A Work Project presented as part of the requirements for the Award of a Master Degree in Economics from the NOVA – School of Business and Economics.

The Health Production Function Revisited:

The Role of Social Networks and Liquid Wealth

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A Project carried out on the Master in Economics Program, under the supervision of:

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January 6th , 2017

To my mother, father and sister

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Abstract: Building upon the Grossman model (1972), we propose an extended model of health production, which accounts for the role of social network interactions and share of liquid wealth. The model predicts that both factors have a positive impact on health production. A recursive system that controls for potential sources of endogeneity of social network contacts, share of liquid wealth and health care demand is used to empirically test the theoretical predictions. The estimation results show that the share of liquid wealth directly affects health in a positive and statistically significant way. Social networks do not have a direct impact on health production, though the model suggests that they indirectly enhance health through a greater use of necessary health care services. Lastly, the empirical model evidences that social networks and the share of liquid wealth act as substitutes in the production of health.

Keywords: health production function; Grossman model; social networks; liquid wealth

Acknowledgements: I thank Professor Pedro Pita Barros for all the support and enriching discussions.

1. Introduction

The 2015 Ageing Report of the European Commission projects that between 2013 and 2060, in the European Union, the life expectancy of men will raise from 77,6 to 84 years and that of women will increase from 83,1 to 89,1 years. Given the phenomenon of population ageing and the associated challenges it poses in terms of the evolution of morbidity conditions, it becomes increasingly relevant to understand which mechanisms older individuals have to prepare for and respond to adverse health shocks. We focus on the role played by the composition of wealth (share of liquid wealth) and by social network interactions on the production of health, paying particular attention to how these two inputs interact. We hypothesise that social networks and the share of liquid wealth act as substitutes in the production of good health, mainly due to the very distinct nature of the opportunity costs of each instrument – the opportunity cost of social networks is the time one must allocate to build and keep them, while the opportunity cost of liquid assets are the services one benefits from illiquid wealth, particularly housing services. Therefore, we conjecture that for individuals with a low share of liquid wealth it is less costly to rely on social networks as an input for health production, while for people with few social network interactions the share of liquid wealth is relatively more important in health production.

The novelty of our study is with the theoretical predictions about the role of social networks and the share of liquid wealth in the production of health. We extend the Grossman model of health production (Grossman, 1972) in order to encompass these two factors. By applying a comparative statics analysis we conclude that, in face of a negative health shock, the optimal response is to increase both the share of liquid wealth as well as social network interactions. The extended model of health production shows the interaction between social networks and the share of liquid wealth on health production to be non-trivial. We conjecture that individuals with relatively illiquid wealth and who, therefore, do not have much room to respond to unexpected health expenses or to engage in preventive healthcare investments, do instead rely on the support provided by their social networks as an alternative input in the production of health. To test these hypotheses, and using data from the Survey of Health, Ageing and Retirement in Europe (SHARE), we develop a four-equation recursive system which allows us to control for the potential endogeneity of social networks and the share of liquid wealth in the production of health. The empirical model corroborates the theoretical predictions and shows that, as initially conjectured, social network interactions and the share of liquid wealth are substitutes in the production of health.

The remainder of the work is organised as follows. Section 2 exposes a brief literature review. Section 3 presents the theoretical model and hypotheses to be tested. Section 4 describes the data used, the empirical methodology followed and presents the results. Section 5 concludes.

2. Literature Review

The modelling of the demand for "good health" was first introduced by Grossman (1972), in an explicit attempt to draw a distinction between health capital and human capital. Indeed, Grossman preconized that while the stock of human capital influences the wage rate of individuals, the stock of health determines the time that agents can devote to the production of money earnings as well as commodities and that, as such, it is not accurate to consider health capital as an integrant part of human capital. Additionally, Grossman intended to highlight the fact that the demand for health care is a derived demand, since what consumers actually demand is the commodity "good health", which is jointly produced by medical services and by consumers themselves, who allocate some of their time to the production of good health. Besides the aforementioned inputs – medical services and consumers' time – the efficiency inherent to the production of "good health" is assumed to be influenced by the education level and age of individuals. Another building block of the Grossman model is the assumption that individuals hand down an initial stock of health, which depreciates over time, but that can be (partially) restored through investments in health capital. As the depreciation rate increases, namely due to the health deteriorating effect of ageing, it becomes increasingly costly to produce good health. Therefore, death occurs when the stock of health falls below a minimum threshold.

Notwithstanding the breakthrough brought about by Grossman, his model has not been immune to criticism. As a matter of illustration, Usher (1975) maintains that the Grossman model fails to account for the impact that uncertainty, one's initial stock of health as well as history – namely of investments in health, wages and medical care prices - have on the decision to invest in health capital. In a similar tone, Case *et al.* (2005) preconize that the model is unable to take into consideration the socio-economic gradient in health, thereby precluding a faster decline in health for individuals in a lower socio-economic position. Moreover, Wagstaff (1986) criticizes Grossman model's prediction of a positive relation between investment in health and the stock of health. Eventually, the most concerning oversight of Grossman's model is its assumption of a health production function with constant returns to scale which, as stressed by Ehrlich *et al.* (1990), gives rise to an indeterminacy problem concerning the optimal level of investment in health and, as a result, those of health, consumption and wealth. Yet, Galama (2015) suggests slight extensions and modifications to the original Grossman model which reveal to be capable of handling the previously referred criticisms and, therefore, to reinforce Grossman's model position as the cornerstone to study health-demand related behaviours.

