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Long term care insurance pricing in Spanish population: a functional data approach

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ABSTRACT
Developed and developing countries are experiencing the consequences of an ever-increasing elderly population, including the challenges of chronic illness, disability, dependency and long term care. All over the world, more people are surviving diseases that were fatal some decades ago. Dependency can be seen as a consequence of the process of gradual aging. In a health context, this contingency is defined as a lack of autonomy in performing basic activities of daily living that requires the care of another person or significant help. In this work we propose a stand-alone insurance, focused on the necessities of the eligible dependent people in Spain, taking into account their health evolution along their lives, in order to enhance the net premium calculation. We use information from the Spanish survey EDAD 2008. The main finding is that, a policyholder can choose to underwrite among three kinds of coverages, going from a minimum to a maximum level of protection, the latter's premium being more than twice the former's, regardless of the onset of dependency.

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1. Introduction

Population aging is a global phenomenon increasing rapidly in developed countries. The number of elderly people is predicted to grow substantially. Europe, in particular, has undergone a demographic shift, with birthrates declining while longevity increases. According to Eurostat's population projections, the percentage of aged 80 or more people in the European Union is expected to double (from 5% in 2013 to 13% in 2080). The growing need and demand for long term care (LTC from now on) policies is generally associated with industrialized countries. Nevertheless, LTC needs are increasing in the developing world at a rate that far exceeds that experienced by industrialized countries and at income levels far lower than those of the industrialized world when those needs emerged (WHO 2003).

According to OECD (2005), LTC is a blanket term that 'brings together a range of services for persons who are dependent on help with basic activities of daily living over an extended period of time'. This central personal care component is frequently provided in combination with support in basic medical services, such as wound dressing, pain management, medication, health monitoring, prevention, rehabilitation or palliative care services. These services are designed to minimize, restore, or compensate for the loss of independent physical, cognitive, and/or mental functioning. Services may be short or long term and may be provided either at home or in institutions. So, LTC provides assistance, typically to older people, with some of the most fundamental activities of daily living, including eating, washing and dressing. There are two ways to obtain these services: LTC can be offered either as a part of the public Social Security portfolio of services or they can be offered by private companies through an insurance contract (from now on, LTCI[1]). The first LTCI design was proposed more than 50 years ago by Starr (1965). This paper is focused in this last perspective.

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The aim of this work is to estimate an LTC premium, that is, the annuity paid by a person until reaching a certain dependency degree (moderate, severe or major), taking into account the personal health evolution along life in order to enhance the net premium calculation. As far as we know, this is the first time that individual health evolution along life is used to enhance the estimation of LTC premiums. The evolution of dependency in the disabled Spanish population is studied through a pseudo panel constructed from EDAD 2008, in the lack of longitudinal studies or the possibility to link different cross-sectional surveys. Other authors used the so-called Markovian multi-state models (Haberman and Pitacco 1999) to study long term care risk, where several states such as autonomy, different degrees of dependency and death must be established (see, for instance, Biessy 2017; Fong, Sherris, and Yap 2017; Levantesi and Menzietti 2018). In the Spanish case, semi-Markovian models were used by Alegre et al. (2006), Herranz, Guerrero, and Segovia (2008) and Bolancé, Alemany, and Guillén (2013) for long term care ratemaking.

Our main contribution is the calculation of LTC premiums by age, gender,[2] dependency degree and homogeneous groups of individuals with similar dependency pattern (according to earlier or later onset of dependency). The characterization in homogeneous groups is obtained through the proximity of the dependency trajectories (that are derived using the retrospective reported information of each individual from birth up to 2008, contained in EDAD 2008) to a central trend within each age-gender group. These central trends are computed via functional data techniques. Dependency-free probabilities are estimated with Cox regression model, expressed in terms of the survival function, having in mind that the event of interest is not 'survival' itself but 'being dependency-free at a given age'. Thus, our work contributes in the line of non-Markovian alternatives, whose seminal papers were Beekman (1990) and Levikson and Mizraki (1994). Insurance premiums are computed as a rate per 1000 euros of a care services package. Nowadays LTCI covers are considered in the framework of health insurance and, beyond actuarial science, LTCI has been addressed in a broad range of scientific literature, such as demography, medicine, gerontology, government publications. See Pitacco (2014) for a recent compact and comprehensive description of the main LTCI products.

The paper proceeds as follows. Section 2 contains a brief explanation on the LTC Spanish system and some information about the Spanish survey EDAD 2008. Section 3 is devoted to explain the construction of homogeneous groups of individuals with similar dependency pattern (that will be called proximity-groups) and LTCI pricing methodology. In Section 4 we analyze the main results and we conclude in Section 5. Spanish legislation on dependency can be found in the Appendix.

2. Dependency and long term care insurance

Given the aging of European populations, LTC financing is high on the policy agenda across Europe. A good theoretical overview is given by Wittenberg, Sandhu, and Knapp (2002) and a more recent attempt of evaluation and comparison of LTC services in Europe can be found in Salvador-Carulla et al. (2013).

LTC systems present significant cross-country variation in Europe, the main differences being the entitlement to the benefits of the system, the degree of integration of the system and the role of cash benefits and of in-kind services. There is a wide range of possibilities in the financing and provision of LTC going from a minimum to a maximum state intervention. In the latter, we find Scandinavian countries that have developed models where local authorities provide services virtually free of charge. In the former, the UK and the US that tend to give a residual role to the State. Most other countries are in between those extreme positions. Summing up, each country has its own definition of LTC and offers its particular package of services with different relative prices. For these reasons, comparing LTC services across different countries is not straightforward. An interesting classification is given in Kraus et al. (2010), where four typologies of LTC systems are established in the EU. These authors use multivariate techniques to classify European countries attending to relevant variables related not only to LTC systems characteristics, but also to the use and financing of care, such as income and needs-corrected spending, share of private expenditures, formal care use, role of informal care and so on. According to them, Spain belongs to a group of countries oriented towards informal care and high private financing, as well as Austria, England, Finland and France. The main characteristics of this group are a medium spending on LTC, high private funding, high informal care use and support and high cash benefits.

2.1. LTC in Spain

In Spain LTC services are provided by Social Security and have a tax funded approach. The access to public LTC system is 'universal, but subjective', that is, the scheme also applies to younger people who have LTC needs, for example, those with early onset of dementia. When an individual is deemed eligible following an assessment of care needs, the Spanish legislation guarantees the access to a package of care services, subject to some cost sharing, regardless of autonomous region, income and financial assets.

Although maximum amount for dependency subsidies are being annually redefined, Spanish autonomous regions are responsible for providing in-kind benefits established by law. As a consequence, public LTC system implementation is very heterogeneous across territories, with respect to services and costs. Another consequence of this competences transfer is that the information of formal and informal care is scarce.

In short, there seems to be an opportunity for cost-sharing schemes and various forms of insurance coverage to emerge, including private supplemental and substitute insurance (Costa-Font and Patxot 2005; Comas-Herrera et al. 2006; Peña-Longobardo et al. 2016).

In this work, we propose a voluntary LTCI that could be underwritten as complementary or substitute for public LTC system.

2.2. EDAD 2008 survey

Three surveys about disability have been undertaken by the Spanish Statistical Office (INE) during the last 30 years. The first one was conducted in 1986 and was the Survey about Disabilities, Impairments and Handicaps. Then came the Survey about Disabilities, Impairments and Health Status, that was prepared using data from 1999. Finally, the last one was EDAD in 2008. Although all of them talk about disabilities, it is not possible to track this phenomenon in a homogeneous way along the years because the definition of that concept changed through the years depending on the classification that was used to prepare the survey. Indeed, EDAD 2008 was the first Spanish survey that used the internationally accepted measures established by the 'International classification of functioning, disability and health'.[3] It was also the first time that the survey included information useful for studying the dependency phenomenon, such as the average hours per week of special care received by the dependent person (see INE 2010 for more details on the sampling methodology).

In 2008 the population registered in Spain reached 46.66 million people, 23.10 million being men and 23.56 million, women. More than 4.1 million people in Spain were suffering at least one kind of disability, according to EDAD 2008. The global prevalence rate was situated between 8.2–8.6% with a 95% of confidence. However, in the case of people living at home, this rate was 8.4% whereas for people living in institutions it rose to 17.7%. Disability is related to two main factors: gender and age; until 45 years old, the male prevalence is statistically significant greater than the female one (2.5–3.0% in men versus 2.0–2.4% in women) whereas the opposite happens after that age. In particular, from 45 to 64 years old the prevalence is 6.9–8.0% in men vs. 8.9–10.3% in women; from 65 to 79 years old, 17.1–19.8% in men vs. 23.4–26.3% in women; and for 80 or more years old, 36.6–43.0% in men vs. 50.0–56.0% in women.

