A System Dynamics Model of Health Insurance Financing in Austria

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ABSTRACT As the financial situation of the health care system in Austria is an important issue, a dynamic model of receipts and expenditures of public health insurance can give important insights on possible future behaviour and outcome of various policies. Therefore a model is developed using the method System Dynamics (as defined by Jay W. Forrester) and for implementation the software Vensim. Based on a dynamic population model, global income and expenses are simulated, where the income results mainly from contributions and expenses come from medical attendance and prescribed drugs, which are calculated from occurring illnesses. After introducing the structure of the underlying social insurance system in Austria, the model structure in detail and the implementation of the demographic population part are explained. Policy and scenario testing can be done very easily with such a model structure.

1 Motivation

In Austria, health care is organized primarily in public health insurances (see for example [4]). Most of them have been under great financial pressure during the last few years, so decisions have to be made in order to reform their structure. However, the health system is apparently complex, and impacts of new policies cannot be predicted easily as the system has various dynamic feedback loops with different delays — for example if one considers the long-term effects of disease prevention programs, which might be costly for the short term, but pay off later. Thus a dynamic cost model of a public health insurance is useful for getting better insight into resulting problems and the suitability of possible solutions. Furthermore it is feasible to simulate various scenarios and get qualitative insights.

2 Background on public health insurances

Public health insurance represents its insured persons when dealing with providers of medical care. It negotiates contracts with them and pays for treatments and prescribed drugs. On the other hand the insurance gets contributions which in Austria depend on the income of the insured. The objective of public health insurances is not to draw profit, but to achieve a balance between receipts and expenses. Even more important is public health in general; insured persons should receive at least all health services which make a substantial contribution to their well-being.

Contrary to private health insurances, public health insurances in Austria are not allowed to demand higher contributions from persons at higher risk for diseases, and therefore people with low income and high risk benefit from the system, which is desirable in a social state. However this can lead to disadvantages for health insurances with a bad risk structure. In Austria there is an equalization fund for compensation of such insurances. For more information on risk structure and risk selection, see [2]. All financial flows of an insurance can be seen from its closing of accounts (for example [5]). It is a promising approach to let the model replicate this structure. System Dynamics seems to be a natural approach for it, as it makes use of stock and flow diagrams and feedback loops. Moreover, System Dynamics models can be simulated quickly and allow mathematical analysis as they are essentially systems of ordinary differential equations. This approach has been used already by Groesser [3] for modelling the German health insurance fund. However, apart from various differences to the Austrian health system, that work does not go into much detail when it comes to the kind of health services provided or the structure of health care.

3 The chosen approach

The relations of main components of the model are represented in Figure 1. The central element is the “Health Insurance Fund”, which is a level that stands for the financial situation of the health insurance. It is modified by “Income” and “Expenses”.

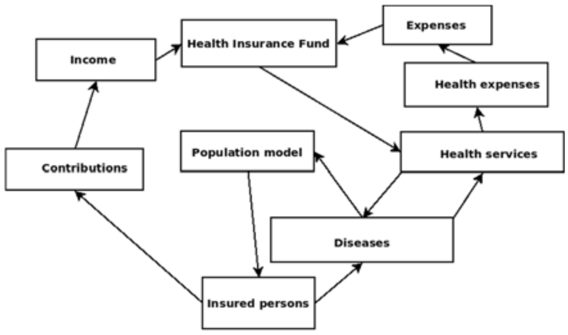

Figure 1. Overview of main components of the model, arrows signify influences between them

"Contributions" are by far the most important source of income, as "Health expenses" are the main source of expenses. To make it not too complex, other parts (like income from financial speculations and expenses from write-off) are not included in the figure. Contributions are paid by the "Insured persons", who are themselves generated by a "Population model", as described later. On the other hand the insured persons develop "Diseases", which generate a need for "Health services" that produce health expenses. Furthermore, diseases can lead to changes in population through mortality, and it depends on the financial situation of the health insurance, which health services it is willing to pay. One of the most important determinants for the situation and further development of a health insurance is the structure of its insured persons — the distribution of age, sex, education, income, morbidity and other factors among them (see [1] for a theoretical model of these factors).

3.1 The population model

To cover the demographic influences, a dynamic population model is integrated into the whole model of the health insurance. It consists of 5-year age compartments for both sexes and the flows between them. Births, migration and deaths are also considered. The importance of this part of the model follows from the predicted change of demographic structure during the next decades.

