A MULTI-STATE MARKOV MODEL FOR PROJECTING HEALTH CARE SPENDING

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Abstract:
Demographic developments have always been central to economic growth and welfare. One of the observed trends has been that people live longer and they also remain healthy for longer. Besides this change, regarding the population structure the birth rates have declined, causing the so-called 'progressive aging of the population'.
Since the aging process is important in the field of social protection, spending on health and long-term care for dependent older people is a first-order policy issue. In this respect, considerable attention has focused on projecting these health care expenditures; emphasis has been given to estimating the number of dependent older people so that government can direct resources and services efficiently and effectively. These projections can be obtained by a multi-state Markov model, which is presented in this paper.
Projections of dependency amongst the elderly provides the basis for assessing the future cost of associated health care and the necessary services in order to guarantee that requirements for the dependent population are suitably covered.

Key Words: Multi-state Markov model, health care, spending

1. Introduction

Estimating the expenditures on health care for dependent older people has been the subject of discussion since several years. In this direction, the proposed paper aims to address, on the one hand, the link between aging and dependency and, on the other hand, the methodology for projecting the future demand for health care in order to serve as a basis for economic planning, in the medium term, of the spending on required assistance.

Due to the progressive aging of the population the growth in the number of older people who need help to perform the basic activities of daily living is unstoppable. Therefore, public institutions must act and provide health and social services that satisfy the needs of this population group.

The phenomenon *Dependency* may affect the society in diverse and complex ways, especially regarding the social security systems. Besides the broadly discussed consequences on the pension insurance schemes, it is very important to determine the influence of dependency on the health care sector, since it will be a fundamental driver of health and long-term care expenditure in the coming decades.

According to Kunkel and Applebaum (1992), the aging of a population has profound effects on all aspects of the nation. From the marketing of products, to retirement and employment patterns and to social relationships between generations, aging of a population results in dramatic changes in the way a society functions. Although these demographic changes have significant effects on every aspect of life in the society, one of the greatest challenges faced by an aging society lies in its ability to provide health and social service care of high quality.

Providing high quality long-term care services for dependent people in a society in which the number of people requiring those services is increasing rapidly raises difficult public policy decisions. Debates about the best approaches to providing health and long-term care, and equally difficult issues concerning what level of resources a society can allocate to this care, have already become common in industrialized nations. Projections of the need for health and long-term care are fundamental for sound public policy. "*If our efforts to plan for our aging population are to become more intelligent*

and less feeble, the highest priority must be given to amassing data and making projections of health care needs" (Brody, Brock and Franklin, 1987).

2. Dependency

Advancing in the development and the individual autonomy of disabled and dependent people in order to get a true quality of life for themselves and their families corresponds to common sense. Since 2003 was proclaimed 'European Year of People with Disabilities' and 2007 'European Year of Equal Opportunities for All', this is an idea that has been and is being widely discussed and analyzed in different international areas (Blanco and Latorre, 2008).

In the following sections the issue of dependency is introduced; for this, firstly its concept is analyzed and then several measures adopted to address it are presented.

2.1. Concept of Dependency

As a phenomenon that affects a significant number of people in our society, Dependency (or Dependence) is of great interest to those who work and live with it, needing solid theoretical frameworks.

According to the expert group constituted in 1998 by the Council of Europe, dependency is:

"*A state in which persons, by reason of lack or loss of physical, psychological or intellectual autonomy, require significant assistance or help in carrying out their usual day-to-day activities*" (p. 2).

From the above definition three basic factors that define the status of dependent people can be extracted:

- The existence of a physical, mental or intellectual limitation.
- The inability to perform autonomously the basic activities of daily living.
- The need for assistance or help from a third party.

The need for assistance derived from dependency situations is not a new issue. In every age there has been a part of the population that -because of age, illness or deficiency- has needed, more or less intensely, the attention of third parties in the development of the daily life. What has changed has been its size (due mainly to the growth in the number and proportion of older people), its social importance (no longer seen as an exclusively individual or family issue, but a problem affecting to society as a whole) and its nature (while representing a redelimitation of the objectives and functions of the Welfare State and involving new protection and funding commitments). For this reason, dependency has become both a social and familiar issue and, at the same time, opens a new field of intervention that tests the ability of society and its institutions to adapt to the new realities of social fragility (IMSERSO, 2005).