Among all the variables registered in EDAD 2008, for each individual we are specially interested in the disabilities suffered, the ages at which they occurred and the individual's current age. A key variable when studying dependency is the dependency score, which is not reported in the survey, but can be computed from the information contained in EDAD 2008 and applying the Spanish legislation on dependency (see the Appendix for a brief summary).

For the present work we have selected those individuals with a dependency score of zero points at the age of 30. Thus, the sample is formed by 7698 individuals that represent 2.74% of the Spanish population in 2008, that is more than one million people (344,932 men and 796,235 women). Each individual in the sample has a raising factor reflecting the population group that represents. These raising factors have been taken into account in all the computations of this paper.

3. Methodology

This section is divided into two parts; in the first one, we obtain what we call the proximity-groups, that is, a classification of the individuals attending to the closeness of their dependency trajectories to the corresponding central trend of each age-gender group. Here it is where we use functional data techniques. This methodology was previously used in Albarrán-Lozano et al. (2019) in order to track the occurrence and evolution of a certain phenomenon in a group of individuals. In the second part we propose a voluntary LTCI as a stand-alone product considering at least a dependency degree for benefit eligibility (not graded benefit) with no recovery possibility. This approach can be included within the actuarial methods based on the probability of becoming disabled. The assumption of no recovery has been used by Alegre et al. (2006), Herranz, Guerrero, and Segovia (2008), Pitacco (2014, 2016). In our case, there were not records with recovery in EDAD 2008 database.

3.1. Obtaining the proximity-groups

3.1.1. Dependency trajectories and deepest curves

Remind that for each individual in the sample we have registered the age when a disability occurs and computed the dependency score. We also know their ages in 2008. Therefore, our starting point is the dependency trajectories or dependency score functions, which are step-functions describing the evolution of the personal dependency situation from birth up to 2008. Notice that, even if the person's health/dependency condition can be seen as a smooth process, the dependency score function is piecewise constant since changes in score only take place once some particular disability status has been reached and recognized according to the Spanish legislation. Thus, we have n discretely observed curves $y_1, \ldots, y_n$ defined in different time intervals $[0, a_i]$, $i = 1, \ldots, n$, where a_i is the age in 2008.

In Figure 1 we illustrate the shape of these trajectories or curves. Notice that they are non-decreasing, which means that recovery is not possible (in spite of adaptation strategies). If we focus our attention on, for example, the purple trajectory, we can see three jumps in the score, taking place at ages 28, 36 and 67. This means that this particular individual became dependent at the age of 28 with a dependency score of 31 points (Degree I); at the age of 36 another disability occurred increasing the score up to 45 points (still in Degree I); finally, at the age of 67 another disability took place and the score jumped to 56 points (Degree II). The trajectory also tells us that the age of this individual in 2008 was 67 years old.

In order to apply functional data techniques, we need functions that are defined over the same interval. Like in other previous studies we consider disjoint groups of people in age intervals of 10 years according to their age in 2008 and we truncate individual curves to get them defined in $[0, A]$, for $A = 30, 40, \ldots, 100$. We decided not to analyze the dependency trajectories of the different cohorts present in the sample. Since the age range of the individuals in the sample is large, this may lead to many different under-represented cohorts. Moreover, we remind the reader that our sample is formed by those individuals with a dependency score of zero at the age of 30, and from now on, they will be grouped in 14 age-gender intervals (7 groups per gender) according to their age in 2008.

3.1.2. Computation of the deepest curves

The aim of this section is to provide a measure of centrality for each age-gender group defined above and this will be achieved through the computation of the corresponding deepest curves.

When computing the central trend of a sample of curves, not only the levels of the curves matter, but also their shapes, whose information is more difficult to incorporate to any numerical summary. The problem aggravates when considering curves for which the main features are not aligned. It is well known that in this context the sample point-wise or cross-sectional mean is a poor estimator of the mean behavior (Gasser et al. 1984; Kneip and Gasser 1992; Gasser and Kneip 1995). Thus, it is of extreme importance to use centrality measures that can cope with the misalignment between the sample curves.

In the particular case of the dependency evolution curves, it is very natural to consider that the evolution of dependency may present a common pattern which is accelerated or delayed in some individuals with respect to others. A general framework for modeling such trajectories is the so-called *time warping* model (see Wang and

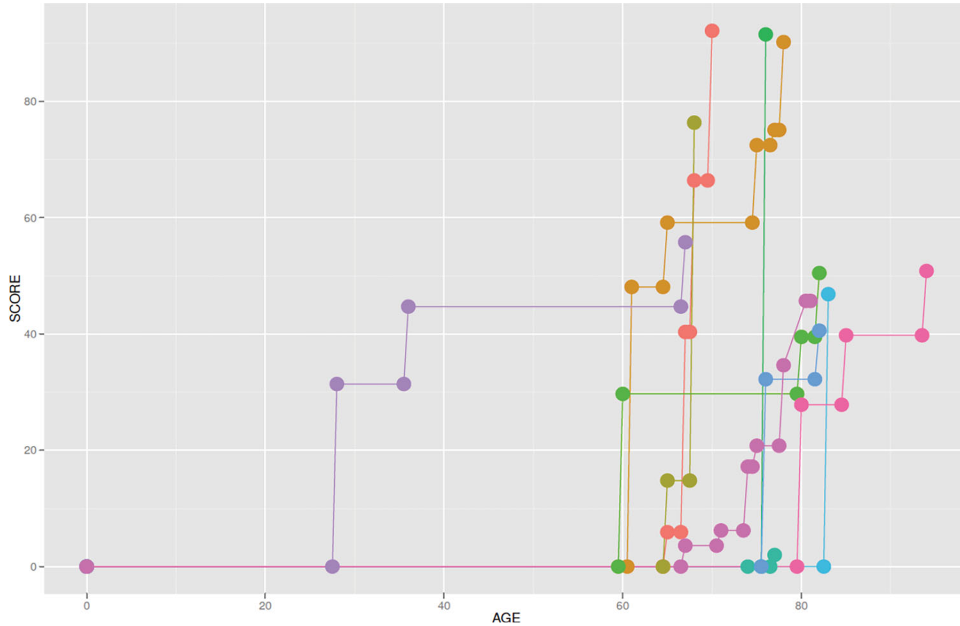


Figure 1. Examples of dependency curves from birth up to 2008.

Gasser 1997 for details). Under this model, there are two different approaches for estimating the central trend or mean behavior of the data: (a) to align or register the curves and to compute any desired sample statistic on the registered sample; and (b) to define appropriate estimators directly on the observed sample, taking into account the nature of the data. The deepest curve is an estimator of this second kind.

The deepest curve of a sample in terms of modified band depth was introduced by López-Pintado and Romo (2009). Broadly speaking, it is the curve that is most surrounded by other curves, so it can be understood as a generalization of the median to functional data. These authors proved that the deepest curve provides an accurate measure of centrality since: first, it is a curve geometrically located in the center of the sample and second, it presents a typical shape because it is one of the observed curves. Additionally, Arribas-Gil and Romo (2012) proved that it is a robust estimator of the central pattern of a sample of curves in the time warping model.

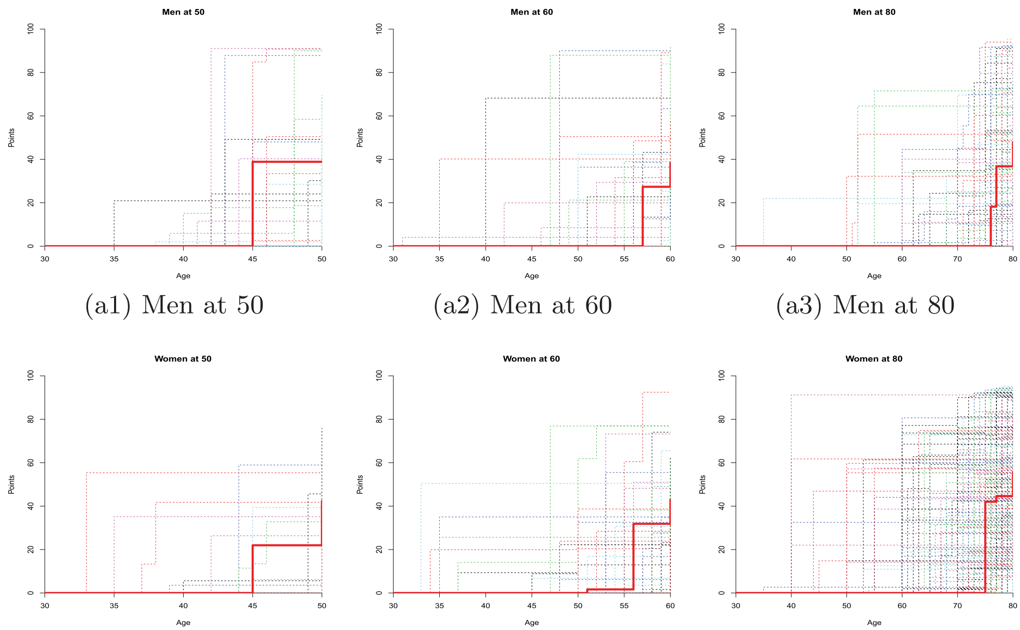
Going back to our data, for each age-gender group we compute the deepest curve using the `roahd` package in `R` by Tarabelloni et al. (2016). In Figure 2 we illustrate the dependency trajectories of several age-gender groups jointly with their deepest curves (in bold red). Looking at (a1) and (b1) panels, we see that the first score value reached by the deepest curve is lower for women than for men, which means that the loss of autonomy is stronger in men than in women at earlier ages. The opposite happens for later ages (compare panels a2–a3 with b2–b3).

