Greece should implement the additional-students-policy to reduce the gap. But the health care costs will increase to around 25%% in 2050. The euthanasia-policy will be very effective costs-wise in Greece, because it covers the costs of the policy implementation.

6.2.12. Hungary

The government of Hungary should implement the technological advancement policies and the additional-students-policy in order to close the gap of the nurses. However the health care costs of implementing the additional-students-policy will increase to 20%. The euthanasia-policy shows a major decrease of the costs in health care and it reduces the health care costs eventually.

6.2.13. Iceland

The health care costs will increase with almost 20%, when the additional-students-policy will be implemented. Furthermore, the euthanasia-policy does not cover all the costs of the policy. The advice to the government in Iceland is to make a trade off between the health care quality and the health care costs.

6.2.14. Ireland

The costs of implementing the additional-students-policy show a major increase in the health expenditures in Ireland. Furthermore, the euthanasia-policy does not cover all the costs of the policy. Therefore the government of Ireland should think of additional policies to reduce the costs or should think about the trade off between the health quality and health care costs.

6.2.15. Italy

The gap of Italy is relative small compared to other countries. Furthermore the implementation of the technological advancement policies have a large impact on the gap. Even the implementation of the additional-students-policy shows a fully closing of the gap of the nurses in the health care in 2050 and a minor gap of the nurses in the health cure. Furthermore, the costs of these policy are relative 'cheap' compared to the other countries. The government of Italy should therefore think about of implementing fully this policy to maintain the quality of care.

6.2.16. Japan

Compared to other countries, the gap of nurses, after implementing the additional-students-policy, is relative high, but the reducing costs of implementation the euthanasia-policy show

an almost coverage of the costs of the additional-students-policy.

6.2.17. Latvia

Latvia has the lowest gap of nurses of all the countries in all the countries. The government of Latvia should implement all the policies to close the gap. The costs will be fully covered with the euthanasia-policy and it will also reduce the health care costs.

6.2.18. Luxembourg

The government of Luxembourg should focus on the implementation of the technological advancement policies, because the impact of these policies are compared to other countries low. However, the implementation of closing the gap has the highest impact on Luxembourg. In order to close the gap, the implementation of the additional-students-policy is needed, on the other side the costs of the implementation are high. The health care expenditures will increase with almost 20% of their current total health expenditure.

6.2.19. Netherlands

The Netherlands will face after the implementation of the additional-students-policy a gap of 0.14%. However the costs of the implementation are high. The health care expenditures will increase between the 15% and 20% of the current total health expenditures, when the Netherlands will implement these policies. On the other side, the extra salary costs will decrease when the euthanasia-policy will be implemented. When the government of the Netherlands will implement the additional-students-policy to overcome the problems of societal aging, they have to think about how to pay for these implementations.

6.2.20. New Zealand

The costs of implementation of the additional-students-policy are with an increase between the 15% and 20% in New Zealand. The government of New Zealand should think about the trade off between the quality of care and the costs of care.

6.2.21. Norway

The costs of the implementation of the additional-students-policy are compared to other countries low. The increase of costs is around 13% of their current total health expenditures. However implementing the euthanasia-policy will decrease the costs. The government of Norway should therefore make the trade off between the quality of health care and the health care costs.

6.2.22. Poland

Poland will face after the implementation of the additional-students-policy a gap of 0.14% as a fraction of the total workforce. However the costs of the implementation are high. The health care expenditures will increase with 20% when they implement these policies. On the other side, the health care costs will decrease to when the euthanasia-policy will be implemented.

6.2.23. Portugal

Portugal will face an increase of health care costs of 11% as a fraction of the current total health expenditure. However, the euthanasia-policy decreases the overall health care costs in 2050. The government of Portugal should implement both policies to survive the problems around societal aging.

6.2.24. Slovak Republic

The costs of implementation of the additional-students-policy show an increase of 36% in Slovak Republic. The government of Slovak Republic should make a trade off between the health care costs and the health care quality.

6.2.25. Slovenia

The additional costs of Slovenia are almost 22% of their current total health care expenditure. However, implementing the euthanasia-policy will cover the costs of the implementation of the additional-students-policy.

6.2.26. Spain

The health expenditure will increase while implementing the additional-students-policy in Spain. However, the euthanasia-policy will cover the additional health expenditures.

6.2.27. Sweden

Sweden will face a low increase of their health care expenditures when the government will implement the additional-students-policy. So the government of Sweden can make a trade off pay less to the people in the health care and save the money to invest in technology in the health care.

6.2.28. Switzerland

Switzerland will face with increasing health care costs, but it is lower compared to other countries. When the euthanasia-policy will be implemented the costs of the implementation will be almost covered.

6.2.29. United Kingdom

The health care costs will increase between the 10% and 15% when the additional-students-policy will be implemented. Furthermore, the costs to cover the additional-students-policy will be covered when the euthanasia-policy will be implemented.

6.2.30. United States

The costs of health care of implementing the additional-students-policy will increase with around 8% as a fraction of the current total health expenditure. The government of the United States should make the trade off of fully close the gap of the nurses in the country or to invest less money in their health care systems.

Ethics and societal aging

This section shows the ethical reflection on the results and the conclusions of this research. The ethical reflection is used on the basis of three dilemmas.

7.1. Dilemma 1: Affordability of community versus common health

The results and conclusions show that a lot of money is needed to solve the problems around societal aging. In this study, only the costs of the salaries are determined and not even other costs. The first dilemma arises is that governments have to choose to invest a lot of money in care to solve societal aging or to invest less money and to accept the consequences. Is the community willing to pay the price of societal aging?