When speaking about dependency, three levels of severity are applied:

- *Degree I. Moderate dependency:* when the person needs help in order to perform various basic activities of daily living, at least once a day or when the person needs intermittent or limited support for his/her personal autonomy.
- *Degree II. Severe dependency:* when the person needs help in order to perform various basic activities of daily living two or three times a day, but he/she does not want the permanent support of a carer or when he/she needs extensive support for his/her personal autonomy.
- *Degree III. Total dependency:* when the person needs help in order to perform various basic activities of daily living several times a day or, due to his/her total loss of physical, mental, intellectual or sensorial autonomy, he/she needs the indispensable and continuous support of another person or when he/she needs generalised support for his/her personal autonomy.

Each of the degrees of dependency established above is classified into two levels, depending on the person's autonomy and on the intensity of care that is required.

2.2. Measures adopted to address dependency

The protection of people with disabilities or those who are dependent on others for their care has become the focus of increasing attention on an international scale. The United Nations' 1948

Universal Declaration of Human Rights, and the Council of Europe's *Convention for the Protection of Human Rights and Fundamental Freedoms* (1950) and *European Social Charter* (1961) were the first such international treatises to make explicit mention of people with disabilities and set out measures designed to achieve optimum support for their personal and professional wellbeing.

In the 1970s, the European Union began to focus its attention on improving the living conditions of people with disabilities, approving in 1974 the initial *Community Action Program for the Vocational Rehabilitation of Handicapped Persons*. This established a basis for cooperation between those entities responsible for this area, and outlined actions intended to establish and disseminate good practice in the field.

These texts, together with others promoted by the World Health Organization (WHO), were followed in 1982 by the United Nations' *World Program of Action Concerning Disabled Persons*. The UN also declared 1983-1992 the *Decade of Disabled Persons*, which was conceived as a vehicle for the World Program of Action. In more recent years, 2006 saw the UN introduce *The Convention on the Rights of Persons with Disabilities*, which aims to promote, protect, and ensure the full enjoyment of human rights by persons with disabilities, ensure their fundamental freedoms, and protect their innate dignity.

Also worthy of note is the current *Council of Europe Action Plan to Promote the Rights and Full Participation of People with Disabilities in Society: improving the quality of life of people with disabilities in Europe 2006-2015*. This plan considers that non-governmental support organisations – that is, those charities and voluntary groups that are exclusively devoted to helping people with disabilities – are perfectly competent and qualified to make policy in this area, and that they should therefore be consulted when making any decision that may have repercussions for the lives of the people they represent.

3. Link Between Aging And Dependency

The social development and the improvement in the quality of life that are taking place in our society are causing an increase in longevity. The extension of life expectancy is coming with a declining birth rate, hence the weight of the elderly population is increasing progressively.

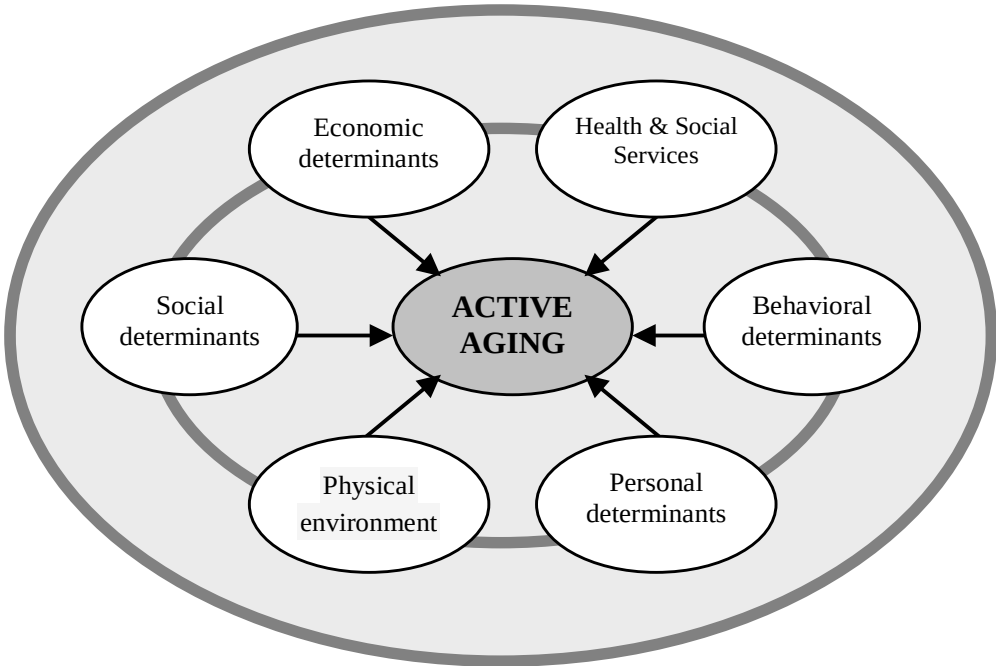
Dependency is strongly related to age. Dependency rates tend to be lowest at the youngest ages and highest for the elderly. This relationship is important because knowledge of a population structure and how this might change gives important information on the current number of dependent people and its possible trend. The strong relationship between age and dependency allows projections to be divided into demographic and dependency risk factors.

