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Resum.- En aquest document de treball s'utilitza el protocol estàndard ODD (Overview, Design concepts and Details) per descriure un model de simulació social que hem anomenat DEMOCARE. El model DEMOCARE és un exemple d'integració de la microsimulació del parentiu amb un model basat en agents (ABM) que s'ha creat per estudiar la dinàmica de la demanda i l'oferta dels serveis d'atenció prestats a persones dependents majors (65+), a Espanya, per persones de l'entorn familiar. La nostra pregunta d'investigació busca determinar la mesura en què la demanda d'assistència pot quedar satisfeta amb el temps disponible dels membres de la família (esposa, fills, germans, fillastres) que reconstruïm en el model, o bé si és necessari recórrer (parcialment o total) a professionals externs a la família. El model té en compte els canvis demogràfics, mitjançant la comparació de cinc generacions espanyoles diferents, amb nivells molt diversos de fecunditat i mortalitat, i utilitza dades observades per la probabilitat de ser dependent, les diferències en els nivells d'educació així com la relació amb l'activitat laboral.

Paraules clau: vellesa; Dependència; Cuidadors familiars; Espanya; Models basats en agents; Micro-simulació; cura informal; cura formal; DEMOCARE.

Resumen.- En este documento de trabajo se utiliza el protocolo estándar ODD (Overview, Design conceptos and Details) para describir un modelo de simulación social que hemos llamado DEMOCARE. El modelo DEMOCARE es un ejemplo de integración entre la microsimulación del parentesco y un modelo basado en agentes (ABM) que se ha creado para estudiar la dinámica de la demanda y la oferta de los servicios de atención prestada a personas dependientes mayores (65+), en España, por personas del entorno familiar. Nuestra pregunta de investigación busca determinar la manera en que la demanda de asistencia se puede satisfacer con el tiempo disponible de los miembros de la familia (esposa, hijos, hermanos, hijastros) que reconstruimos en el modelo, o bien si es necesario recurrir (parcial o totalmente) a profesionales externos a la familia. El modelo tiene en cuenta las tendencias sociodemográficas, mediante la comparación de cinco generaciones españolas diferentes, con niveles muy distintos de fecundidad y mortalidad, y utiliza datos observados para la probabilidad de ser dependiente, las diferencias en los niveles de educación así como la relación con la actividad laboral.

Palabras clave: Vejez; Dependencia; Cuidadores familiares; España; Modelos basados en agentes; Micro-simulación; Cuidado informal; Cuidado formal; DEMOCARE.

Abstract.- In this working paper we apply the standard ODD (Overview, Design concepts and Details) Protocol to describe a social simulation model that we have called DEMOCARE. The DEMOCARE model is an example of integrating microsimulation of kinship with agent-based modelling (ABM) that has been developed to study the dynamics of the demand and supply of elderly (65+) care in Spain at the family level. Our research question is to determine the extent to which the request for assistance can be covered by the time that family members (spouse, children, brothers and sisters, step-children) that we reconstruct in the model have available, or If it is necessary to resort (partially or totally) to professionals from outside the family. The model considers demographic change by means of comparing five different Spanish generations with very different levels of fertility and mortality and uses observed data on the probability of being dependent, educational differences and labour force participation.

Key words: Elderly; Dependency; Family caregivers; Spain; Agent Based Models; Micro-simulation; Informal care; Formal care; DEMOCARE.

Résumé.- Dans ce travail nous utilisons le protocole standard ODD (Overview, Design concepts and Details) pour décrire un modèle de simulation que nous appelons DEMOCARE. C'est un modèle mixte de microsimulation de la parenté et de ABM (modèle de simulation d'agents) que nous avons développé pour étudier la dynamique de la demande et l'offre de temps pour l'assistance aux personnes âgées (65 ans et plus) en Espagne au niveau familial. Notre question de recherche est de déterminer dans quelle mesure la demande d'assistance peut être couverte par le temps des membres de la famille proche (conjoint, enfants, éventuellement frères et soeurs, enfants par alliance) que nous reconstruisons dans le modèle, ou bien s'il est nécessaire de recourir (partiellement ou totalement) à des professionnels externes à la famille. Le modèle tient en compte le changement démographique, par une comparaison entre cinq différentes générations espagnoles avec des niveaux de fécondité et de mortalité très différents, et utilise des données observées pour les probabilités d'être dépendant, les différences de niveau éducatif, ainsi que l'activité.

Mot-clés: Vieillesse; Dépendance; Soigneurs familiaux; Espagne; Modèle de simulation d'agents; Microsimulation de la parenté; Soins officiels; Soins familiaux; DEMOCARE.

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APPLICATION OF THE OVERVIEW, DESIGN CONCEPTS AND DETAILS (ODD) PROTOCOL TO DESCRIBE THE DEMOCARE AGENT BASED MODEL[1]

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The following model description follows the ODD (Overview, Design concepts, Details) protocol (Grimm et al. 2010; Grimm et al. 2006). The purpose of following the ODD protocol is to standardize the descriptions of social simulation models and to clarify the components of the model. We use this protocol to allow the analysis to be reproduced by other researchers.