The stakeholder map in section 4.1 shows that the public has a high interest in the decision-making process regarding to societal aging. A lot of money is needed, when governments will implement the additional-students-policy. Two ways to make money available for health care is to shorten money on other expenses or to increase taxes. The public will be affected in both ways. When the government will shorten on other expenses, for example on education, the costs of education will increase for the public or the quality of education decreases. Furthermore, if the taxes increase, the public has to pay more.

However, when the public is not able to pay for societal aging, the quality of health care decreases. This means that not everyone gets the care they need.

The government is the key player in the decision-making process. The government determines the rules, laws and amount of taxes. When governments decide to increase the amount of taxes, the public has to pay more. On the other side when the affordability of the community is not enough, the government is not able to pay the salaries of the nurses.

The dilemma for governments is whether to choose for health care and to make sacrifices elsewhere or to leave the elderly to their fate. The question is whether that is morally justified.

7.2. Dilemma 2: Affordability as an individual versus right to live

The second dilemma is the interaction between the affordability as an individual and the right to live.

Another possibility for the government is to let everyone pay individually for their own care instead of solving the problem collectively. This means poor people are not able to pay for care. The right to live is basically predestined for the rich people.

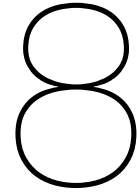
Is it morally justified when only the rich people can pay the price?

Basically, governments are responsible for their people and everybody has the right to get health care. That is why governments will have to ensure that the price of care remains affordable for everyone.

7.3. Dilemma 3: Affordability of community versus living through as an individual with dementia

Another policy, in this study, to cover the costs is to have all people with dementia commit euthanasia. This is an effective tool of covering at least the salary costs in all countries. However, this is ethically very irresponsible, because as a government you impose the rule to kill if someone suffers from a disease. Moreover, it is a very aggressive measure to reduce costs. As a person you are used as a tool of payment to solve another problem in society. In addition, it can be a very distressing situation for family members when a relative suffers dementia, because the person has to commit euthanasia. As a reaction to this inhumane prospect, family members will remain silent if someone close to them suffers from dementia.

This research does show that such measures have a positive effect on the outcomes, but that it is ethically very irresponsible to implement it as government. Governments will have to think about other measures to reduce the costs of aging.



Discussion & future research

The discussion in this chapter discuss first the results. Second this chapter reflects the model and third it reflects the data used in this research.

8.1. Discussion

8.1.1. Results

One interesting finding is the impact of the implementation of the technological-advancement-policies. The current study found that the impact of these policies are not effective in each scenario given the large uncertainty of the future. Another important finding was that the salary costs of the extra needed nurses are high for all the countries. An average of 15.20% across all the OECD-countries of salary costs of the current total health expenditure is high. Furthermore, additional costs such as education have not yet been included. The most interesting finding was that countries with a high aging population such as Japan and the Netherlands are not affected the most by the policies.

8.1.2. Reflection of the model

The model used in this study can be improved in different ways.

The first major improvement of the model is to implement multi-scalability. This means that the countries interact with each other in the model itself. The model used in this study works for each country on its own and not with each other.

Another improvement of the model is the use of assumptions in the model. Various assumptions have been made to simulate the model. Without these assumptions, the uncertainty in the model will decrease and the results will become more certain.

8.1.3. Data

The data used in this research is gathered from different data sources. The consistency between these data sources leaves much to be desired. Recent data is not always available and in many cases data was not available. The lack of data could have a major influence on the model behavior. To improve the data acquisition, other databases can be used. National statistics of countries can be gathered in order to find more and better data.

8.2. Future research

8.2.1. Model recommendations

Population model

The following recommendations to the model can be added in the future.

- Add 1 year age cohorts in the subscripts
- Add the sex ratio of the population, to conduct the fertile population more precisely

- Add a dynamic birth rate, based on the economic growth
- Add a dynamic death rate, based on country specific data.
- The migration rate changes over time. The migration rate can be conducted with adding political and demographic factors.
- In order to compute the life expectancy more precise, the effects of fruit and vegetable consumption, use of illicit drugs among adults and the effects of air pollution can be added to the model.
- Compute the health expenditure better than only using the ratio of elderly to the population as an indicator.

Health demand model

The current health demand is based on the average relative productivity of the countries. A future recommendation is to add a health productivity function to compute the work pressure in the health work force.

Health supply model

A future recommendation for the health supply is to study the distribution of nurses over the age groups in the countries. The aging structure in the health supply model will be more accurate in this way.

8.2.2. Data handling

Comparison of different data sources

A future recommendation is to compare the data from the databases. The CIA-factbook, the World Data Bank, the OECD and the National Statistics have the same kind of data, but sometimes the interpretation of the data is contrasting. Therefore, different simulations can be performed in order to show the difference in data and show the effect of this difference on the model.

Historical data research

In the model several growth constants are used. As a future recommendation, a historical trend analysis can be executed. The historical trend analysis shows the historic trend and determines the growth or decline rate for each country.

Furthermore, a historical trend analysis could analyze why some historical data behaves because of certain events in the past. This could be very useful in a system dynamics model, because relations between events become more clear. Therefore, the effect of different events could be simulated in the future.

Interactive dashboard as visualization

In order to solve the problems regarding to the visualization of the results, an interactive dashboard can be made. This interactive dashboard is able to show heat maps of problems over time in different countries. It is also easier to visually show the impact of the different policies over time in each country.