Although there have always been disabled and dependent persons (even not considered as such), it is true that the accelerated aging process that is currently experiencing the population, the high survival rates (due, largely, to medical advances) and the changes in family structure are causing social awareness for the protection of the seniors found in these conditions.

However, this aging process should not only be considered as a problem, but also as a social opportunity that must be seized. The aging population is the expression of an human achievement: live longer and live better. It constitutes one of the major social transformations produced in the last third of the last century: to advance in age and to do it actively.

Active aging is the optimizing process of opportunities for health, participation and security in order to improve the quality of life when people become older (WHO, 2002). It lets enhance physical, social and mental welfare throughout the entire life cycle of the individual. The term "active" refers not only to a physical capacity, but also a continued participation in the social, economic, cultural and civic one.

Specifically, the determinants that influence active aging are summarized in the following graphic:



Graphic 1. Determinants of the active aging

Aging is a challenge that has to be answered. It is a complex challenge because the increasing number of older people and the increasing care needs arising from this growth coincide with a crisis of informal support systems that have been responding to those needs, motivated by other two major social changes: the change in the family model and the increasing incorporation of women into the workforce (IMSERSO, 2005).

The aging of the population is having a great impact in various sectors of the society: the pension system, the demand for technical assistance and social/health services, etc... For the elderly who, in varying degrees, suffer a loss of personal autonomy it is being especially significant the increase of the demand for long-term care (LTC) services. Long-term care is the personal assistance that enables dependent people to perform activities of daily living, such as eating, bathing and dressing. These services may be provided at home by family and friends, through home and community-based services such as home health care, personal care and adult day care; or in institutional settings, such as nursing or residential care facilities.

Since the challenge of social protection for dependent people is unavoidable for social policies, it is necessary that health and social services systems face it up, satisfying the personal help needs of these citizens.

In this line, in the context of aging population, to study different issues about the forecasting of the older care has become a major objective for many countries of the Organisation for Economic Co-operation and Development (see Achterberg et al., 2010; Batljan and Lagergren, 2004; Haynes, Hill and Banks, 2010; OECD, 2005).

4. Projecting Methodology

In order to estimate the cost of the health care that will be required by dependent older people, it is previously necessary to project the dependent elderly population to the year for which the forecast wants to be made. For this, there are different methods, being one of the most recurrent the projection of the prevalence rates (Siegel, 2002).

Under this method, the projected prevalence rates are applied to the total projected population. Prevalence rates indicate the proportion of people of all ages who have some kind of dependency at a given time respect to the total population.

$D(x, i, t) = N(x, t) \cdot P(x, i, t)$

where:

- $D(x, i, t)$ is the number of persons aged x, with a level of dependency i at time t.
- $N(x, t)$ is the total projected population aged x at time t.
- $P(x, i, t)$ is the dependency prevalence rate of level i, aged x and projected at time t.

There are two scenarios that may arise regarding the projected prevalence rates: to remain them unchanged over time (static prevalence rates) or to vary them (dynamic prevalence rates).

Although this method has been widely used (Giles, Cameron and Crotty, 2003; Harwood, Sayer and Hirschfeld, 2004; Lee and Miller, 2002; Schulz, Leidl and König, 2004), incorporating different levels of severity and with the purpose of knowing more about the transitions that may occur between several states and of relating the dependency with other factors -such as mortality-, it is necessary a methodology that, while still based on prevalence rates, is more complex and responds to issues like indicated above. Thus appear macrosimulation methodologies, such as multi-state models.

4.1. Multi-state Markov model

Multi-state models have been extensively applied in the social sciences, in particular to the analysis of longitudinal data. Hence, given the remarkable advances in statistics, these models are used in various fields such as medicine, biology, physics, economics...