3.1.3. Distance to the deepest curve and proximity-groups

The next step is to determine how close/far is each trajectory from the central trend of its corresponding age-gender group.

Thus, within each age-gender group we compute the L^2-distance of each trajectory to the corresponding deepest one multiplied by 1 (or -1) if the trajectory is most of the time above (or below) the deepest curve. Let $y_{ij}(\cdot)$ be the dependency trajectory of individual i in group j, and $m_j(\cdot)$ the deepest curve of group j. Then,

$$d_j(i) = \sqrt{\sum_t (y_{ij}(t) - m_j(t))^2} \cdot \text{sign}\left(\sum_t (y_{ij}(t) - m_j(t))\right), \quad i = 1, \ldots, n_j,\ j = 1, \ldots, 14, \qquad (1)$$



(a1) Men at 50 (a2) Men at 60 (a3) Men at 80

(b1) Women at 50 (b2) Women at 60 (b3) Women at 80

Figure 2. Dependency trajectories and deepest curves (in bold).

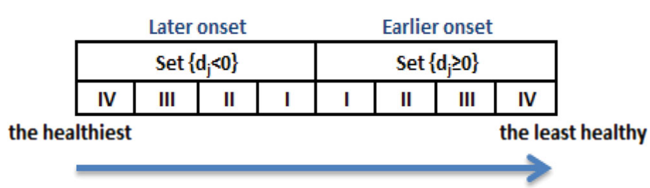


Figure 3. Scheme of the proximity-groups.

where n_j is the number of individuals in group j, defines a numerical summary for each trajectory that can be used to establish different patterns.

Note that with formula (1) we get a first classification of the individuals in two sets (per gender): $\{i : d_j(i) < 0\}$ and $\{i : d_j(i) \geq 0\}$, each one with a different meaning. In particular, the first one contains the individuals whose trajectories are below the deepest curve, that is, individuals with lower dependency scores than those of the central trend of their age-gender groups, that is later onset of dependency compared to the central trend (healthier individuals). On the other hand, the second set contains the individuals whose trajectories are above the deepest curve and, hence, individuals with higher dependency scores than those of the central trend of their age-gender groups, that is, earlier onset of dependency compared to the central trend (less healthy individuals).

Finally, we obtain the proximity-groups per gender by using the partition established by the quartiles within sets $\{i : d_j(i) < 0\}$ and $\{i : d_j(i) \geq 0\}$, which yields to eight groups per gender (see Figure 3). Other partitions can be considered, depending on the particular interest of the researcher.

As we will see, proximity-groups are relevant in the computation of the dependency-free probabilities and, thus, yielding to quite different premiums.

3.2. Long term care insurance pricing

In order to design LTCI, four main aspects should be considered: the scope of the contract (individual or group policies), the theoretical framework on which it is based, the evaluation of the coverage and its financing. Here we describe the ratemaking for a voluntary individual LTCI, stand-alone product, based on the latest survey on Spanish disabled population, whose premiums are established as a rate per 1000 euros of a care services package. Public financing is out the scope of this paper.

3.2.1. Scenarios considered

We establish several scenarios for LTCI ratemaking attending to gender, proximity-groups (IV–I for $\{d_j < 0\}$ and I–IV for $\{d_j \geq 0\}$) and dependency degree (Degree I or moderate, Degree II or severe, Degree III or major). Thus, the number of total scenarios ascends to 48. Notice that the dependency history of an individual may not reach all the states in a sequential way, that is, the first score reached by an individual can be greater than 50 or 75 points. Therefore, for a non-dependent person we propose to compute three net premiums regarding to the following three situations: covering dependency of at least Degree I, covering dependency of at least Degree II and covering dependency of Degree III. That is, the contract with the widest benefits is that for a situation in which the individual can suffer any kind of dependency (score equal or greater than 25 points); The intermediate situation is that for a contract that covers situations linked to at least severe dependency (score equal or greater than 50 points); Finally, the most restrictive contract is that referred only to major dependency (score equal or greater than 75 points).

3.2.2. Estimation of dependency-free probabilities

We are interested in estimating dependency-free probabilities as well as in identifying the variables (ADL) with persistent, high and low impacts on dependency-free probabilities. Both objectives can be achieved with Cox proportional hazards regression model (Cox 1972; Cox and Oakes 1984), which is one of the most popular regression techniques in survival analysis and can be written as follows:

$$h(t, \mathbf{z}) = h_0(t) \exp\left(\boldsymbol{\beta}'\mathbf{z}\right), \tag{2}$$

where $\mathbf{z}$ is the vector of explanatory variables, $\boldsymbol{\beta}$ is the vector of coefficients of the explanatory variables, function $h(t)$ is the expected hazard at time t and $h_0(t)$ is the baseline hazard function, that represents the hazard when all explanatory variables are equal to zero.

The model can be specified in terms of the survival function $S(t)$. Using the wellknown relationship

$$S(t) = \exp\left(-\int_0^t h(t)\,\mathrm{d}t\right)$$

and modeling the hazard function by (2), we get

$$S(t, \mathbf{z}) = S_0(t)^{\exp(\boldsymbol{\beta}'\mathbf{z})}, \tag{3}$$

where $S_0(t) = \exp(-\int_0^t h_0(t)\,\mathrm{d}t)$ is the baseline survival function at time t, $\mathbf{z}$ and $\boldsymbol{\beta}$ are defined as before.

In our case, the event of interest is not 'survival' itself, but 'being dependency-free of at least Degree d at a given age', $d =$ I, II, III. That is, we interpret function $S(t, \mathbf{z})$ of (3) as the probability of being free of dependency of at least Degree d at time t. In time-discrete framework, t refers to age x. For the sake of simplicity, vector $\mathbf{z}$ is omitted and, from now on, the survival function for each dependency Degree d will be named as $S^d(x)$.

We estimate and validate Cox regression model with the `survival` package in `R`. For each gender, the vector $\mathbf{z}$ of explanatory variables is formed by the proximity-group and the disabilities recorded in EDAD 2008 related to dependency (ADL), that is to present difficulties in performing postural changes, bathing/hygiene, control of physical needs, conducting household life, maintaining interaction and interpersonal relationships, following medical treatments and mobility difficulties (inside and outside the house). The input data are those individuals that in 2008 were between 30 and 100 years old, with a dependency score of zero at the age of 30. For each gender and proximity group, the output of the Cox regression model will be the estimates of the probability of being free of dependency of at least Degree d at age x, $S^d(x)$, for $d =$ I, II, III and $x \in \{30, 31, \ldots, 100\}$.

3.2.3. Actuarial equivalence principle

In what follows we proceed with the estimation of the premiums. The equivalence principle establishes the equality between inflows, that is the actuarial value of premiums, P_x, and outflows, the actuarial value of benefits, B_x (Bowers et al. 1997).

The probabilities involved in the calculus of net premiums can be divided into two groups: one related with the possibility of becoming dependent at a certain degree and other with survival. The first group is calculated considering the probabilities derived from Cox regression model and the prevalence rates for the global Spanish population. In particular, the number of people free of dependency of at least Degree d ($d = \text{I, II, III}$) at age x is obtained as

$$l_x^d = l_{x-1}^d s_{x-1}^d (1 - pr_x^d), \tag{4}$$

where l_{x-1}^d is the number of people free of dependency of at least Degree d at age $x-1$, s_{x-1}^d is the probability of being free of dependency of at least Degree d at age $x-1$ (that is, $s_{x-1}^d = S^d(x-1)$) and pr_x^d is the prevalence rate for the Spanish population with dependency of at least Degree d at age x, which is calculated as the ratio of the number of individuals with at least dependency Degree d at age x to the global Spanish population at age x. Formula (4) gives the raw estimates and we smooth them using GAM models (Werner and Modlin 2016), but keep the same notation for the sake of simplicity. Now we can calculate the probability of being free of dependency of at least Degree d at age x as

$$p_x^d = \frac{l_{x-1}^d}{l_x^d}.$$

The second group of probabilities involved in the calculus of net premiums are those linked to survival. In this case, we have considered the mortality table used by the Spanish Social Security Authority for permanent handicapped pensioners (Orden TAS/4054/2005 2005), in the absence of other information.