8.2.3. Policy recommendations

Implementation the impact of other policies

In this research different policies have been tested. However, these policies are implemented in a simple way. Future recommendations regarding to these policies is to link the technological advancements with the technological growth of a country.

Other policies can be implemented as well in the future. For example the policy to implement is to decentralize health care. This policy focuses on having the specialized health care units moving to one place. In addition to this policy, privatization as decentralization strategy can be implemented. The system is therefore able to analyze the impact of privatization in health care.

Another policy could be invest in health care labor platforms. Health care labor platforms combine health supply and health demand. The disruptive characteristics of these labor platforms will have an impact on the health supply within the health care systems. People who need care can use these health care labor platforms to find health care 'on-demand'. The benefits of these platforms are the increase of utilization, because the use of smart algorithms decreases the gap between health supply and health demand.

Another technological advancement is the implementation of robots in nursing homes and hospitals. Robots are able to take over activities of the nurses. Hypothetically, if the number of nurses in a country stays the same and the implementation of robots is executed, extra FTE in the health supply will be generated.

The last technological advancement is that computers are able to predict when patients die, using deep learning (Rajkomar et al., 2018). If the moment of death of patients can be determined, choices to provide or not to provide care can be made to cut health care costs .

9

Future research

9.1. Model recommendations

9.1.1. Population model

The following recommendations to the model can be added in the future.

- Add 1 year age cohorts in the subscripts
- Add the sex ratio of the population, to conduct the fertile population more precisely
- Add a dynamic birth rate, based on the economic growth
- Add a dynamic death rate, based on country specific data.
- The migration rate changes over time. The migration rate can be conducted with adding political and demographic factors.
- In order to compute the life expectancy more precise, the effects of fruit and vegetable consumption, use of illicit drugs among adults and the effects of air pollution can be added to the model.
- Compute the health expenditure better than only using the ratio of elderly to the population as an indicator.

9.1.2. Health demand model

The current health demand is based on the average relative productivity of the countries. A future recommendation is to add a health productivity function to compute the work pressure in the health work force.

9.1.3. Health supply model

A future recommendation for the health supply is to study the distribution of nurses over the age groups in the countries. The aging structure in the health supply model will be more accurate in this way.

9.1.4. Data handling

Comparison of different data sources

A future recommendation is to compare the data from the databases. The CIA-factbook, the World Data Bank, the OECD and the National Statistics have the same kind of data, but sometimes the interpretation of the data is contrasting. Therefore, different simulations can be performed in order to show the difference in data and show the effect of this difference on the model.

Historical data research

In the model several growth constants are used. As a future recommendation, a historical trend analysis can be executed. The historical trend analysis shows the historic trend and determines the growth or decline rate for each country.

Furthermore, a historical trend analysis could analyze why some historical data behaves because of certain events in the past. This could be very useful in a system dynamics model, because relations between events become more clear. Therefore, the effect of different events could be simulated in the future.

Interactive dashboard as visualization

In order to solve the problems regarding to the visualization of the results, an interactive dashboard can be made. This interactive dashboard is able to show heat maps of problems over time in different countries. It is also easier to visually show the impact of the different different policies over time in each country.

9.1.5. Policy recommendations

Implementation the impact of other policies

In this research different policies have been tested. However, these policies are implemented in a simple way. Future recommendations regarding to these policies is to link the technological advancements with the technological growth of a country.

Other policies can be implemented as well in the future. For example the policy to implement is to decentralize health care. This policy focuses on having the specialized health care units moving to one place. In addition to this policy, privatization as decentralization strategy can be implemented. The system is therefore able to analyze the impact of privatization in health care.

Another policy could be invest in health care labor platforms. Health care labor platforms combine health supply and health demand. The disruptive characteristics of these labor platforms will have an impact on the health supply within the health care systems. People who need care can use these health care labor platforms to find health care 'on-demand'. The benefits of these platforms are the increase of utilization, because the use of smart algorithms decreases the gap between health supply and health demand.

Another technological advancement is the implementation of robots in nursing homes and hospitals. Robots are able to take over activities of the nurses. Hypothetically, if the number of nurses in a country stays the same and the implementation of robots is executed, extra FTE in the health supply will be generated.

The last technological advancement is that computers are able to predict when patients die, using deep learning (Rajkomar et al., 2018). If the moment of death of patients can be determined, choices to provide or not to provide care can be made to cut health care costs .