1.- Purpose

Because of remarkable improvements in life expectancy of 30-40 years since the end of the 19th century in western Europe, the USA, Canada, Australia, New Zealand and Japan and with no sign of deceleration, most high-income countries experience rapidly growing population of old-aged individuals (Christensen et al. 2010). This has led to new areas of research that deal with how these people live, including changes in family and household composition, trends in morbidity and disability, as well as gender and socioeconomic inequalities in these outcomes. In the case of Spain, which is the focus of our research on elderly care strategies, the process of population ageing has been particularly rapid with a doubling of the number of persons aged over 65 years of age in the last 30 years. This age

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group now represents 19% of the total population, and with the 80+, the age group for which about half of them have difficulties to carry out one or more (instrumental) activities of daily living (Spijker and Zueras 2016), experimenting a four-fold increase to 6% of the total. Moreover, Spanish studies on old-age care have shown that informal (i.e. unpaid and mainly family-based) care is the most common source of support received by older people. For instance, according to studies by Spijker and Zueras (2016) and (Durán 2000, Durán 2002), 80 to 90 per cent of people aged 65 years and older who obtained care at their own home relied on informal care and for the remainder on formal care (i.e. home-based professional care and institutions). Other studies that focused on Spain have identified a mixed care pattern that combines any type of formal care with informal care at the same time (Rodríguez 2014; Rogero-García 2009; Rogero-García et al. 2008).

As a result, particularly since the start of this century much concern has been expressed by public commentators, governments and social scientists about how both current and future provision of elderly care can be met by both informal care and formal care (WHO 2002; WHO 2015). Informal care is often preferred by the elderly to formal care (Pinquart and Sörensen 2002; Rogero-García 2009). However, the supply of informal caregivers may decline in future due to changes in the age composition of the population as well as for other reasons including the effect of having smaller family sizes (Clarke 1995), the rising incidence of childlessness (Evandrou and Falkingham 2000), increasing female labour force participation (Allen and Perkins 1995) and rising rates of divorce and remarriage (Albertini and Saraceno 2008; Glaseret al. 2006; Lin 2008; Wells and Johnson 2001; Ganong et al. 2009; Grimm et al. 2006; Van Der Pas and Van Tilburg 2010). The way in which family structures and family relations are likely to evolve in the future may have direct implications for the amount and type of informal elderly care provided by family members (e.g. being divorced and having no daughter may imply having no kin available for personal care). As any reduction in informal care supply will have a substantial influence on the demand for formal care, a better understanding of the impact of socio-demographic trends on informal care dynamics is therefore clearly an issue of great importance.

The main purpose of this paper is to document the development of an agent-based model of both elderly care demand on the one side and informal elderly care supply on the other. We take into consideration the effects of socio-demographic trends that include low birth rates, increasing life expectancy and changing family structures (in which we currently account for fewer offspring and more childlessness but not yet for the fact that there are more divorced elderly as well as fewer widows and widowers) as well as educational attainment and labour force participation. The specific purpose of our model is to determine how the needs for the elderly will be covered through formal, informal or mixed (formal + informal) care. The simulated individuals (or agents) are representative of five different birth cohorts in Spain (1928, 1938, 1948, 1958 and 1968), persons who we will refer as 'egos' throughout this manuscript, each 'ego' will be the root of the family networks of agents. The demographic characteristics of these different cohorts provide a good view of ongoing demographic changes. In general terms, as Table 1 shows, both male and female life expectancy has steadily increased, while the total cohort fertility rate (CTFR) has been declining since the 1938 female birth cohort who had 2,6 children, compared to 1,5 among those born in 1968. Each ego will have a different family network of potential caregivers available. The generation of the ego's children has the same survival, union formation and fertility risks as their parents. As shown in Table 1, these risks correspond to the mean values of the total fertility rate, the age at first marriage, the proportion who ever married and, therefore, who were at risk of having a child and, for the latter, the probabilities of having a first, second and third or plus child. These family networks are created by a micro-simulation of kinship in a stochastic way, considering heterogeneity at the individual level for each dimension of the family formation process.

Table 1.- Demographic parameters of the simulated Spanish cohorts of egos

Cohort	Total Fertility Rate (CTRF) #	Age at first Union †	Proportion ever in union †	Probability first child #	Probability second child #	Probability third+ child #	Life expectancy Female	Male†
1928	2,520	25	0,86	0,822	0,854	0,557	57,0	55,6
1938	2,599	25	0,90	0,862	0,892	0,586	65,0	63,4
1948	2,265	24	0,95	0,867	0,882	0,453	73,7	71,9
1958	1,820	26	0,92	0,846	0,800	0,305	80,6	78,6
1968	1,527	28	0,92	0,792	0,724	0,221	85,5	83,4

Source: #estimations based on (Devolder) (accepted for publication). †estimations made by authors.