Finally, we have that the inflows or net premiums can be expressed as

$$P_x = \sum_{i=x}^{x_{\max}} P_i \left(\frac{1+\pi_p}{1+r}\right)^{i-x} {}_{i-x}p_x \; {}_{i-x}p_x^d, \tag{5}$$

where $x_{\max}$ is the highest age allowed by the company to pay the premium (usually 65 years old), P_i is the nominal premium annually received (by the insurance company) in advance at age i, π_p is the annual growth rate for the premiums, ${}_{i-x}p_x$ is the probability that an individual with age x will remain alive at age $x+i$ (which is given by the disabled Spanish pensioners' mortality table Orden TAS/4054/2005 2005), ${}_{i-x}p_x^d$ is the probability that an individual with age x will reach the age $x+i$ free of dependency of at least Degree d and r is the technical interest rate applied in this case. Hence, premiums are received by the insurance company whenever the individual remains alive and free of dependency of at least Degree d.

Regarding the outflows or benefits, they can be expressed as

$$B_x = \sum_{i=x}^{\omega} B_i \frac{(1+\pi_b)^{i-x}}{(1+r)^{i-x+k}} \; {}_{i-x}p_x \; {}_{i-x|}q_x^d, \tag{6}$$

where ω is the maximum age for receiving the benefits, B_i is the nominal value of the annual benefits (assuming that they will be null during a waiting time of two years), π_b is the annual growth rate for the benefits, k is a parameter related to the benefits payment ($k = 0.5$ if the payment takes place at the middle of the period or $k = 1$ if it takes place at the end of it; we have assumed $k = 1$ in our computations), ${}_{i-x|}q_x^d$ is the probability that an individual with age x will reach the age $x+i$ free of dependency Degree d but he/she falls in at least dependency Degree d during the next year, ${}_{i-x}p_x$ and r are as before.

For each age, the initial premium is computed using the actuarial equivalence principle that establishes the equality between formulas (5) and (6) and considering the following parameter values: $\pi_p = 0.01$, $\pi_b = 0.02$, $r = 0.015$, $x_{\max} = 65$, $\omega = 100$ and $k = 1$. The rest of the premiums are obtained using their link to initial one through the growth rate π_p.

4. Results

4.1. Searching for main effects on dependency-free probabilities

The variable impacts on dependency-free probabilities derived from Cox regression model are presented in Table A2 in the Appendix. The variable effects (in terms of e^{β} estimates) are shown by dependency degree, proximity-group and gender; values within parenthesis correspond to standard deviation of β's estimates. From this table we observe that the highest impact on men's probabilities is registered by bathing/hygiene (51.078) and by control of physical needs regarding women's probabilities (12.842). However, the interpretation of theses magnitudes is not straightforward as in linear regression models. For instance, if we consider two individuals, one with a certain disability and the other with no disabilities, the probability that the first individual becomes dependent of at least Degree d is e^{β} times that of the second one. Thus, we are more interested in the sensitivity of the different variables (disabilities) across groups rather than in the magnitudes. For this reason, a summary is presented through a heat map in Figure 4, where light colors represent low, sometimes null, impacts on dependency-free probabilities, whereas dark colors stand for high effects on dependency-free probabilities.

From Figure 4 we observe that dark colors tend to be more present in proximity groups with $\{d_j < 0\}$ than with $\{d_j \geq 0\}$; this means that the loss of autonomy, that is, the occurrence of disabilities, is more relevant for people with later onset of dependency than for people with earlier onset of dependency compared to a central trend; this pattern is observed in both genders. Another general pattern that can be observed in both genders is that the greater the dependency degree the darker the color, indicating that the variables' impacts on the loss of autonomy increase with the dependency degree.

Which variables present the highest/lowest effects? If we focus on Degree III, there are several variables with high impacts on both genders' probabilities, that are postural changes, control of physical needs and interpersonal relationships. Concerning at least Degree II, the variable with a most persistent impact on both genders' probabilities is medical treatments. Finally, regarding at least Degree I, we observe that the first variable that highly affects women's probabilities is household life. On the other hand, mobility difficulties inside and outside the house have the lowest impact on both genders' probabilities.

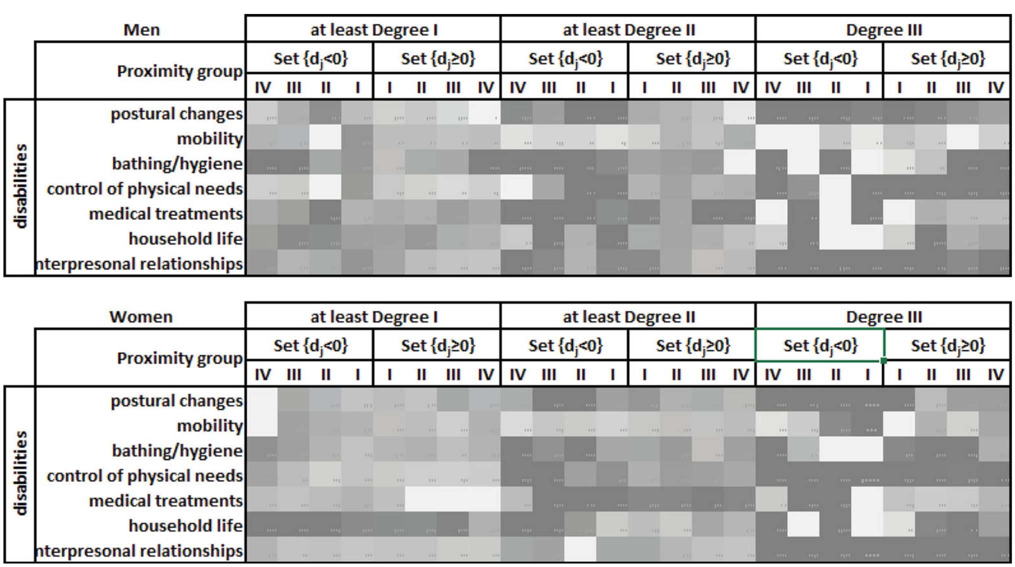


Figure 4. Heat map of main effects derived from Cox regression results (based on Table A2 in Appendix). The darker the color the higher the effect.