Bibliography

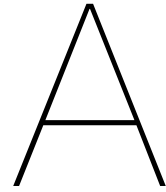
- Alzheimer's Association (2018). Planning for care costs. Retrieved from <https://www.alz.org/help-support/caregiving/financial-legal-planning/planning-for-care-costs>. Latest accessed on September 26, 2018.
- Angelis, A., Tordrup, D., and Kanavos, P. (2017). Is the funding of public national health systems sustainable over the long term? evidence from eight oecd countries. *Global Policy*, 8(S2):7–22.
- ANP/Redactie (2018). 'groot personeelstekort in de zorg: ruim 120.000 vacatures'. Retrieved from https://www.ad.nl/gezond/groot-personeelstekort-in-de-zorg-ruim-120-000-vacatures_a7a30bc0/. Latest accessed on September 26, 2018.
- Auping, W. L., Pruyt, E., and Kwakkel, J. H. (2015). Societal ageing in the netherlands: a robust system dynamics approach. *Systems Research and Behavioral Science*, 32(4):485–501.
- Bankes, S. (1993). Exploratory modeling for policy analysis. *Operations Research*, 41(3):435–449. Retrieved from <http://www.jstor.org/stable/171847>. Latest accessed on September 26, 2018.
- Benenson, I., Omer, I., and Hatna, E. (2002). Entity-based modeling of urban residential dynamics: the case of yaffo, tel aviv. *Environment and Planning B: Planning and Design*, 29(4):491–512.
- Bloom, D. E., Boersch-Supan, A., McGee, P., Seike, A., et al. (2011). Population aging: facts, challenges, and responses. *Benefits and compensation International*, 41(1):22.
- Burke, R. J., Cooper, C. L., and Field, J. (2013). The aging workforce: Individual, organizational and societal opportunities and challenges. *The SAGE handbook of aging, work and society*, pages 1–20.
- Central Intelligence Agency (2018). The world factbook 2018. Retrieved from <https://www.cia.gov/library/publications/the-world-factbook/index.html>. Latest accessed on September 26, 2018.
- Colombo, F. and Tapay, N. (2004). Private health insurance in oecd countries.
- Eggink, E., Verbeek-Oudijk, D., Woittiez, I. B., and Ross, J. A. (2010). *Zorgen voor Zorg: ramingen van de vraag naar personeel in de verpleging en verzorging tot 2030*. Sociaal en Cultureel Planbureau.
- Eurostat (2018). Activity rates by sex, age and country of birth. Retrieved from http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lfsa_argacob&lang=en. Latest accessed on September 26, 2018.
- Forrester, J. W. (1997). Industrial dynamics. *Journal of the Operational Research Society*, 48(10):1037–1041.
- Francesca, C., Ana, L.-N., Jérôme, M., and Frits, T. (2011). *OECD health policy studies help wanted? Providing and paying for long-term care: providing and paying for long-term care*, volume 2011. OECD Publishing.
- George, G., Howard-Grenville, J., Joshi, A., and Tihanyi, L. (2016). Understanding and tackling societal grand challenges through management research. *Academy of Management Journal*, 59(6):1880.

- Gompertz, B. (1833). On the nature of the function expressive of the law of human mortality, and on a new mode of determining the value of life contingencies. in a letter to Francis Baily, Esq. FRS &c. by Benjamin Gompertz, Esq. FRS. In *Abstracts of the Papers Printed in the Philosophical Transactions of the Royal Society of London*, volume 2, pages 252–253. The Royal Society.
- Grigoroudis, E. and Phillis, Y. A. (2013). Modeling healthcare system-of-systems: a mathematical programming approach. *IEEE Systems Journal*, 7(4):571–580.
- Harper, S. (2014). Economic and social implications of aging societies. *Science*, 346(6209):587–591.
- Health Careers Center (2018). Health care administrator. Retrieved from <http://www.mshealthcareers.com/careers/healthcareadmin.htm>. Latest accessed on September 26, 2018.
- HelpAge International (2018). Our vision and strategy | about us | helpage international. Retrieved from <http://www.helpage.org/who-we-are/our-values-and-ambitions/>. Latest accessed on September 26, 2018.
- Hussem, A., Van Ewijk, C., Ter Rele, H., and Wong, A. (2016). The ability to pay for long-term care in the Netherlands: a life-cycle perspective. *De Economist*, 164(2):209–234.
- IFA (2018). About ifa. Retrieved from <https://www.ifa-fiv.org/about/>. Latest accessed on September 26, 2018.
- Jensen, A., Thuesen, C., Müller, R., Andersen, E. S., Kvalnes, Ø., Shao, J., Sankaran, S., and Turner, J. (2014). Stakeholders' attributes, behaviors, and decision-making strategies in construction projects. *Decision Making*.
- Kenney, J. and Keeping, E. (1962). Mathematics of statistics. *Mathematics of Statistics*, 3:102–103.
- Kwakkel, J. (2018). Ema workbench documentatio. Retrieved from <https://emaworkbench.readthedocs.io/en/latest/>. Latest accessed on October 17, 2018.
- Marmot, M. (2005). Social determinants of health inequalities. *The Lancet*, 365(9464):1099–1104.
- Melrose, J., Perroy, R., and Careas, S. (2015). World population prospects: The 2015 revision, key findings and advance tables.
- Ministerie van Volksgezondheid, Welzijn en Sport (2018a). Extramurale zorg | monitor langdurige zorg. Retrieved from <https://www.monitorlangdurigezorg.nl/overmlz/begrippen/extramurale-zorg>. Latest accessed on September 26, 2018.
- Ministerie van Volksgezondheid, Welzijn en Sport (2018b). Intramurale zorg | monitor langdurige zorg. Retrieved from <https://www.monitorlangdurigezorg.nl/overmlz/begrippen/intramurale-zorg>. Latest accessed on September 26, 2018.
- Niccoli, T. and Partridge, L. (2012). Ageing as a risk factor for disease. *Current Biology*, 22(17):R741–R752.
- Nursestation (2018). Verpleegkundige besteedt 39nursestation. Retrieved from <https://www.nursestation.nl/magazine/nieuws/verpleegkundige-besteedt-39-tot-49-van-tijd-aan-administratie>. Latest accessed on September 26, 2018.
- OECD (2011). *Health reform: meeting the challenge of ageing and multiple morbidities*. OECD Publishing. Retrieved from <http://www.oecd.org/els/health-systems/meeting-the-challenge-of-ageing-and-multiple-morbidities.htm>. Latest accessed on September 26, 2018.