2.- Entities, state variables, and scales

The model has two kinds of entities or agents (persons simulated by the model; in Netlogo parlance: breed [collection, state]):

- Individual who are either dead or not born at time t (In Netlogo syntax breed [deads dead])
- Individual who are alive at time t (breed [living alive])

The global variables of the model (globals[...]) which are shared by all agents and can also be used anywhere in the NetLogo model correspond to the following list:

- CareDict (The different categories of care each agent can provide or receive?)
- CareTable (The number of hours of care that each agent can offer or may need, according to age, labour force participation status and dependency level)
- ActTransTable (Multistate transition table for labour force participation: transition from/to each of the activity level (not active, part-time or full-time job), by age, sex, educational level and dependency status)
- ActTrans (Transition probability of going from a activity state to another, by age, educational level and dependency status)
- DependencyTable (Proportion of persons by dependency status (0 corresponds to a person with no disability, 1 to a person with a low level of disability and who is not dependent, 2 to a person who has a mild dependency due to having difficulties to carry out one activity of daily living (ADL) or any instrumental activity of daily living (IADL), 3 to a person who is fully dependent because she/he has difficulties to carry out at least two ADL's), according to age, sex and education level)
- TransitionProbs (Transition probability of going from a dependency state to another, by age, sex and educational level)
- varsHeader (A variable to read the initial tables)
- counter_setup

Each individual agent (ego) is also characterised by its owns variables (turtles-own[...]) which are provided below together with their definitions. The level of most ego's is set at the beginning of the program and is constant afterwards (e.g. gender, idfamily, status, tickIn, tickOut), but some of them will change during the simulation (e.g. age, dependency, needed, care). In Netlogo they are defined as follows:

Agent's variables

- gender
- aged (Age of agents: increasing by one year for each step or 'tick')
- status (Social status of agents based on their educational level (low(L)/medium(M)/high(H))
- tickIn Year (tick) when agents enter into the simulation (either by birth or by marriage)
- tickOut (Year (tick) when agents die and exit the simulation)

- ego (whether the person is a member of the birth cohort whose demand for care is studied in the model. Egos are also the root of the family networks of agents)
- dependency (0 corresponds to a person with no disability, 1 to a person with a low level of disability but who is not dependent, 2 to a person who has a mild dependency due to having difficulties to carry out one activity of daily living (ADL) or any instrumental activity of daily living (IADL), 3 to a person who is fully dependent because she/he has difficulties to carry out at least two ADL's): this level is stochastically determined as each step or tick, based on the previous state of dependency and on a table of transition probabilities going in a unidirectional way from lower to higher level of dependency. Disability stands for functional impairments and limitations acquired by an individual that affects their daily life activities. Dependency is defined here as the requirement of personal assistance to overcome such limitations.
- needed (total hours of care needed before receiving any care from family members): it changes according to the dependency status of the person.
- care (net hours of care still needed after receiving the maximum number of hours that can be given by the family network, i.e. by the partner and/or the children): it changes according to the difference between the value of needed and the total number of hours of care provided by the family network.
- idfamily (the family network identification number)

Variables for labour force activity

- activity (status of not working (U) —i.e. unemployed, and retired or out of the workforce for any other reason—, having a part-time job (P) or having a full-time job (F)): it changes at each tick in a stochastic way according to the table of labour force activity transition probabilities from/to any of these three states.
- ageRecAct (we re-codify the activity age being 16 years old as the minimum age to enter the labour market and 69 years old as the maximum age for being in the labour market).
- activityRec (we re-codify the labour force activity status as not working (1), working half-time (2), working full-time (3))