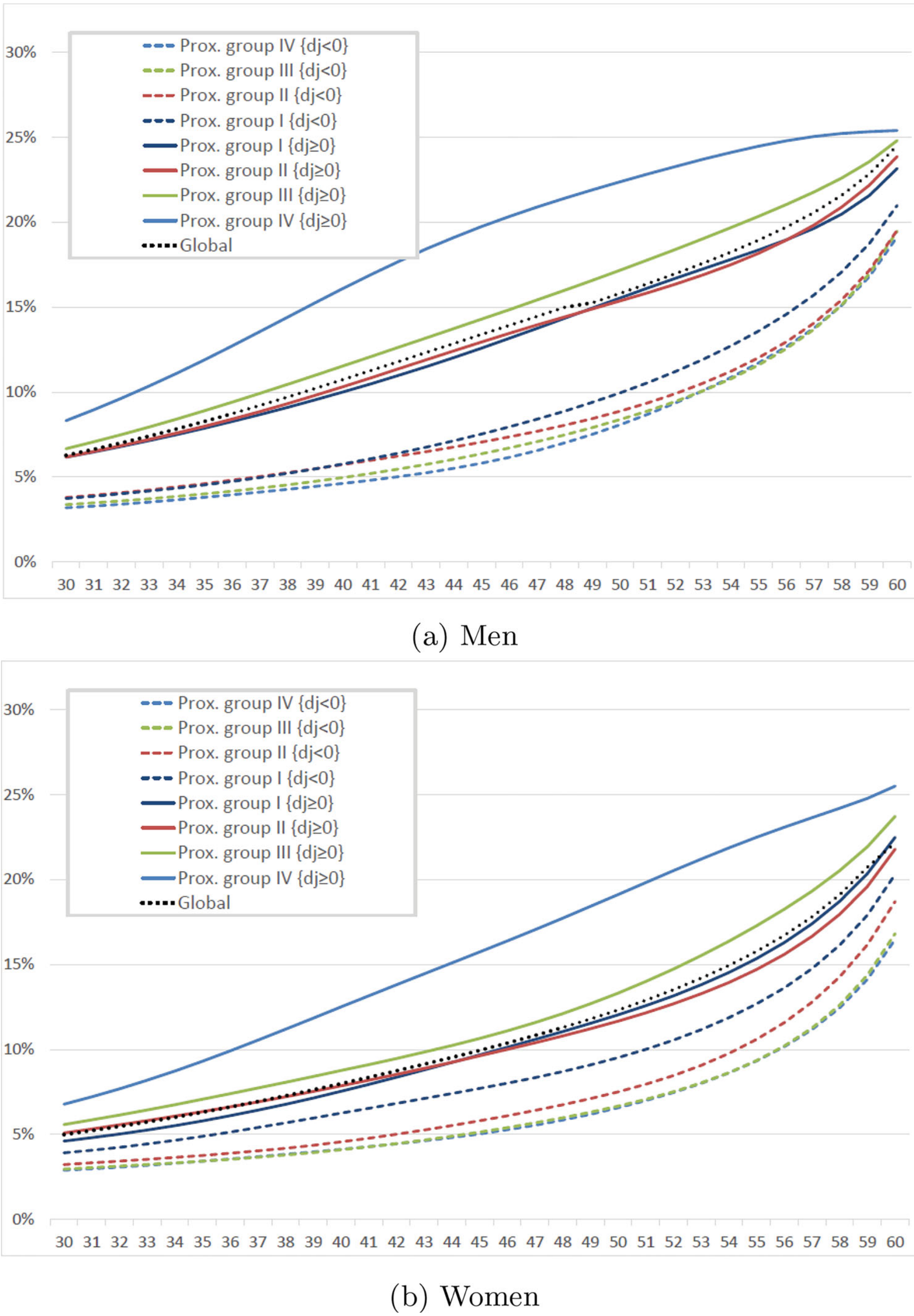
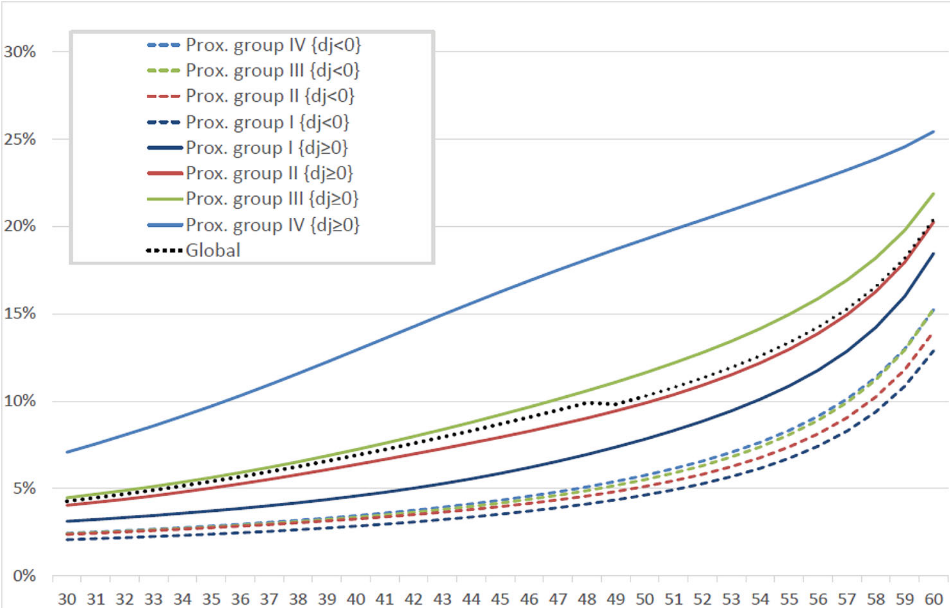


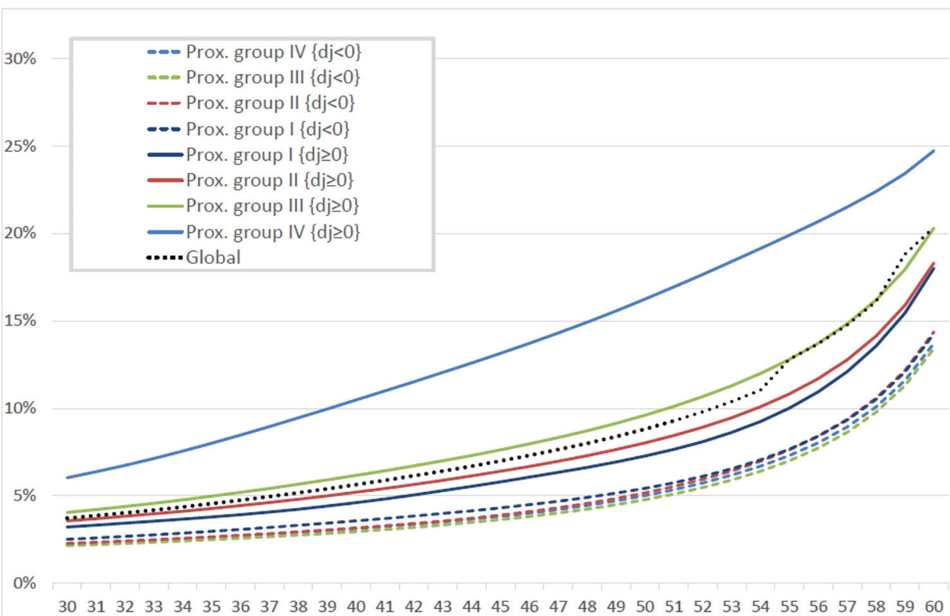
Figure 5. Estimated premiums for 'At least Degree I' by proximity group and gender.

4.2. Contribution of the proximity-groups on LTC ratemaking

In Figures 5–7 we present the estimated premiums for the eight proximity-groups for men and women along age. Premiums are estimated from 7698 observations (2340 corresponding to men and 5358, to women), that represent more than one million of the Spanish population. Regarding each type of contract, premiums for



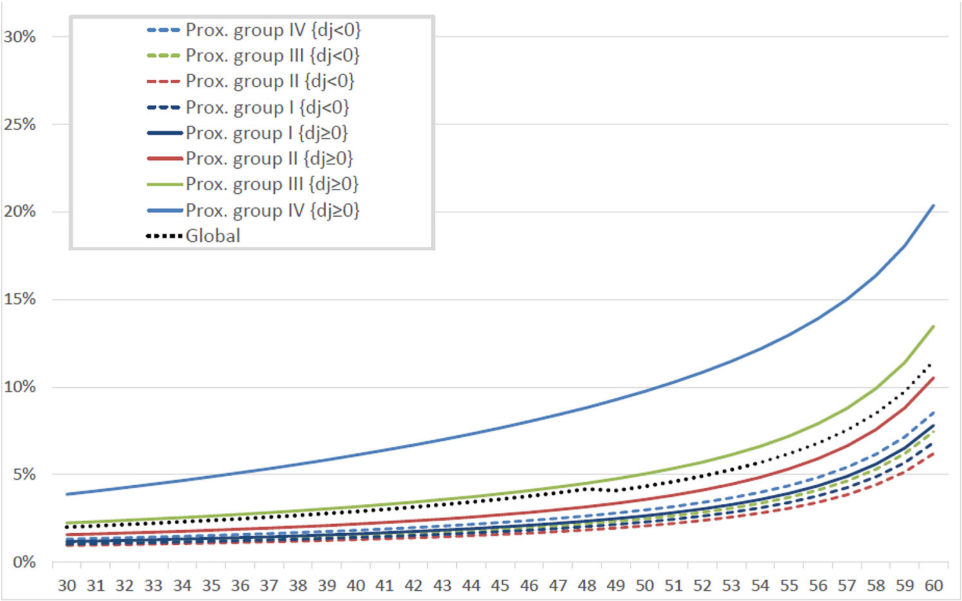
(a) Men



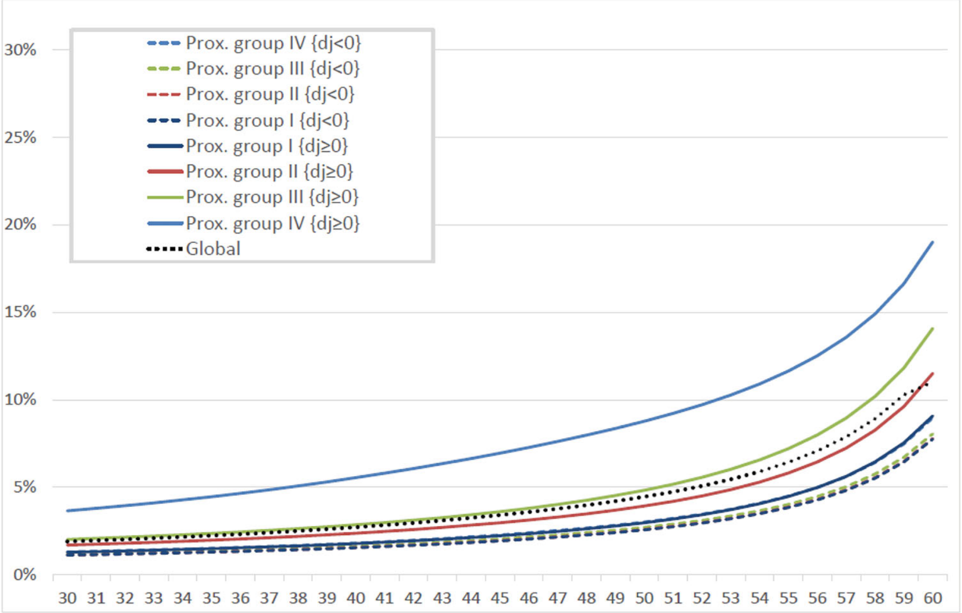
(b) Women

Figure 6. Estimated premiums for 'At least Degree II' by proximity group and gender.