A multi-state model is defined as a model for a stochastic process, which at any time occupies one of a set of discrete states. In medicine, the states can describe conditions like healthy, diseased, diseased with complication and dead. A change of state is called a transition, or an event. This then corresponds to outbreak of disease, occurrence of complication and death. It is important to recognize the difference between an event (like death) and a state (like dead). The state structure specifies the states and which transitions from state to state are possible. The full statistical model specifies the state structure and the form of the hazard function (intensity function) for each possible transition (Hougaard, 1999).

The greatest utility of these models in dealing with the issue of dependency is the posibility of projecting the number of persons who will be in a situation of dependency based on transition probabilities or rates between states, that is, if a healthy person becomes dependent, if a dependent person moves to another level of severity or whether a person, regardless of his/her health, dies.

Specifically, the projection model to be used would require the following tasks:

1. Generating baseline estimates of the level of dependency of the current older population.
2. Determining the transition rates between states.
3. Formulating assumptions about the transition rates.
4. Projecting the number of older people with need for long-term care under different scenarios.

Although all tasks play a key role in the projection methodology, the second and the third ones need to be discussed further.

Regarding the second task, the ideal method would be to obtain the transition probabilities directly from the data available, having followed a number of people and observed if they had changed over a period; then, we would work with longitudinal information. However, normally the survey data allow to calculate the prevalence rates but not to know when a transition between states occurs.

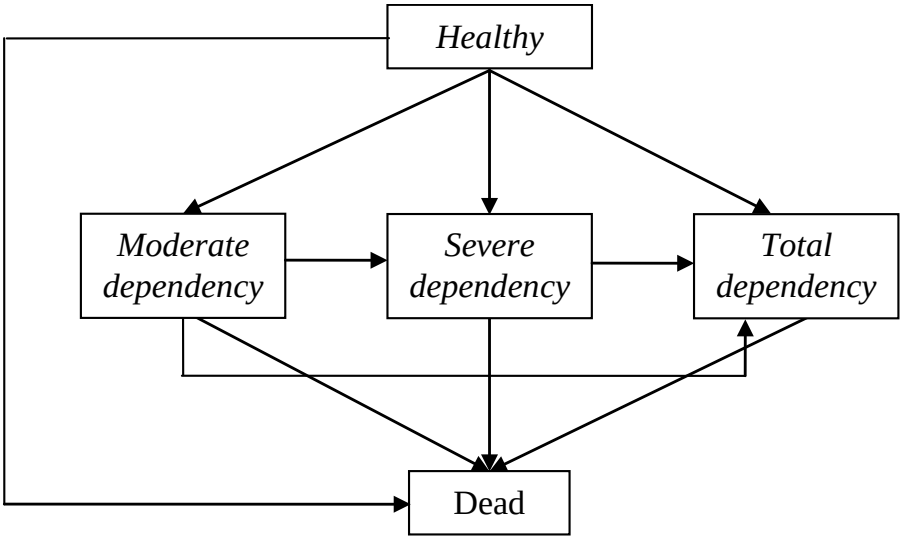
As posed Leung (2006), one possibility could be to compare the prevalence rates in two or more consecutive surveys and to calculate the maximum likelihood estimations of the probability of, after *t* years, a person aged *x* has undergone a transition from state *i* to state *j*, through the following expression:

$$p_x^{ij} = \frac{n_{x,x+t}^{ij}}{\sum_k n_{x,x+t}^{ik}}$$

where $n^{ij}_{x,x+t}$ is the number of people in state *i*, aged *x* at the moment of the first survey and in the state *j*, aged $x+t$ years in the date of the second survey.

The biggest disadvantage that usually appears when applying this method is that the surveys to be compared have been designed differently. Although in some cases both surveys can present common data, there are normally some conceptual differences, since different classifications of Disability, Dependency and Health could have been used. For this reason, the maximum likelihood estimation is not useful in this type of investigation. An alternative to calculate transition rates is the Markov model based on the method proposed by Sullivan (1971).

The state structure of the Dependency multi-state Markov model is shown in the following graphic:



Graphic 2. Transitions in the multi-state model

From these possible transitions it can be defined the following set: $\wp = \{a \to d_1, a \to d_2, a \to d_3, a \to m, d_1 \to d_2, d_1 \to d_3, d_1 \to m, d_2 \to d_3, d_2 \to m, d_3 \to m\}$, where the correspondence between the terms and the states is as follows:

$a \to$ Healthy

$d_1 \to$ Moderate dependency

$d_2 \to$ Severe dependency

$d_3 \to$ Total dependency

$m \to$ Dead

We can define p_x^{ij} as the probability that a person aged *x* had undergone a transition from state *i* to state *j* during a year, being $i, j =$ healthy, moderate dependency, severe dependency, total dependency and dead.