- OECD (2016). Ageing and employment policies - statistics on average effective age of retirement - oecd. Retrieved from <http://www.oecd.org/els/emp/average-effective-age-of-retirement.htm>. Latest accessed on September 26, 2018.
- OECD (2017a). Government at a glance 2017. Retrieved from <http://www.oecd.org/gov/govataglance.htm>. Latest accessed on September 26, 2018.
- OECD (2017b). Health at a glance 2017. Retrieved from https://www.oecd-ilibrary.org/content/publication/health_glance-2017-en. Latest accessed on September 26, 2018.
- OECD (2018). About the oecd - oecd. Retrieved from <http://www.oecd.org/about/>. Latest accessed on September 26, 2018.
- OECD Data (2017). Prevalence of dementia across all oecd countries by age group (indicator). Retrieved from http://dx.doi.org/10.1787/health_glance-2017-76-en. Latest accessed on September 26, 2018.
- OECD Data (2018a). Alcohol consumption (indicator). Retrieved from <https://data.oecd.org/healthrisk/alcohol-consumption.htm>. Latest accessed on September 26, 2018.
- OECD Data (2018b). Doctors (indicator). Retrieved from <https://data.oecd.org/healthres/doctors.htm>. Latest accessed on September 26, 2018.
- OECD Data (2018c). Graduation rates and entry rates (indicator). Retrieved from https://stats.oecd.org/Index.aspx?DataSetCode=EAG_GRAD_ENTR_RATES. Latest accessed on September 26, 2018.
- OECD Data (2018d). Health spending (indicator). Retrieved from <https://data.oecd.org/healthres/health-spending.htm>. Latest accessed on September 26, 2018.
- OECD Data (2018e). Ict value added (indicator). Retrieved from <https://data.oecd.org/ict/ict-value-added.htm>. Latest accessed on September 26, 2018.
- OECD Data (2018f). Nurses (indicator). Retrieved from <https://data.oecd.org/healthres/nurses.htm>. Latest accessed on September 26, 2018.
- OECD Data (2018g). Overweight or obese population (indicator). Retrieved from <https://data.oecd.org/healthrisk/overweight-or-obese-population.htm>. Latest accessed on September 26, 2018.
- OECD Data (2018h). Term care resources and utilization (indicator). Retrieved from https://stats.oecd.org/Index.aspx?DataSetCode=HEALTH_LTCR. Latest accessed on September 26, 2018.
- OECD, Trends Shaping Education (2008). Chapter 1, ageing oecd societies. Retrieved from <https://www.oecd.org/berlin/41250023.pdf>. Latest accessed on September 26, 2018.
- Pammolli, F., Riccaboni, M., and Magazzini, L. (2012). The sustainability of european health care systems: beyond income and aging. *The European Journal of Health Economics*, 13(5):623–634.
- Pruyt, E., Logtens, T., and Gijsbers, G. (2012). Societal aging in the netherlands: exploratory system dynamics modeling and analysis. In *Proceedings of the 30th International Conference of the System Dynamics Society, St. Gallen, Switzerland, 22-26 July 2012*. System Dynamics Society.

- Rajkomar, A., Oren, E., Chen, K., Dai, A. M., Hajaj, N., Hardt, M., Liu, P. J., Liu, X., Marcus, J., Sun, M., et al. (2018). Scalable and accurate deep learning with electronic health records. *npj Digital Medicine*, 1(1):18.
- Rosenberg, P., Ross, A., and Garçon, L. (2013). Who global forum on innovations for ageing populations. In *Kobe, Japan*.
- Schoenman, A. and Chockley, N. (2017). The concentration of health care spending—nihcm foundation data brief july 2012.
- Shields, P. M. and Rangarajan, N. (2013). *A playbook for research methods: Integrating conceptual frameworks and project management*. New Forums Press.
- Simoens, S., Villeneuve, M., and Hurst, J. (2005). Tackling nurse shortages in oecd countries. oecd health working papers, no. 19. *OECD Publishing (NJ1)*.
- Sorenson, C., Drummond, M., and Khan, B. B. (2013). Medical technology as a key driver of rising health expenditure: disentangling the relationship. *ClinicoEconomics and outcomes research: CEOR*, 5:223.
- United Nations (2017a). World population ageing 2017 highlights. Retrieved from http://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2017_Highlights.pdf. Latest accessed on September 26, 2018.
- United Nations (2017b). World population prospects: The 2017 revision. Retrieved from <https://esa.un.org/unpd/wpp/Download/Standard/Population/>. Latest accessed on September 26, 2018.
- United Nations (2018). World population prospects 2017. Retrieved from <https://esa.un.org/unpd/wpp/Download/Probabilistic/Population/>. Latest accessed on September 26, 2018.
- World Bank (2018). Gdp (current us\$). Retrieved from <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD>. Latest accessed on September 26, 2018.
- World Health Organization (2015). *World report on ageing and health*. World Health Organization. Retrieved from <http://www.who.int/ageing/events/world-report-2015-launch/en/>.