contracts with the widest benefits are calculated from 3213 observations (957 corresponding to men and 2256, to women); for intermediate contracts, premiums are obtained from 2747 observations (811 men and 1936 women); finally, for the most restrictive contracts, premiums are computed from 2000 observations (594 men and 1406 women). The premiums for contracts with the widest benefits (covering dependency of at least Degree I) are shown in Figure 5, intermediate contracts covering dependency of at least Degree II are shown



(a) Men



(b) Women

Figure 7. Estimated premiums for 'Degree III' by proximity group and gender.

in Figure 6 and the most restrictive contracts covering only major dependency are shown in Figure 7. In each figure, we include the premium computed without taking into account the partition by proximity-groups (dotted line); we refer to this curve as Global. We remind that insurance premiums are expressed as a rate per 1000 euros of a care services package and that the LTCI only can be purchased by people under 65 years old.

Table 1. Premiums (in euros) considering number of required packages at the same age.

		The widest benefits (at least Degree I)			Intermediate contract (at least Degree II)			The most restrictive one (Degree III)		
	Age	35	45	55	35	45	55	35	45	55
Men	Prox. group IV $\{d_j < 0\}$	76.2	116.4	234.4	57.2	86.8	166.6	30.8	45.4	87.6
2 packs.	Global premium	165.6	268.0	378.8	108.2	174.0	267.0	48.0	72.2	124.0
(2000 eur.)	Prox. group IV $\{d_j \geq 0\}$	238.0	394.8	489.4	194.4	325.2	441.2	97.8	153.4	259.6
Women	Prox. group IV $\{d_j < 0\}$	102.9	151.2	279.9	78.9	114.6	219.3	45.6	68.7	135.0
3 packs.	Global premium	183.9	298.5	473.4	136.8	219.3	384.3	67.5	102.6	193.2
(3000 eur.)	Prox. group IV $\{d_j \geq 0\}$	279.6	472.2	674.7	240.3	394.5	597.3	134.1	207.6	349.2

Firstly, we observe that the Global premium does not divide the individuals according to earlier or later onset of dependency. In fact, it is almost always between proximity-groups II and III with earlier onset of dependency, which means that this Global premium is biased towards the worst dependency situation. As a consequence, individuals with later onset of dependency or in proximity-groups I and II with earlier onset of dependency would pay more than the real risk covered by the insurance company, whereas the opposite would happen for people in proximity-groups III and IV with earlier onset of dependency. Secondly, we can observe that the differences between premiums for groups with earlier onset of dependency tend to diminish as the contract's coverage decreases. Finally, looking at both genders, we can see that women's premiums are lower than men's for most of the ages considered; this may seem a surprising finding, but in fact it is not, since insurance premiums are expressed as a rate per 1000 euros of a care services package and, at the same age, the number of packages required by gender may not be the same. Indeed, according to Artís et al. (2007), at the same age, for each package required by men, women would require 1.5 packages. Thus, for better comparison, in Table 1 we present the net premiums in euros, considering the number of required packages at the same age, for the latest and earliest onset of dependency groups, at three particular ages, jointly with the Global premium.

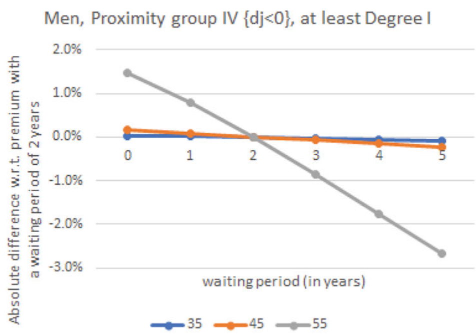
The highest difference between premiums is observed for women's contracts with coverage of at least Degree I (ranging 176.7 to 394.8 euros) and the lowest one occurs in men's contracts with Degree III coverage (ranging from 67.0 to 172.0 euros). For each kind of contract we observe that the premium for the earliest onset of dependency group is around three times the corresponding premium for the latest onset of dependency group. Most interesting, from a policyholder point of view, three types of coverages can be underwritten, going from a minimum level of protection (Degree III) to a maximum one (at least Degree I), the latter being more than twice the former, regardless of the onset of dependency.

Concerning the waiting period of two years, we have driven a simulation study for waiting periods of t years, $t = 0, 1, \ldots, 5$, in order to know how sensitive the premium estimations are to this assumption. To illustrate the results we have chosen the same age values reported in Table 1 and Proximity groups IV with $\{d_j < 0\}$ and IV with $\{d_j \geq 0\}$. In Figures 8 and 9 we depict the absolute differences with respect to premium with a waiting period of $t = 2$ years.

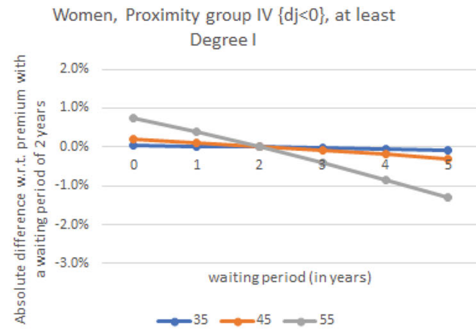
In general, we observe that absolute differences between premiums computed on a waiting period of t years w.r.t. a waiting period of $t = 2$ years tend to increase with

(i) the contracts' coverage; the greatest differences are registered for premiums for the widest contracts (compare Figure 9 with Figure 8),
(ii) the age of the policyholder; this difference is greater for men than for women (compare a-panels with b-panels in both figures),
(iii) the waiting period; the greatest differences are registered by premiums for the widest contracts for men in proximity group IV $\{d_j \geq 0\}$ (compare Figure 9 with Figure 8).

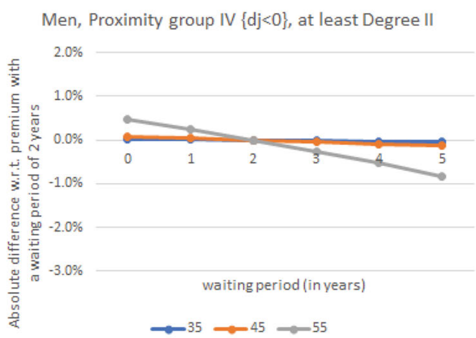
Finally, the smallest differences are registered by premiums for the most restrictive contracts for women in proximity group IV $\{d_j < 0\}$.



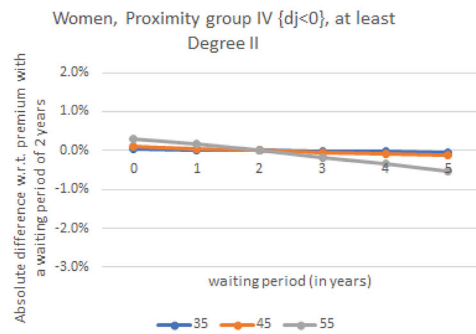
(a1) Men, at least Degree I



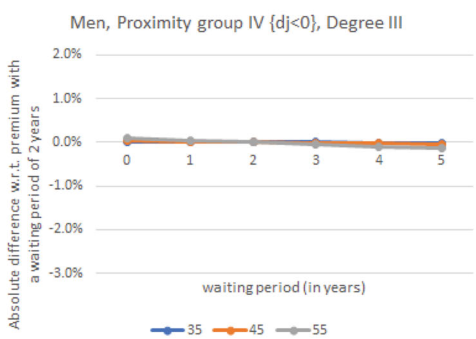
(b1) Women, at least Degree I



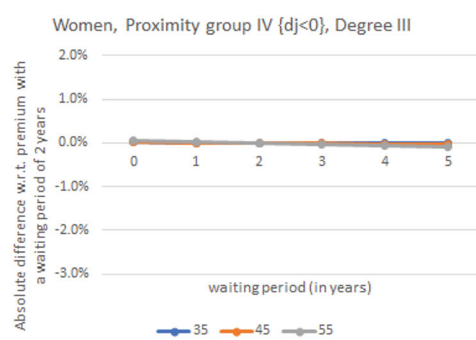
(a2) Men, at least Degree II



(b2) Women, at least Degree II



(a3) Men, Degree III



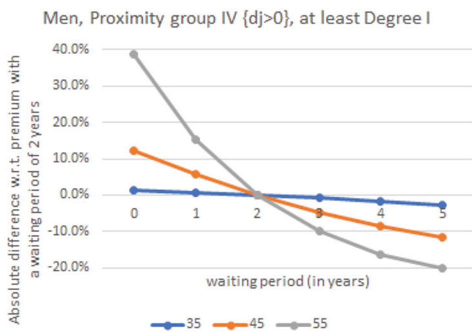
(b3) Women, Degree III

Figure 8. Sensitivity analysis for premiums with waiting period of t years, $t = 0, 1, \ldots, 5$, for proximity group IV $\{d_j < 0\}$. Absolute difference with respect to premium with a waiting period of $t = 2$ years.