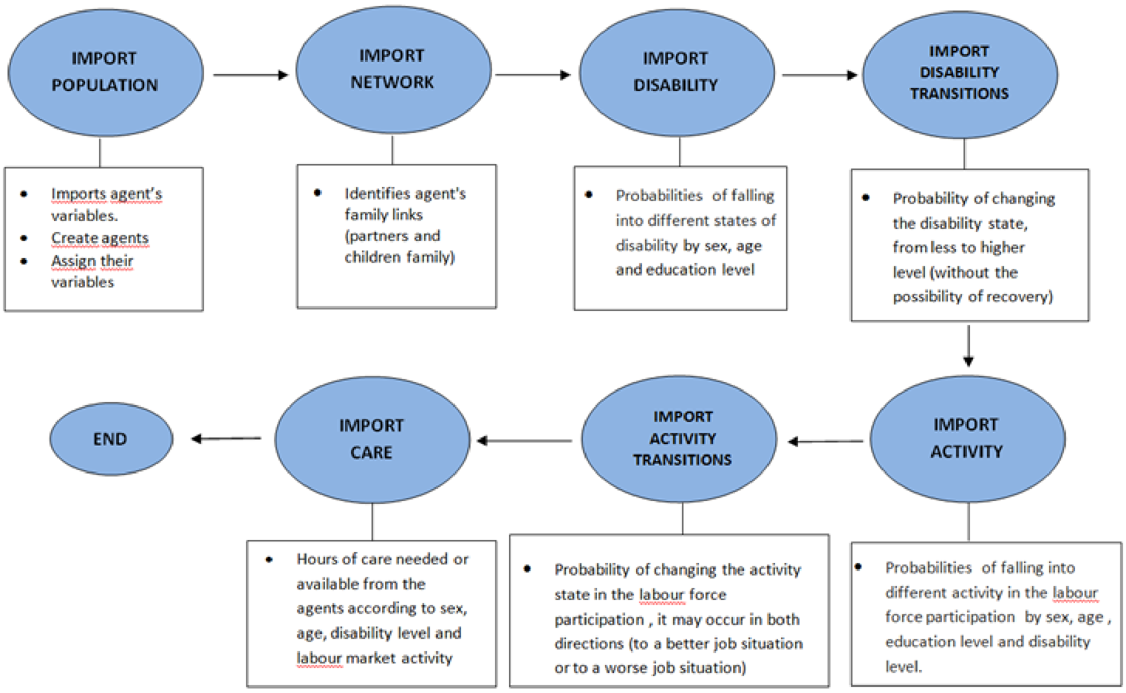
Variables for dependency

- ageRecDep (we re-codify the minimum age to have a dependency as 20 years old)
- statusRec (we re-codify social status or educational level as 0 being low (less than primary education), 1 being medium (primary education) and 2 being high (secondary or higher education)
- ageRecCare (we re-codify the maximum lifespan to be 104, if there is any agent older than 104 it is recoded at 104)

3.- Process overview and scheduling

Here we deal with the dynamics of our agents, which mean all the processes that change the state variables of the agents. Thus, to provide an overview of a model's processes we simply must ask ourselves: what are the model agents doing? What behaviours do the agents execute as simulated time proceeds? What updates and changes happen in their environment? We first start with the initialization of the model by defining a procedure named SETUP summarized in the following flowchart.

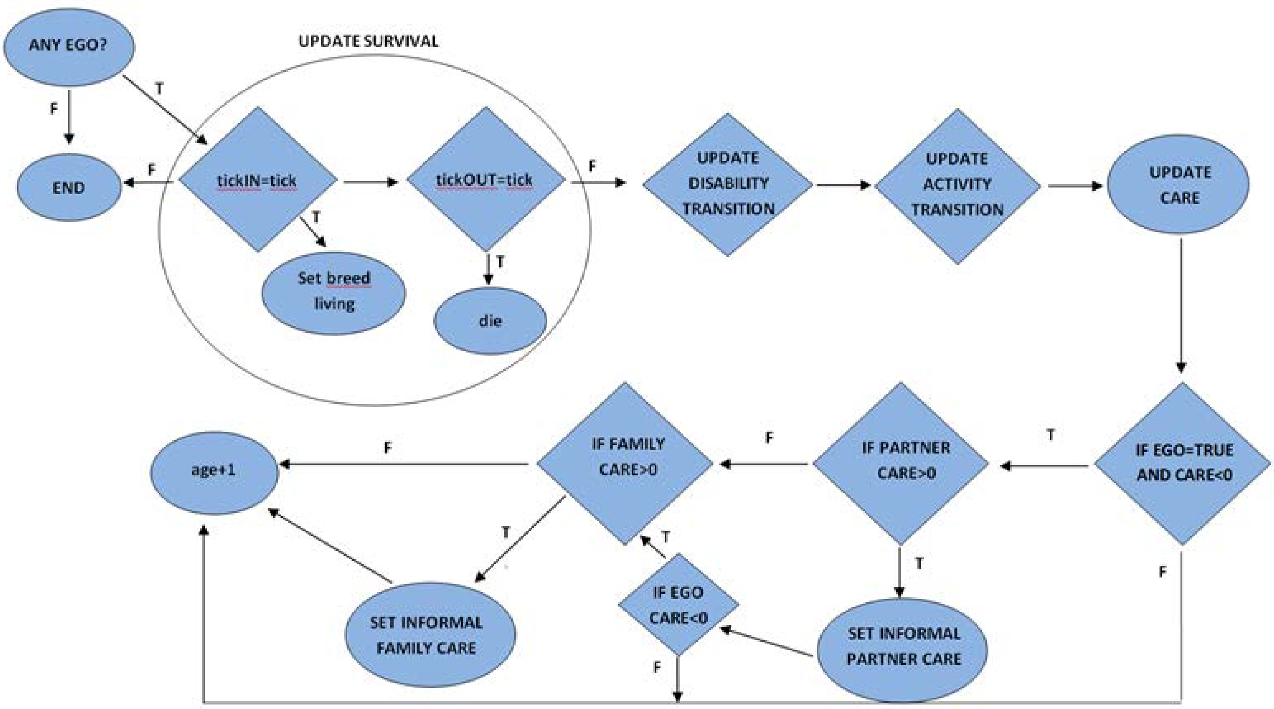
Figure 1.- Flowchart of the SETUP



After the import of the data (the SETUP procedure), the dynamic simulation process takes place with successive cycles (ticks). The following flowchart summarizes the changes of states that occur at each cycle (tick) where the situation of each agent is updated based on a combination of:

(1) Transition tables (MICROSIMULATION)
(2) Situation of the agent in relation to his/her social network (ABM)

Figure 2.- Flowchart of the GO (changes of states that occur at each cycle (tick))



At the start of each year (or cycle or tick), the model checks whether there is any 'ego' alive, and if not, the model ends. If there are still living agents, their situation is updated starting with the survival module. Each agent has a tickIn and a tickOut value that determine whether for the current tick they will form part of the family network. If the current tick value is superior or equal to the individual's tickIn value, which corresponds either to a case of a birth or a marriage, the agent is alive (which correspond to NetLogo breed living state). If the tickOut value is the same to the actual tick, the agent dies and moves out of the model. If the agent dead is an 'ego' then he or she and all his or her family members are removed from the model. Next, each individual or agent's labour force activity and dependency levels are updated in a stochastic way. The model generates random numbers using the uniform distribution between 0 and 1 and it is compared to the probability given from the tables (dependency-transition table and labour force activity-transition table); if the random number generated is less than the probability of having a disability or labour force activity, then our agent experiences a transition and a new level of dependency (0/1/2/3) or labour force activity (U/P/F) is assigned to the agent. Then we assign to each agent the hours of CARE needed or available per week according to its age and the new level of dependency and labour force activity status. Table 2 shows the maximum number of hours of informal care that an agent can deliver or need per week, contingent on his/her own varying characteristics, such as his/her age, labour force activity and dependency level.

Now, if the agent EGO with needed CARE (care<0) has not family members alive, it is assumed that all his/her CARE will have to be satisfied by formal care. But if EGO has some family members alive, we go to a kinship module to check whether his/her CARE needs can be fulfilled by his/her family (the partner is considered first and if necessary, then the children are). Each individual of EGO's family network (i.e. EGO's partner as well as her/his children and their own direct family members, who are the daughters-in-law, sons-in-law and grandchildren of EGO) goes through the same kinship module which compare the amount of care needed or available. First, the model tries to satisfy the EGO´s care needs by checking whether his/her partner has any available (the ego-rule-partner) and, afterwards, if all his/her demand of care cannot be satisfied, the kinship module is used to check whether his/her children have some time for care available, which depends on turn on the necessity of children's own family (ego-rule-family). If still part, or all, of the demand of EGO´s care cannot be supplied by his/her family, then it is assumed that it will be satisfied by formal care. In the case that EGO's partner also needs care we work with the assumption that each children's family agent will provide informal care to both parents. Thus, there is a direct interaction between EGO and his/her partner because they both compete for the informal care supply provided by their children and children's family. In the case that both need care, children's family supply is distributed proportionally according to the number of hours needed, depending on their dependency level. For example, if an EGO male agent aged 90 years is in a state of severe dependency (Dep3), he will require 80 hours of care per week. Let's say that he lives with his 82-years-old wife who has a less severe dependency (Dep2), but nevertheless requires 30 hours per week of care. In terms of care provision, let's suppose that their children and children's family can only deliver up to 90 hours of care per week. These 90 hours of care supply are then proportionally distributed in the following way: EGO receives 65h27m (80/(80+30))*90 and his wife 24h32m (30/(80+30))*90, and the remaining 14h33m of care required by EGO are satisfied by formal care. Here we are only interested in the results regarding the EGOs because they are our representative population.

Then we start another year or tick and again all agent's situation is updated and we go through the same process to check whether the egos care need can be fulfilled by informal care, depending on the number of hours for care that can be provided by the family network, until all the egos die.

4.- Design concepts

Basic principles

To produce our estimates, three steps require to be undertaken:

1.- Reconstruct the family structures – For this we use a stochastic micro-simulation kinship models.

2.- Estimate the potential number of carers and the hours they have available on the basis of their age, health and employment status and the age of their own children, if they have any.

3.- Calculate the demand for care according to hours needed based on the severity of the disability.

As output the model estimates the percentage of care that is covered by family members (first by the partner and afterward the children). Our model is related to Noble et al (2012) where they studied the implications of household formation and of other demographic processes for the supply of, and demand for, social care situation in the UK using an agent-based model.

Adaptation

Agents adapt to their environment, as the circumstances change through the agent life (e.g. change activity in the labour force participation, worsening in the level of dependency). In every cycle or tick, agents make a count of needs in their family network or "social environment".