Appendices



Python code of open exploration

A.1. Python code of open exploration for needed nurses

Base case open exploration-Appendix

October 17, 2018

1 Base case open exploration

1.1 1. Importing the required Python packages

```
In [ ]: import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
from matplotlib import gridspec
import pandas as pd
import timeit
import numpy.random

% matplotlib inline

from ema_workbench import (Model, RealParameter, CategoricalParameter, TimeSeriesOutcom
from ema_workbench.em_framework.parameters import Policy, create_parameters
from ema_workbench.em_framework.evaluators import LHS, SOBOL, MORRIS
from ema_workbench.analysis.plotting import lines
from ema_workbench.analysis.plotting_util import KDE
from ema_workbench import (Model, RealParameter, Constant, IntegerParameter, CategoricalPa
Policy, perform_experiments, ema_logging, save_results, load
from ema_workbench.connectors.vensim import VensimModel
from ema_workbench import MultiprocessingEvaluator

ema_logging.log_to_stderr(ema_logging.INFO)

numpy.random.seed(123456789)
```

1.2 2. Loading the vensim model

```
In [ ]: wd = r'c:\users\wvanderpaauw\Work Folders\Desktop\Master Thesis - Wijnand van der Paauw'
model = VensimModel('HealthModel', wd = wd , model_file='Societal Aging and Health Car
ema_logging.log_to_stderr(ema_logging.INFO)    # we want to see what EMA is doing
```

1.3 3. Specify uncertainties and outcomes

In []: *#Specify the uncertainties that affect the outcomes of interest*

```
uncertainties = [  
    RealParameter('Growth rate alcohol', 0.01, 0.05),  
    RealParameter('increase rate',0.01,0.02),  
    RealParameter('Graduation uncertainty factor',0.6,1.4),  
    RealParameter('influence of smoking on life expectancy',1.2,2.4),  
    RealParameter('influence of inactive population on life expectancy',0.1,0.3),  
    RealParameter('influence of obesitas on life expectancy',0.2,0.8),  
    RealParameter('influence of heavy drinking on life expectancy',0.1,0.3),  
    RealParameter('hours of extramural care',500,1000),  
    RealParameter("Annual relative change due to eHealth policy",0.3,0.5),  
    RealParameter("Annual relative change due to TECH ADV policy",0.3,0.5),  
    RealParameter("Fertility rate uncertainty factor",0.6,1.4)  
]
```

In []: *#Specify the outcomes of interest*

```
outcomes = [  
    TimeSeriesOutcome('GAP NURSES CURE[Australia]'),  
    TimeSeriesOutcome('GAP NURSES CARE[Australia]'),  
  
    TimeSeriesOutcome('GAP NURSES CURE[Austria]'),  
    TimeSeriesOutcome('GAP NURSES CARE[Austria]'),  
  
    TimeSeriesOutcome('GAP NURSES CURE[Belgium]'),  
    TimeSeriesOutcome('GAP NURSES CARE[Belgium]'),  
  
    TimeSeriesOutcome('GAP NURSES CURE[Canada]'),  
    TimeSeriesOutcome('GAP NURSES CARE[Canada]'),  
  
    TimeSeriesOutcome('GAP NURSES CURE[Czech Republic]'),  
    TimeSeriesOutcome('GAP NURSES CARE[Czech Republic]'),  
  
    TimeSeriesOutcome('GAP NURSES CURE[Denmark]'),  
    TimeSeriesOutcome('GAP NURSES CARE[Denmark]'),  
  
    TimeSeriesOutcome('GAP NURSES CURE[Estonia]'),  
    TimeSeriesOutcome('GAP NURSES CARE[Estonia]'),  
  
    TimeSeriesOutcome('GAP NURSES CURE[Finland]'),  
    TimeSeriesOutcome('GAP NURSES CARE[Finland]'),  
  
    TimeSeriesOutcome('GAP NURSES CURE[France]'),  
    TimeSeriesOutcome('GAP NURSES CARE[France]'),  
  
    TimeSeriesOutcome('GAP NURSES CURE[Germany]'),  
    TimeSeriesOutcome('GAP NURSES CARE[Germany]'),  
]
```

```

TimeSeriesOutcome('GAP NURSES CURE[Greece]'),
TimeSeriesOutcome('GAP NURSES CARE[Greece]'),

TimeSeriesOutcome('GAP NURSES CURE[Hungary]'),
TimeSeriesOutcome('GAP NURSES CARE[Hungary]'),

TimeSeriesOutcome('GAP NURSES CURE[Iceland]'),
TimeSeriesOutcome('GAP NURSES CARE[Iceland]'),

TimeSeriesOutcome('GAP NURSES CURE[Italy]'),
TimeSeriesOutcome('GAP NURSES CARE[Italy]'),

TimeSeriesOutcome('GAP NURSES CURE[Ireland]'),
TimeSeriesOutcome('GAP NURSES CARE[Ireland]'),

TimeSeriesOutcome('GAP NURSES CURE[Japan]'),
TimeSeriesOutcome('GAP NURSES CARE[Japan]'),

TimeSeriesOutcome('GAP NURSES CURE[Latvia]'),
TimeSeriesOutcome('GAP NURSES CARE[Latvia]'),

TimeSeriesOutcome('GAP NURSES CURE[Luxembourg]'),
TimeSeriesOutcome('GAP NURSES CARE[Luxembourg]'),

TimeSeriesOutcome('GAP NURSES CURE[Netherlands]'),
TimeSeriesOutcome('GAP NURSES CARE[Netherlands]'),

TimeSeriesOutcome('GAP NURSES CURE[New Zealand]'),
TimeSeriesOutcome('GAP NURSES CARE[New Zealand]'),

TimeSeriesOutcome('GAP NURSES CURE[Norway]'),
TimeSeriesOutcome('GAP NURSES CARE[Norway]'),

TimeSeriesOutcome('GAP NURSES CURE[Poland]'),
TimeSeriesOutcome('GAP NURSES CARE[Poland]'),

TimeSeriesOutcome('GAP NURSES CURE[Portugal]'),
TimeSeriesOutcome('GAP NURSES CARE[Portugal]'),

TimeSeriesOutcome('GAP NURSES CURE[Slovak Republic]'),
TimeSeriesOutcome('GAP NURSES CARE[Slovak Republic]'),

TimeSeriesOutcome('GAP NURSES CURE[Slovenia]'),
TimeSeriesOutcome('GAP NURSES CARE[Slovenia]'),

TimeSeriesOutcome('GAP NURSES CURE[Spain]'),
TimeSeriesOutcome('GAP NURSES CARE[Spain]'),