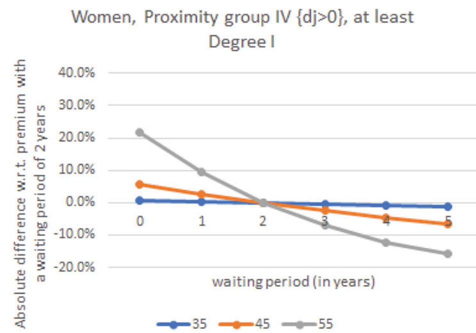
5. Conclusions

Demographic and epidemiological transitions will result in dramatic changes in world populations' health needs. Developed and developing countries are experiencing a steep increase in the need for LTC.

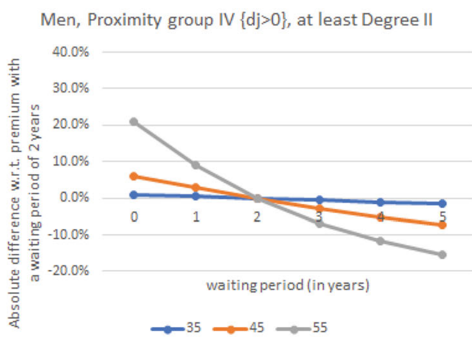
In this work, we introduce a voluntary stand-alone LTCI, focused on the necessities of the eligible dependent population in Spain. The evolution of dependency in the disabled Spanish population is studied through a pseudo panel constructed from EDAD 2008, in the lack of longitudinal studies or the possibility to link different cross-sectional surveys. Our contribution is to use the personal health evolution along life in order to enhance the net premium calculation.



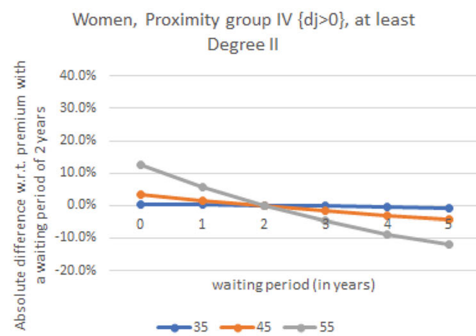
(a1) Men, at least Degree I



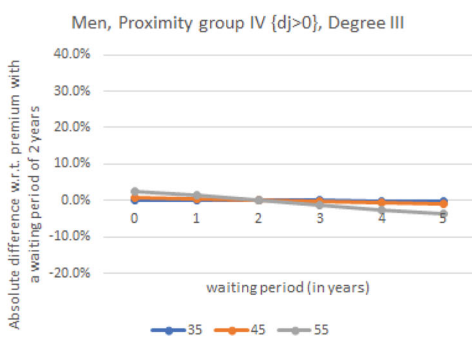
(b1) Women, at least Degree I



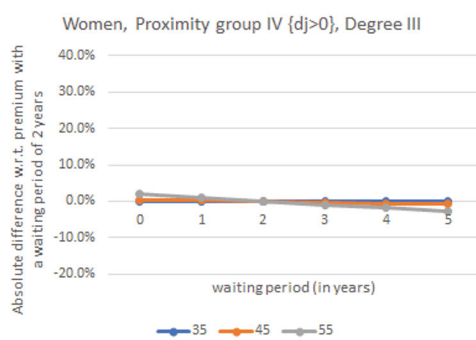
(a2) Men, at least Degree II



(b2) Women, at least Degree II



(a3) Men, Degree III



(b3) Women, Degree III

Figure 9. Sensitivity analysis for premiums with waiting period of t years, $t = 0, 1, \ldots, 5$, for proximity group IV $\{d_j \geq 0\}$. Absolute difference with respect to premium with a waiting period of $t = 2$ years.

The most relevant findings are: First, using personal dependency evolution we are able to establish a wide rage of premiums depending on the onset of dependency. The Global premium calculated without taking into account personal health evolution is 'biased' towards the worst dependency situation. As a consequence, those people with later onset of dependency or in proximity-groups I and II with earlier onset of dependency would pay more than the real risk covered by the insurance company; Second, the differences between premiums for groups with earlier onset of dependency tend to diminish as the contract's coverage decreases; Third, in general, premiums (expressed as a rate per 1000 euros of a care service package) are lower for women than for men for most of the ages considered; This is not contradictory to the insurance literature, since, at the same age, the number of packages required by gender is different (in Spain, 1.5 packages for women for each package for men). Taking this into account, if we express the net premiums in euros, women's premiums are between 1.2 and 1.5 times those of men. Finally, our LTCI proposal can be considered as complementary or substitute for public LTC system, going from a minimum to a maximum level of protection. Thus, a policyholder can choose to underwrite among three kinds of coverages, the widest coverage's premium being more than twice the most restrictive one, regardless of the onset of dependency.

Notes

1. Actuarial Standard Board (2010) defines LTCI as 'a policy, contract, or arrangement providing LTC benefits, either on a stand-alone basis or as part of a plan that provides other benefits as well, except where the LTC benefits are an immaterial feature'.
2. Article 5(1) of Council Directive 2004/113/EC prohibits any result whereby differences arise in individuals premiums and benefits due to the use of gender as a factor in the calculation of premiums and benefits. It does not prohibit the use of gender as a risk-rating factor in general. Such use is allowed in the calculation of premiums and benefits at the aggregate level, as long as it does not lead to differentiation at individual level. After the Test-Achats ruling, it therefore remains possible to collect, store and use gender status or gender-related information within those limits, i.e. reserving and internal pricing, reinsurance pricing and marketing and advertising (European Comission 2012).
3. In 2001, the World Health Organization (2001) established a framework for measuring health and disability at both individual and population levels, which was known as the 'International classification of functioning (ICF), disability and health'. The ICF tries to establish a consensus in its understanding, by establishing a difference between the basic activities of daily living (ADL) and the instrumental ADL. The basic activities are defined as those activities which are essential for an independent life.

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Appendix

Spanish legislation on dependency

Dependency situation in Spain is ruled by article 2 of Act 39/2006, of 14th December, on the Promotion, Personal Autonomy and care for Dependent persons and Royal Decree 504/2007.

The former contains the definition of dependency itself as a "permanent state in which persons that for reasons derived from age, illness or disability and linked to the lack or loss of physical, mental, intellectual or sensorial autonomy require the care of another person/other people or significant help in order to perform basic activities of daily living or, in the case of people with mental disabilities or illness, other support for personal autonomy".

The latter establishes a rating scale, going from 0 to 100 points, that takes into account the disabilities suffered and their intensities. This rating scale is categorized in four degrees: No dependency (less than 25 points), Degree I or moderate dependency (greater or equal to 25 but under 50 points), Degree II or severe dependency (greater or equal to 50 but under 75 points), Degree III or major dependency (greater or equal to 75 points). In turn each degree is divided into two levels. See Table A1 in for more details.

According to the score reached by an individual in the dependency rating scale, the Spanish legislation establishes a minimum level of protection, which is defined and financially guaranteed by the General State Administration.

Table A1. Dependency graduation according to Spanish legislation.

Dependency	Degree	Level	Score	Dependency	Degree	Level	Score
Non-dependent	–	–	[0, 25]	Severe	II	1	[50, 65]
					II	2	[65, 75]
Moderate	I	1	[25, 40]	Major	III	1	[75, 90]
	I	2	[40, 50]		III	2	[90, 100]

Moderate dependency	The person needs help in order to perform various basic ADL[a] at least once a day or the person needs intermittent or limited support for his/her personal autonomy
Severe dependency	The person needs help in order to perform various basic ADL two or three times a day, but he/she does not want the permanent support of a carer or he/she needs extensive support for his/her personal autonomy
Major dependency	The person needs help in order to perform various basic ADL several times a day or he/she needs the indispensable and continuous support of another person or he/she needs generalised support for his/her personal autonomy

[a] ADL stands for Activities of Daily Living.

Table A2. Cox regression results for men and women: e^{β}'s and β's standard deviation (within parenthesis).