Each compartment is changed by four flows. If three consecutive compartments are called A, B, and C (for example A... "women 20-25", B... "women 25-30", C... "women 30-35") as in Figure 2, these flows are:

1. People come from A to B when they excess the lower age limit of B.
2. People come from B to C when they excess the lower age limit of C.
3. People who die while they are in B are collected in the flow "deaths" from B.
4. People who migrate or immigrate while they are in the age of B build the flow "migration" to B.

For calculating survival probabilities of persons in various compartments, the distribution function — which is given by $F(t) = 1 - \exp\left(-\left(\frac{t}{a}\right)^b\right)$ — of a Weibull distribution was fitted to data from mortality tables, but just for a cohort which starts at one year of age, because mortality during the first year of life is an outlier and cannot be fitted with the distribution.

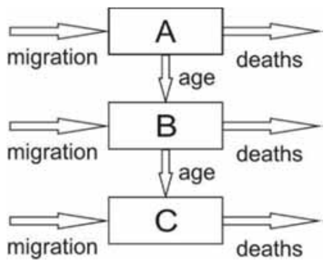

Figure 2. Scheme of age compartments, each compartment is changed through flows of migration and deaths, and people

Life expectancies are predetermined reasonably for the future, and the parameter a of the Weibull distribution should be changed according to get the same life expectancies for persons in the model (infant mortality during the first year of life is held constant). If X stands for the time someone survives in his first year of life, and Y for the time he survives after his first year of life, then X+Y is the age he reaches (of course Y can only be unequal to 0 if X is 1).

Let p be the probability of dying in the first year of life and life expectancy for someone who actually dies before his first birthday be 1/8 of a year (which is a reasonable value because mortality of newborns is especially high in the first days of life). Then the life expectancy E(X+Y) in the model can be calculated to

$$E(X+Y) = \frac{p}{8} + (1-p) \cdot (1 + E(Y_1))$$

if $E(Y_1)$ is the remaining life expectancy of somebody who already survived the first year.

As this is modelled by a Weibull distribution with the expected value $E(Y_1) = a \cdot \Gamma\left(\frac{1}{b} + 1\right)$ with given E(X+Y), p and b (the parameter b is held constant and calculated from the fit with present life tables) the parameter a is obtained at each time. From this calculated Weibull distribution the model gets the probabilities of survival for each compartment. If U and 0 are the lower and upper age limit of a certain compartment, then the probability W is:

$$W(U,O) = 1 - \frac{\big(1 - F(U)\big) - (1 - F(O)}{1 - F(U)}$$
$$= exp\left(\frac{U^b}{a} + \frac{O^b}{a}\right)$$

Concerning migration and births, the total number of migrants and general fertility rates are given over time, furthermore the age distribution of migration and fertility is held constant at present values. From this, actual migrants and births (the latter are equal to the flows into the first male and female age-compartments) are calculated.

3.2 Insured persons

The “population” - subsystem generates the insured persons of the health insurance. It was chosen to model a regional insurance because there is exactly one in every federal state and most people are covered in them. Aside from this, only special occupational groups are insured in other insurances.

In the population model the development of the population of the observed federal state is simulated. From present ratios of employees, retirees, unemployed persons, co-insured persons and others, which are held constant (but could be varied over time for further investigations and scenarios), these groups are calculated. They differ in their contributions and other important characteristics. Most co-insured persons for example do not pay any contributions, and retirees do not have to pay the fixed annual payment for the so called E-card (€10 at present). The contributions of each group are calculated. For employees and retirees, contributions depend on their income, therefore pension adjustments and pay increases over time are also considered.

3.3 Illnesses and medical services

On the one hand, contributions of the various insured persons are a large part of the insurances income. On the other hand, the most important matters of expense are ambulatory and stationary medical attendance as well as prescribed drugs [5]. Therefore these parts are modelled in detail.

Central for the expenses is the generation of illnesses (the insured persons develop a certain amount of illnesses per year, according to their demographic structure and other influencing variables), which are separated in “light acute”, “heavy acute” and “chronic” diseases, because these types have to be treated differently in the model. Whereas acute illnesses last only a relatively short amount of time, chronic illnesses are often lifelong. The difference between light and heavy acute diseases is that the latter need stationary treatment. As seen in Figure 3, each of them is modelled in various levels (or stocks) which accumulate new illnesses.