Objectives

Our objective is to see how changes in four key socio-demographic dimensions - demographic dynamics, health/disability/dependency, education and employment- shape the amount of demand for informal and formal care. Our first objective is to analyse the impacts of demographic change across generations on the dynamics of care of the old dependent population by keeping constant the education, health and employment profiles and transitions. A second and future step will be to examine the effects on care dynamics of implementing changes related to education, health and paid work situation.

Learning /prediction

In our model individuals do not change their adaptive traits over time as a consequence of their experience. As a result, there is no feedback effect on this side. For example, a partner or a child does not adapt her/his behaviour (employment, family formation) to accommodate ego’s needs for care.

Sensing

The model assumes that all agents have complete knowledge of their own family network composition.

Interaction

Agents interact with one another within family networks and this family network structure can be interpreted as an extreme case of what is known as a "small world" in the sense given by Watts & Strogatz (1998). Between EGO and his/her partner exist a direct interaction because they both compete for the informal care supply provided by their children. In the case that both need care, children's hours of care supply are distributed proportionally according to the number of hours needed depending on their dependency level. EGOs and their partners also compete with their children’s partner as well as their grandchildren for the informal care of their (biological or in-law) children. EGO's children own family needs will be satisfied first, and only the surplus will be available for EGO and her/his partner.

Stochasticity

The model has some partially stochastic rules (e.g. transitions tables) and some that are entirely deterministic (micro-simulation). The stochastic rules are probabilistic, and based on uniform distributions.

Collectives

In our model our agents do not have any role or action "as collective entities". They only form groups of agents (family network) to manage the needs (care demand) and the resources (care supply) of elderly care.

Observation

We repeat the simulation 100 times to produce confidence intervals for the estimate obtained with the model in a process akin to bootstrapping.

5.- Initialization

Our model is cohort based, it addresses the formal and informal elderly care dynamics of five different cohorts in Spain across the 20th century. (1928, 1938, 1948, 1958 and 1968). By comparing five different cohorts we try to determine the effects of the socio-demographic changes over five decades related to the change in family sizes and structure, the longer life expectancy and especially the increase of the number of years lived at older ages. Each run of the model starts with around 50,000 agents which include a cohort of 10,000 agents called EGOs who are 50 years of age at the start of the simulation process. The rest of the around 40,000 agents are member of the EGO's family network. The life of all agents is simulated until the death of the ego of each family network. The social and health context is representative, is fixed, and correspond to the situation of the year 2008. The information is provided by the Spanish 2008 Survey on Disability, Personal Autonomy and Dependency Situations (EDAD08) that is the main data source used to obtain the agent's health, labour force activity and educational profiles and the hours of care that they require. In that sense, our DEMOCARE model is part of the so-called "Empirically Grounded Models (EGM)" (Bruch & Atwell 2015) or "Empirically Calibrated Models (ECM)" (Hedström 2005), characterized by incorporating the characteristics of an empirical population into an agents synthetic population that constitutes the model.

The first step of the initialization or SETUP (see Figure 1) consists in the use of the population table to create our agents list and initialize their state space (for example with social status, age at death,...). Next, we import the network link table to connect the agents who form part of the same family network. Those two tables exist at the start of the simulation and come from a separate micro-simulation stochastic kinship model. Therefore, for the Agent Based Model they can be considered as of a deterministic kind. The population table is formed by two groups of persons. The first one corresponds to individuals who are aged 50 years at the start of the simulation and who form part of the cohort whose demand for care we are studying. These individuals are the centre (or the starting point) of a family network and for that reason they are referred to as 'ego'. The second group of individuals are members of the family network of each ego. For example, a partner (if ego has one) and a certain number of children. In turn the children have a probability of being assigned a partner. If they have one, a specific number of children will then be the grandchildren of ego. The population table starts for example with 10 000 egos aged 50 years to whom are added a variable number of members of their family network. This number will vary according to the levels of demographic parameters (fertility and mortality level) and will vary also in stochastic way, taking into account heterogeneity at the individual level through the use of fertility and mortality tables.

The third and fourth steps correspond to the import of the dependency probabilities and transitions tables. The first one is used in the setup phase in a stochastic way to assign an initial state of dependency to each agent, according to their sex, age and social status, and the second one is used after the initialization stage to determine at each tick whether each individual progresses toward a higher state of dependency. These two tables are based on data from the Survey on Disability, Personal Autonomy and Situations of Dependency (EDAD08). We assume that transitions between disability states only go in one direction, from less to more disability; i.e. there is no possibility of recovery. Therefore, at each tick, each individual either remains in her/his present state of (no) dependence or progresses toward a higher one, up to level 3.

The next steps relate to the import of multistate labour force activity tables. First, as with the dependency state, individuals are assigned during the setup phase a labour force activity state in a stochastic way, according to a labour force activity rates table which takes into account their sex, age, social status and dependency level. Then, when the simulation runs, their activity status can change at each tick, again in a stochastic way, according to the level of labour force activity transition probabilities table that take into account the probability of remaining in the same status and the transition between activity status, that can take place in both directions: i.e. from not being employed to a part-time or full-time job, or from a part-time to a full-time job, as well as the other way around. This means there are a total of 6 transition probabilities, which again vary according to the sex, age, educational level and dependency status of individuals.