	At least Degree I or Moderate Dependency								At least Degree II or Severe Dependency								Degree III or Major Dependency							
	Set $\{d_j < 0\}$				Set $\{d_j \geq 0\}$				Set $\{d_j < 0\}$				Set $\{d_j \geq 0\}$				Set $\{d_j < 0\}$				Set $\{d_j \geq 0\}$			
Prox. group	IV	III	II	I	I	II	III	IV	IV	III	II	I	I	II	III	IV	IV	III	II	I	I	II	III	IV
Men																								
postural changes	1.297	1.671	2.107	1.520	1.258	1.363	1.158	0.800	2.137	1.896	3.706	4.589	1.724	1.616	1.451	0.922	2.534	3.165	2.911	2.217	20.362	2.209	2.031	1.876
	(0.017)	(0.016)	(0.015)	(0.016)	(0.01)	(0.01)	(0.01)	(0.012)	(0.021)	(0.023)	(0.025)	(0.032)	(0.013)	(0.013)	(0.012)	(0.013)	(0.031)	(0.047)	(0.081)	(0.101)	(0.087)	(0.024)	(0.019)	(0.02)
mobility	1.080	1.056	0.000	1.562	0.905	0.908	0.806	0.890	0.334	0.511	0.540	0.310	0.575	1.058	0.812	1.182	0.000	0.000	0.755	0.202	0.818	0.632	0.000	0.609
	(0.036)	(0.019)	0.000	(0.017)	(0.01)	(0.011)	(0.011)	(0.015)	(0.029)	(0.025)	(0.026)	(0.036)	(0.014)	(0.014)	(0.013)	(0.015)	(0)	(0)	(0.084)	(0.117)	(0.06)	(0.021)	0.000	(0.019)
bathing/hygiene	6.644	1.926	1.310	1.542	0.867	1.226	1.248	2.225	14.626	3.996	2.830	1.765	1.342	1.418	1.524	0.000	51.078	0.000	7.882	0.000	0.335	0.830	6.736	2.893
	(0.056)	(0.022)	(0.019)	(0.019)	(0.013)	(0.013)	(0.016)	(0.022)	(0.105)	(0.042)	(0.047)	(0.04)	(0.021)	(0.018)	(0.02)	(0)	(0.162)	(0)	(0.161)	0.000	(0.043)	(0.05)	(0.089)	(0.04)
physical needs	0.623	0.673	0.000	1.505	0.715	0.579	0.430	0.610	0.000	1.282	2.704	3.858	1.082	1.334	1.071	1.169	2.554	1.612	0.000	3.583	3.755	3.511	6.151	4.143
	(0.017)	(0.017)	(0)	(0.018)	(0.01)	(0.01)	(0.011)	(0.01)	(0)	(0.021)	(0.026)	(0.032)	(0.013)	(0.013)	(0.012)	(0.011)	(0.038)	(0.043)	0.000	(0.108)	(0.051)	(0.03)	(0.033)	(0.022)
medical treatments	1.200	1.407	2.184	1.095	1.201	1.123	1.430	1.249	5.796	2.963	4.402	1.716	1.837	1.312	2.357	3.717	0.000	6.060	0.000	14.932	0.000	1.146	0.922	0.954
	(0.035)	(0.018)	(0.016)	(0.016)	(0.013)	(0.012)	(0.013)	(0.017)	(0.084)	(0.037)	(0.034)	(0.034)	(0.019)	(0.015)	(0.017)	(0.021)	(0)	(0.15)	(0)	(0.189)	(0)	(0.04)	(0.033)	(0.021)
household life	1.403	1.753	1.712	1.380	1.349	1.516	1.180	1.114	0.707	1.941	1.120	2.472	1.236	1.328	1.149	0.850	0.619	2.708	0.000	0.000	0.583	14.458	1.154	1.312
	(0.035)	(0.023)	(0.019)	(0.018)	(0.012)	(0.012)	(0.013)	(0.017)	(0.041)	(0.037)	(0.033)	(0.038)	(0.017)	(0.016)	(0.016)	(0.019)	(0.056)	(0.12)	(0)	(0)	(0.055)	(0.08)	(0.027)	(0.026)
interpers. rel.	1.516	1.059	1.211	1.588	1.317	0.935	0.833	0.795	2.149	1.773	1.087	1.771	1.779	1.290	0.852	0.957	3.208	3.047	10.165	4.798	3.715	2.021	1.767	1.942
	(0.016)	(0.018)	(0.02)	(0.019)	(0.01)	(0.01)	(0.009)	(0.009)	(0.017)	(0.024)	(0.029)	(0.03)	(0.014)	(0.012)	(0.01)	(0.01)	(0.024)	(0.04)	(0.086)	(0.104)	(0.035)	(0.019)	(0.014)	(0.012)
Women																								
postural changes	0.000	1.732	1.436	1.101	1.274	1.095	1.774	1.435	1.649	3.129	2.765	1.882	2.110	1.516	1.654	1.321	3.478	2.601	2.983	8.433	2.976	1.289	1.963	1.992
	(0)	(0.011)	(0.009)	(0.008)	(0.006)	(0.007)	(0.007)	(0.008)	(0.017)	(0.018)	(0.015)	(0.016)	(0.009)	(0.009)	(0.009)	(0.008)	(0.027)	(0.032)	(0.054)	(0.073)	(0.024)	(0.016)	(0.014)	(0.013)
mobility	0.000	1.373	1.170	1.097	0.862	0.923	0.625	1.119	0.425	0.771	0.672	0.558	0.741	0.876	0.839	0.931	0.327	0.661	1.772	5.480	0.000	1.118	0.593	1.305
	(0)	(0.012)	(0.01)	(0.008)	(0.007)	(0.007)	(0.008)	(0.009)	(0.021)	(0.016)	(0.015)	(0.016)	(0.009)	(0.009)	(0.009)	(0.009)	(0.027)	(0.03)	(0.052)	(0.095)	0.000	(0.015)	(0.012)	(0.013)
bathing/hygiene	1.685	1.394	1.090	0.841	1.049	1.121	0.880	1.101	4.423	1.674	2.236	1.303	1.317	1.498	0.873	1.403	2.236	1.030	0.000	0.000	1.820	1.995	2.291	1.174
	(0.017)	(0.014)	(0.012)	(0.01)	(0.009)	(0.008)	(0.009)	(0.011)	(0.036)	(0.027)	(0.024)	(0.023)	(0.013)	(0.013)	(0.011)	(0.013)	(0.08)	(0.076)	(0)	(0)	(0.047)	(0.03)	(0.026)	(0.028)
physical needs	1.354	0.960	0.571	0.829	0.694	0.632	0.615	0.662	4.212	2.225	1.395	1.670	1.141	1.475	1.408	1.269	8.523	6.656	8.796	12.842	8.117	3.522	1.915	2.038
	(0.01)	(0.01)	(0.01)	(0.01)	(0.006)	(0.007)	(0.007)	(0.007)	(0.016)	(0.015)	(0.013)	(0.016)	(0.008)	(0.009)	(0.008)	(0.008)	(0.033)	(0.04)	(0.049)	(0.079)	(0.034)	(0.02)	(0.015)	(0.011)
medical treatments	0.936	0.834	0.951	1.108	0.885	0.000	0.000	0.000	0.944	2.158	2.057	3.926	1.819	1.826	1.950	1.836	0.703	2.183	2.119	0.000	0.831	0.662	0.713	1.034
	(0.014)	(0.01)	(0.01)	(0.009)	(0.007)	(0)	(0)	(0)	(0.02)	(0.019)	(0.018)	(0.021)	(0.01)	(0.011)	(0.01)	(0.01)	(0.042)	(0.046)	(0.052)	0.000	(0.027)	(0.018)	(0.014)	(0.013)
household life	3.664	4.235	2.951	1.765	1.745	1.731	1.887	1.134	2.313	2.212	1.518	0.677	0.911	0.678	1.294	1.033	4.464	0.000	11.758	0.000	0.330	1.824	3.007	1.402
	(0.02)	(0.019)	(0.016)	(0.013)	(0.01)	(0.01)	(0.011)	(0.01)	(0.031)	(0.03)	(0.024)	(0.024)	(0.013)	(0.012)	(0.012)	(0.011)	(0.074)	0.000	(0.154)	0.000	(0.042)	(0.026)	(0.029)	(0.019)
interpers. rel.	1.085	0.820	0.846	0.768	0.822	0.826	0.682	0.689	1.308	1.367	0.000	1.308	1.317	1.036	0.848	0.796	2.572	4.818	2.125	3.358	5.231	2.299	2.157	2.407
	(0.009)	(0.011)	(0.011)	(0.013)	(0.008)	(0.007)	(0.007)	(0.006)	(0.011)	(0.013)	0.000	(0.018)	(0.009)	(0.008)	(0.007)	(0.006)	(0.015)	(0.025)	(0.033)	(0.049)	(0.021)	(0.011)	(0.01)	(0.008)