```



```

TimeSeriesOutcome('GAP NURSES CURE[Sweden]'),
TimeSeriesOutcome('GAP NURSES CARE[Sweden]'),

TimeSeriesOutcome('GAP NURSES CURE[Switzerland]'),
TimeSeriesOutcome('GAP NURSES CARE[Switzerland]'),

TimeSeriesOutcome('GAP NURSES CURE[United Kingdom]'),
TimeSeriesOutcome('GAP NURSES CARE[United Kingdom]'),

TimeSeriesOutcome('GAP NURSES CURE[United States]'),
TimeSeriesOutcome('GAP NURSES CARE[United States]'),

]

In [ ]: policies = [
    Policy('None',
        **{
            'SWITCH RETIREMENT AGE':0,
            'SWITCH TECHNOLOGICAL ADVANCEMENT':0,
            'SWITCH eHEALTH':0,
            'SWITCH ADDITIONAL INFLOW NURSES':0
        }),

    Policy('Technological',
        **{
            'SWITCH RETIREMENT AGE':1,
            'SWITCH TECHNOLOGICAL ADVANCEMENT':1,
            'SWITCH eHEALTH':1,
            'SWITCH ADDITIONAL INFLOW NURSES':0
        }),

    Policy('Student inflow',
        **{
            'SWITCH RETIREMENT AGE':1,
            'SWITCH TECHNOLOGICAL ADVANCEMENT':1,
            'SWITCH eHEALTH':1,
            'SWITCH ADDITIONAL INFLOW NURSES':1
        })
    ]

In [ ]: #Specify number of experiments
        nr_scenarios = 100

In [ ]: model.uncertainties = uncertainties
        model.outcomes = outcomes

```

1.4 4. Experiments

```
In [ ]: start_time = timeit.default_timer()

        with MultiprocessingEvaluator(model) as evaluator:
            results = evaluator.perform_experiments(scenarios=nr_scenarios,policies=policies)

        elapsed = timeit.default_timer() - start_time
        print("Total time in minutes:", elapsed/60, "-- Time per run in seconds:", elapsed/(nr

In [ ]: import matplotlib.pyplot as plt
        from ema_workbench.analysis.plotting import lines

In [ ]: experiments, outcomes = results

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Australia]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Australia]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Austria]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Austria]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Belgium]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Belgium]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Canada]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Canada]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Czech Republic]'), group_by='p
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Czech Republic]'), group_by='p

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Denmark]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Denmark]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Estonia]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Estonia]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Finland]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Finland]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[France]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[France]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Germany]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Germany]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Greece]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Greece]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Hungary]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Hungary]'), group_by='policy')
```

```

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Iceland]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Iceland]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Italy]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Italy]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Ireland]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Ireland]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Japan]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Japan]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Latvia]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Latvia]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Luxembourg]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Luxembourg]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Netherlands]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Netherlands]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[New Zealand]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[New Zealand]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Norway]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Norway]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Poland]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Poland]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Portugal]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Portugal]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Slovak Republic]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Slovak Republic]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Slovenia]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Slovenia]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Spain]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Spain]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Sweden]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Sweden]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[Switzerland]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[Switzerland]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[United Kingdom]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[United Kingdom]'), group_by='policy')

In [ ]: fig = lines(results, outcomes_to_show=('GAP NURSES CURE[United States]'), group_by='policy')
        fig = lines(results, outcomes_to_show=('GAP NURSES CARE[United States]'), group_by='policy')

```

A.2. Python code of open exploration for costs

Open exploration costs

October 16, 2018

1 Base case open exploration costs

1.1 1. Importing the required Python packages

```
In [ ]: import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
from matplotlib import gridspec
import pandas as pd
import timeit
import numpy.random

% matplotlib inline

from ema_workbench import (Model, RealParameter, CategoricalParameter, TimeSeriesOutcom
from ema_workbench.em_framework.parameters import Policy, create_parameters
from ema_workbench.em_framework.evaluators import LHS, SOBOL, MORRIS
from ema_workbench.analysis.plotting import lines
from ema_workbench.analysis.plotting_util import KDE
from ema_workbench import (Model, RealParameter, Constant, IntegerParameter, CategoricalPa
Policy, perform_experiments, ema_logging, save_results, load
from ema_workbench.connectors.vensim import VensimModel
from ema_workbench import MultiprocessingEvaluator

ema_logging.log_to_stderr(ema_logging.INFO)

numpy.random.seed(123456789)
```

1.2 2. Loading the vensim model

```
In [ ]: wd = r'c:\users\wvanderpaauw\Work Folders\Desktop\Master Thesis - Wijnand van der Paauw'
model = VensimModel('HealthModel', wd = wd , model_file='Societal Aging and Health Car
ema_logging.log_to_stderr(ema_logging.INFO)
```