The final step of this setup process is to import the table of hours of care needed or available for each agent according to their dependency level, labour force activity status, sex and age (Table 2). For now, we have assumed that individuals who have dependency levels 2 or 3 are not active in the workforce.

Table 2.- Net numbers of weekly hours of care needed (-) or available (+), according to age, level of dependency (Dep) and labour force activity status*

Activity status	Age Group	Dep 0	Dep 1	Dep 2	Dep 3
Not employed	0 - 4	-20	-30	-60	-80
	5 - 10	-10	-30	-60	-80
	11 - 16	-5	-30	-60	-80
	17 - 110	60	30	-60	-80
Employed part-time	17-69	45	22.5	N/A	N/A
Employed full-time	17-69	30	15	N/A	N/A

* Own estimates based on data from EDAD2008.

6.- Input data

Data used to initialize the ABM come from several sources. We draw mainly on the EDAD08 survey to obtain data on education, paid work and dependency. We derive from that survey two different types of tables: tables of proportions by age of dependency and labour force activity status that are used during the setup step, as well as transition tables between these statuses that are used during the lifecycle simulation phase. We also use the distribution of educational attainment levels of the population aged 20 and over in 2008 by sex and age as observed in that survey. We use three different educational levels: low (less than primary), medium (primary) and high (secondary and higher). We use this distribution to assign an educational level to each individual in a stochastic way. In the present version of the model, we don't take into account intra-familiar correlation between educational levels (which means that there is no correlation between the partners' educational level or between the parents and their children's one).

The dependency profile of the population (aged 20 years and more) by sex, age, labour force activity status and educational level as well as the transition probabilities are derived from the information provided by the EDAD08 survey. We use this distribution to setup the dependency status of all the agents and to compute probabilities of transition from a lower to a higher dependency status by sex, age and education as if it were a synthetic cohort. The table of transition probabilities are obtained solving a 4x4 system of linear equations, for each sex, age and educational level in a separate way:

$$\begin{cases} \Delta p(0) = -m_{0\to1} \\ \Delta p(1) = +m_{0\to1} - m_{1\to2} \\ \Delta p(2) = +m_{1\to2} - m_{2\to3} \\ \Delta p(3) = +m_{2\to3} \end{cases}$$

Where p(i) is the proportion of persons of age x with the dependency level i, Δp(i) is the variation of this proportion between age x and x+1, and m_(i→i+1) is the proportion of persons of age x whose dependency level changed from i to i+1 before age x+1.

Transition probabilities are then computed as m_(i→i+1)⁄p(i)

The key assumption which allows us to compute these probabilities from only one survey is that dependency status can only increase (and the health condition get worse) with age and the progression is always from a dependency level to the immediate following one (i.e. nobody can jump from dependency level 0 to 2 or 3). Another implicit assumption is that mortality risks do not depend on the dependency level, which obviously is probably wrong. The effects of this last assumption are made smaller as we interpolate the level of these proportions by single year of age using LOESS smoothing.

We use the labour force participation distribution of the population aged 16 years and more by sex, age, educational level and dependency status to obtain a multistate table of transitions between three labour force activity statuses (not working, working part-time and working full-time). Between ticks, transitions can happen between any two activity statuses and in both directions. So, we have a linear system of only 3 equations with 6 unknowns. In order to estimate these probabilities, we use extra information from the Spanish Labour Force survey (EPA) from two consecutive waves (2nd quarter of 2007 and of

2008) from which we compute the transition probabilities between labour force activity status by single year of age and sex. Transitions probabilities of changes between the three activity states are then computed in a separate way for each sex, age, educational level and dependency status in an iterative way.

First, we estimate the set of 6 proportions of persons at age x (of the same sex, educational level and dependency status) whose activity status changed (varied) before age x+1 using EPA transition probabilities by sex and age:

$$\Delta p_{s,x,e,d}(a \to b) = p_{s,x,e,d}(a).\, m_{s,x}^{EPA}(a \to b) \qquad \textbf{[1]}$$

Where p_(s,x,e,d) (a) is the proportion of persons of age x, of sex s, of education level e and with dependency status d who were in labour force activity state a; 〖Δp〗_(s,x,e,d) (a→b) is the variation of this proportion between age x and x+1 due to a change in activity status from a to b; m_(s,x)^EPA (a→b) is the transition probability at age x, for sex s between labour force activity status a to b, as observed in the Spanish Labour Force survey between the 2nd quarter of 2007 and the 2nd quarter of 2008.