People from each compartment of the population model have expected values for the number of new diseases of each type which they get in one year, so there is a flow into the levels “light acute diseases untreated”, “chronic diseases unrecognized” and “heavy acute diseases”. It is assumed that heavy acute diseases are always recognized and treated (this is clear when one takes for example a heart attack), light acute illnesses are recognized (here a good example would be a common cold), but the person has to decide whether he or she wants to consult a doctor and get treatment (which results in the flow into the level “light acute general practitioner” for illnesses treated by a general practitioner), and chronic diseases need to be recognized (flow into “chronic diseases recognized”) and a decision if they should be treated has to be made (flow into “chronic diseases treated”).

In Figure 3 only general practitioners are considered for simplification, but in the model there is also a level for cases of medical specialists.

Untreated or unrecognized chronic diseases generate additional new acute illnesses (complications), therefore the health insurance may save money in the short term but have to spend more in the long term.

Note that when somebody is released from hospital (where he or she is “with a heavy acute disease”) then there is a certain chance that he or she has to be treated ambulatory for a certain time (or gets a “light acute disease” in the language of the model) and a chance that a chronic disease is developed. The first case leads automatically to a contact with a physician.

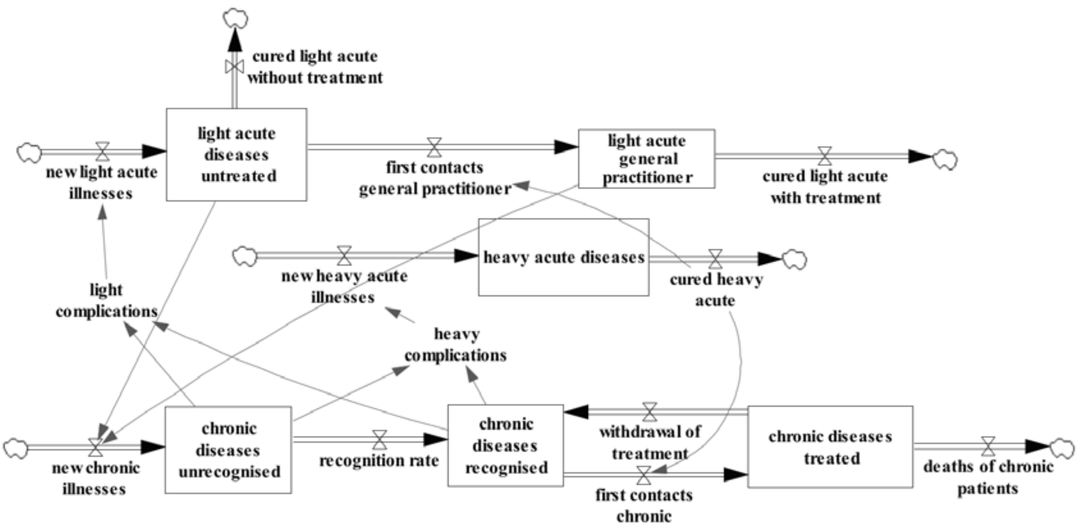

Figure 3. Modelling of diseases (simplified). Diseases are divided into three different types, and each type is further separated into one to three different stages (depending on if they are recognized and if they are treated)

As diseases get treated (which also includes the prescription of drugs), they generate costs for the health insurance. Doctors become a flat charge for each patient who has visited them in a quarter, no matter how often this was. Additionally there are certain services for whom they get paid extra. Accumulated data about how much was paid to doctors (separately for general practitioners and different medical specialists) and how many cases per quarter they treated was available from the Main Association of Austrian Social Security Institutions for the last few years. Even better data was available concerning medical prescriptions (also from the Main Association), because here costs and prescriptions were broken down by active ingredient of the drug and age of the patient. Therefore not only the average rate of prescriptions per case can be found and used in the model, but there would be even the possibility to model at least for one group of drugs and a few associated illnesses in more detail.

4 Summary

Various other financial flows are less important and therefore modelled in less detail. The whole model is implemented with the simulation software Vensim. Financial development of the public health insurances during the last years is known and thus the model can be validated. Many parameters, like fertility rates, life expectancies, expected values for new illnesses, compliance etc. lend themselves to be varied over reasonable ranges in order to test model sensitivity. Furthermore a stability analysis is performed numerically as the model is far too complex for an analytical analysis.

Altogether the model gives a comprehensive image of where costs are accumulated and which unintentional behaviour might occur from its structure and different policies. Particularly, easy testing and simulating of scenarios and policies which could be important in future health care makes this System Dynamics approach of a health insurance model so promising.

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