1.3 3. Specify uncertainties and outcomes

In []: *#Specify the uncertainties that affect the outcomes of interest*

```
uncertainties = [  
    RealParameter('Growth rate alcohol', 0.01, 0.05),  
    RealParameter('increase rate', 0.01, 0.02),  
    RealParameter('Graduation uncertainty factor', 0.6, 1.4),  
    RealParameter('influence of smoking on life expectancy', 1.2, 2.4),  
    RealParameter('influence of inactive population on life expectancy', 0.1, 0.3),  
    RealParameter('influence of obesitas on life expectancy', 0.2, 0.8),  
    RealParameter('influence of heavy drinking on life expectancy', 0.1, 0.3),  
    RealParameter('hours of extramural care', 500, 1000),  
    RealParameter("Annual relative change due to eHealth policy", 0.3, 0.5),  
    RealParameter("Annual relative change due to TECH ADV policy", 0.3, 0.5),  
    RealParameter("Fertility rate uncertainty factor", 0.6, 1.4)  
]
```

In []: *#Specify the outcomes of interest*

```
outcomes = [  
    TimeSeriesOutcome('Costs of policy[Australia]'),  
  
    TimeSeriesOutcome('Costs of policy[Austria]'),  
  
    TimeSeriesOutcome('Costs of policy[Belgium]'),  
  
    TimeSeriesOutcome('Costs of policy[Canada]'),  
  
    TimeSeriesOutcome('Costs of policy[Czech Republic]'),  
  
    TimeSeriesOutcome('Costs of policy[Denmark]'),  
  
    TimeSeriesOutcome('Costs of policy[Estonia]'),  
  
    TimeSeriesOutcome('Costs of policy[Finland]'),  
  
    TimeSeriesOutcome('Costs of policy[France]'),  
  
    TimeSeriesOutcome('Costs of policy[Germany]'),  
  
    TimeSeriesOutcome('Costs of policy[Greece]'),  
  
    TimeSeriesOutcome('Costs of policy[Hungary]'),  
  
    TimeSeriesOutcome('Costs of policy[Iceland]'),  
  
    TimeSeriesOutcome('Costs of policy[Italy]'),  
  
    TimeSeriesOutcome('Costs of policy[Ireland]'),  
]
```

```

TimeSeriesOutcome('Costs of policy[Japan]'),
TimeSeriesOutcome('Costs of policy[Latvia]'),
TimeSeriesOutcome('Costs of policy[Luxembourg]'),
TimeSeriesOutcome('Costs of policy[Netherlands]'),
TimeSeriesOutcome('Costs of policy[New Zealand]'),
TimeSeriesOutcome('Costs of policy[Norway]'),
TimeSeriesOutcome('Costs of policy[Poland]'),
TimeSeriesOutcome('Costs of policy[Portugal]'),
TimeSeriesOutcome('Costs of policy[Slovak Republic]'),
TimeSeriesOutcome('Costs of policy[Slovenia]'),
TimeSeriesOutcome('Costs of policy[Spain]'),
TimeSeriesOutcome('Costs of policy[Sweden]'),
TimeSeriesOutcome('Costs of policy[Switzerland]'),
TimeSeriesOutcome('Costs of policy[United Kingdom]'),
TimeSeriesOutcome('Costs of policy[United States]')
]

```

```

In [ ]: policies = [ Policy('Student inflow',
                            **{
                                'SWITCH RETIREMENT AGE':1,
                                'SWITCH TECHNOLOGICAL ADVANCEMENT':1,
                                'SWITCH eHEALTH':1,
                                'SWITCH ADDITIONAL INFLOW NURSES':1,
                                'SWITCH EUTHANASIA':0
                            }
),
  Policy('Euthanasia',
        **{
            'SWITCH RETIREMENT AGE':1,
            'SWITCH TECHNOLOGICAL ADVANCEMENT':1,
            'SWITCH eHEALTH':1,
            'SWITCH ADDITIONAL INFLOW NURSES':1,
            'SWITCH EUTHANASIA':1
        }
)
]

```

```
    })
]
```

```
In [ ]: #Specify number of experiments
        nr_scenarios = 100
```

```
In [ ]: model.uncertainties = uncertainties
        model.outcomes = outcomes
```

1.4 4. Experiments

```
In [ ]: start_time = timeit.default_timer()

        with MultiprocessingEvaluator(model) as evaluator:
            results = evaluator.perform_experiments(scenarios=nr_scenarios,policies=policies)

        elapsed = timeit.default_timer() - start_time
        print("Total time in minutes:", elapsed/60, "-- Time per run in seconds:", elapsed/(nr.

In [ ]: import matplotlib.pyplot as plt
        from ema_workbench.analysis.plotting import lines

In [ ]: experiments, outcomes = results

In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Australia]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Austria]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Belgium]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Canada]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Czech Republic]'), group_by='p
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Denmark]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Estonia]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Finland]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[France]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Germany]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Greece]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Hungary]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Iceland]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Italy]'), group_by='policy')
```



```

In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Ireland]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Japan]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Latvia]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Luxembourg]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Netherlands]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[New Zealand]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Norway]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Poland]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Portugal]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Slovak Republic]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Slovenia]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Spain]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Sweden]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[Switzerland]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[United Kingdom]'), group_by='policy')
In [ ]: fig = lines(results, outcomes_to_show=('Costs of policy[United States]'), group_by='policy')

```