These variations of the proportion between age x and age x+1 are then used to derive an estimate of the proportions by labour force activity status at age x+1 attained if the transition probabilities would have been those observed from the EPA survey. We compare these estimated proportions at age x+1 with their observed level and use the relationship between the two to correct the set of 〖Δp〗_(s,x,e,d) (a→b) numbers:

$$\Delta p^{*}_{s,x,e,d}(a \to b) = \Delta p_{s,x,e,d}(a \to b).\frac{p_{s,x+1,e,d}(b)}{\widehat{p_{s,x+1,e,d}}(b)} \qquad \textbf{[1]}$$

This allows us to compute a new set of transition probabilities:

$$m^{*}_{s,x,e,d}(a \to b) = \frac{\Delta p^{*}_{s,x,e,d}(a \to b)}{p_{s,x+1,e,d}(a)} \qquad \textbf{[2]}$$

This new set is plugged in equation [1] and we iterate through [1] to [3] until

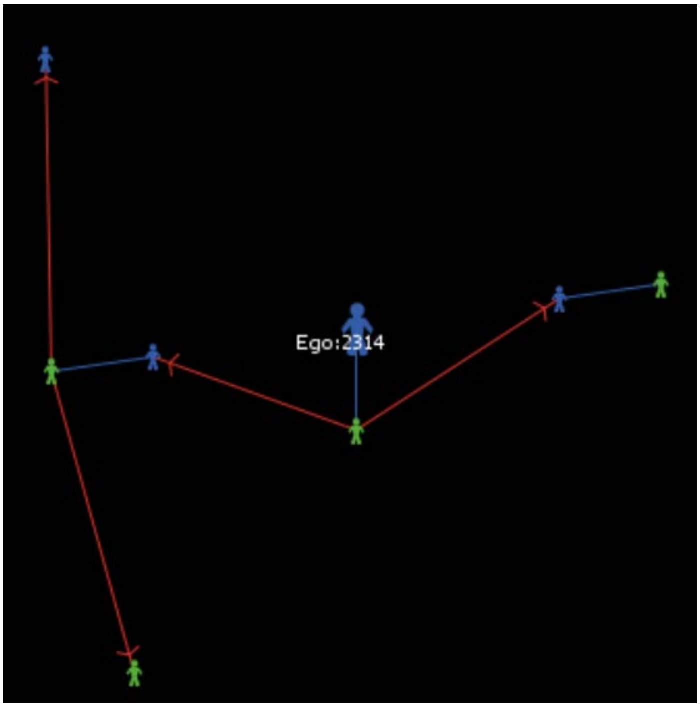
$\sum_a \left(p_{s,x+1,e,d}(a) - \widehat{p_{s,x+1,e,d}}(a)\right)^2$ reaches a minimum.

7.- Submodels

We reconstruct the close family of the initial population of EGOs using a micro-simulation kinship model (Devolder 2002). Based on nuptiality, fertility and mortality average levels of past decades (Table 1), each EGO has, at age 50, a certain probability of having a living spouse, and if it the case, corresponding probabilities of having living children, sons- or daughters-in-law and grandchildren. For each individual, the micro-simulation model determines the age relative to that of the EGO, the age at union, the age at childbirth, as well as the age at death in order to determine whether and how many relatives are alive and susceptible to be a caregiver for EGO. All individuals have a specific educational level assigned to them, according to distributions observed in EDAD08.

The data obtained by the micro-simulation is exemplified in Figure 3 representing an EGO family network, and the tables are the information obtained by the micro-simulation.

Figure 3.- An example of an EGO family network obtained by the micro-simulation



(green shape : female, blue shape : male, blue line: married link, red line: descendant link)

ID	ID	Relationship	ID family
2314,	2316,	M,	363
2317,	2319,	M,	363
2316,	2317,	D,	363
2318,	2320,	M,	363
2316,	2318,	D,	363
2320,	2321,	D,	363
2320,	2322,	D,	363

(data from the links table, relationship is married (M) or descendant(D))

id,	sex,	age,	ageDef,	status,	tickIn,	tickOut,	linked,	ego
2314,	M,	50,	80,	L,	0,	30,	TRUE,	TRUE
2316,	F,	49,	84,	L,	0,	35,	TRUE,	FALSE
2317,	M,	13,	80,	H,	0,	67,	TRUE,	FALSE
2318,	M,	12,	68,	H,	0,	56,	TRUE,	FALSE
2319,	F,	9,	78,	L,	15,	69,	TRUE,	FALSE
2320,	F,	9,	89,	L,	19,	80,	TRUE,	FALSE
2321,	F,	0,	72,	L,	19,	91,	TRUE,	FALSE
2322,	M,	0,	90,	L,20,	110,	TRUE,	FALSE	

(data from the population table; ageDef: age at death; social status is the educational level: low (L), medium (M) and high (H); tickIn: year (tick) when agents enter the simulation; tickOut: year (tick) when agents die in the simulation; linked means if the individual has a union (link) with another individual; ego: agent that execute mechanisms)

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