Following the transition of a person aged *x* through a discrete-time process $\{S(x),\ x \in N\}$, the probabilities satisfy the Markov property:

$$\text{Prob}\{S(x+1) = s_{x+1} / S(x) = s_x \wedge S(x-1) = s_{x-1} \wedge ... \wedge S(0) = s_0\} =$$
$$= \text{Prob}\{S(x+1) = s_{x+1} / S(x) = s_x\}$$

According to Monteverde (2004), the Sullivan method presents two main advantages: first, the simplicity of its calculations and, second, the wide availability of the information required. Its main drawback is that the transitions between states are not observed; however, these can be estimated from the observed prevalence.

In relation to the third task, it would be necessary to make assumptions about the following transition probabilities:

- Probability that a healthy person becomes dependent.
- Probability that the health of a dependent person worsens and he/she moves to a more severe level of dependency.
- Probability of death of healthy people.

- Probability of death of dependent people. It is assumed that dependent people present an extra-mortality respect to the healthy persons.

For example, regarding to the first two transition probabilities, following the trend of recent years an improvement in the incidence of restrictions for the basic activities of daily living could be expected. In this case, we would be assuming a decrease in the number of people that move to the more severe dependency levels in two dimensions: first, fewer people move to a situation of dependency and then, less dependent people pass to more severe degrees.

Considering the different trends that transition rates may present, it is possible to determine several scenarios under which the projections can be generated. It would not deal a static scenario in which rates were assumed to remain unchanged with respect to the latest available, but a dynamic setting. In this case, different assumptions about rates may be established, assuming that each rate undergoes a change, distinguishing the way they do it: slightly, moderately or markedly.

Concretely, considering that improvements on health have the same effect on all transitions, we could establish some scenarios under which to carry out the projection of the dependent elderly population. Although for each scenario this group is expected to increase over the next years, the way in which the number of older dependents increases depends on the scenario: the more accused the assumed reductions in the components of deterioration are, the lower the projected number of dependents.

4.2. Projecting health care expenditures

Empirical evidence suggests that per-capita expenditure on health is higher for persons in situations of dependency and for those in their declining years. This expenditure increases in line with age, as the older people become, the more likely they are to find themselves in at least one of these categories (Bryant, Teasdale, Tobias, Cheung and McHugh, 2004). This, combined with the increasingly aging population, suggests that demand for care amongst the elderly dependent will become a socio-economic issue of growing concern.

To estimate the cost of care for the elderly dependent, we can draw on the number of dependents, together with the unit cost of services that may be used, such as home helps, day care centers, residential care homes and telephone-based remote care services (‘telecare’). For each service, estimated cost could be calculated as follows:

- *Number of users of the service*: the projected population multiplied by the percentage of the population expected to use the service.
- *Units of service*: The number of users of the service multiplied by the units of service used by each user.
- *Total costs*: Units of service used by the entire population multiplied by the expected cost per unit of service.

On the other side, there are many different ways to assign care services to each degree of severity for the elderly dependent. For example, one of the options may only consider home care. Another alternative assignation of services, thinking that they are close to the real needs of the moderate, severe and total dependent population, may be the following: for the moderately dependent person, telecare and home help (one hour per day); for the severely dependent person, a place at a day centre and home help (one hour per day); and for the person who is totally dependent, a place in a residential home.

5. Conclusion

The aging population will be one of the most important social phenomena of the twenty-first century. It is projected that old population aged 65 and over will increase so much in the next decades and much faster than population as a whole. The most significant growth will be among the oldest seniors aged 85 or older, who have the greatest probability of losses in physical functioning. This surge will produce a similar increase in the demand for long-term care services. This trend, accompanied by the decline in informal care resources, resulted from reduced family size and increased proportion of women in the labor force, raises doubts about sustainability of the current

distribution of LTC financing and the incentives for the increased demand for long-term care without heightening budgetary strains.

For this reason, projecting the health care required by dependent elderly populatiom and estimating their costs have become a subject of particular interest for researchers, since this provides the basis for creating predictive systems capable of identifying the context in which public and private policy needs to be shaped.

The financing framework will experience pressures in coming years not only as a result of the rising number of dependent elderly population but also because of other demographic trends, such as declining numbers of informal caregivers.

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