Surprisingly, though, little attention has been devoted to understand how individuals' wealth portfolio composition affect their demand for health. Grossman (1972) adopts the traditional view that the intertemporal budget constraint consists in equalizing the present value of total expenditures in medical care and other market goods to the present value of their wealth, which comprises the lifetime stream of earnings income plus the inherited assets. Nevertheless, it is reasonable to assume that the intertemporal budget constraint should also take into consideration the composition of the individual's wealth - for instance, by decomposing it between liquid and illiquid assets. To the best of our knowledge, this issue was only addressed by Yogo (2016), who developed a model where individuals' decision to invest in bonds, stocks and housing is affected by a stochastic health depreciation rate. The study of wealth portfolios is especially relevant when analysing the demand for health of retired individuals, who, according with the Life Cycle Hypothesis, should have accumulated wealth over their working years so that to finance a smooth consumption pattern in retirement (Modigliani, 1986). Nonetheless, in reality, retirees tend to incur in a sub-optimal level of dissaving – retirement saving puzzle -, thereby reaching death with positive assets that may be related with unwitting bequests (Romiti *et al.*, 2014). Additionally, retirees' portfolios usually suffer from a lack of diversification, given their high dependence on housing wealth and shortage of liquid assets, which hampers retirees' ability to respond to unexpected financial needs, such as those motivated by adverse health shocks (Romiti *et al.*, 2014). Despite being transversal to most countries, these retirees portfolio's features evidence some cross-country peculiarities. Indeed, Nakajima *et al.* (2013)

identify two groups of countries – the high and the low retirement saving puzzle (RSP) countries, depending on the extent of assets' decumulation pursued by retirees - and reported that homeownership rates tend to be higher in high-RSP countries than in low-RSP ones. Moreover, Nakajima *et al.* (2013) highlight that the difference in the rate of decumulation of assets between high- and low-RSP countries is essentially governed by the dissaving of financial assets, which indicates that housing assets do not seem responsive to spending risk and so should not be considered a precautionary asset. Corroborating this statement is Brunettis *et al*.'s (2015) finding that homeownership increases an individual's probability of being subject to financial fragility, which the authors define as the condition of being able to meet predicted expenses but incapable of affording unforeseen outlays. Hence, we do believe that the Grossman model should be extended so that to encompass the impact that an individual's portfolio composition has on his/her demand for health.

Contrary to the approach of the portfolio's composition association with health, the relationship between an individual's social networks and health has received considerable attention. The concept of social networks was first introduced by Barnes (1954), when studying the social organization of a small Norwegian parish, so that to describe interpersonal links that arose by means of friendship and that did not fit into conventional social groups as those built upon family and work. Social networks are thought to influence individuals' health mainly, though not exclusively, through the provision of social support, which can be further disentangled into emotional (love, caring, understanding), instrumental (tangible assistance and services), informational (recommendations addressing specific needs) and appraisal support (guidance for decision-making) (Berkman *et al*., 2000). Social networks are distinguished based on a multitude of structural characteristics, ranging from the size of the network to the degree of reciprocity of the transactions carried between members of a network (Berkman *et al*., 2000).

The first pieces of evidence underpinning the hypothesis of a relationship between social networks and health remote to the 1970s, when there appeared studies substantiating that social networks could have an impact on the mortality risk (Smith *et al.*, 2008). More recently, a meta-analytic review concluded that the magnitude of the protective effect of satisfactory social relationships "is comparable with quitting smoking and it exceeds many well-known risk factors for mortality (e.g., obesity, physical inactivity)" (Smith *et al*. 2010, p.14), thereby bolstering the above-cited thesis. Besides, a growing number of studies has been providing evidence of possible ways in which social networks interact with health, particularly by enhancing alterations in the circulatory, neuroendocrine and immune systems (Uchino, 2006; Seeman *et al.*, 2014).

Building upon the aforementioned evidence, we hypothesise that social networks and the share of liquid wealth have a positive impact on the production of health. Moreover, we conjecture that older (50+) individuals with relatively illiquid wealth and who, therefore, do not have much room to respond to unexpected health expenses or to engage in preventive healthcare investments, do instead rely on the support provided by their social networks as an alternative input in the production of health. More precisely, we want to ascertain *whether retirees' social networks and liquid wealth are substitutes in the production of health*.

3. An extended health production model

With the aim of understanding how the consumption of medical goods and services, the interaction with one's social network and the share of liquid wealth influence the overall level of utility attained by individuals and, more specifically, their stock of health, we must comprehend, beforehand, the costs and benefits associated with each of the aforementioned items. Firstly, the consumption of medical goods and services increases the utility level through a positive contribution in the production of health. The cost inherent to the consumption of medical goods and services corresponds to their price and/or to the time required to obtain them. Concerning social networks, their benefits are mainly associated with their potential role as an input in the health production function and their costs correspond to the time required to build and maintain social network contacts. Lastly, a lower share of liquid wealth is detrimental since it decreases individuals' disposable income. On the other hand, if the illiquid wealth is mainly composed of housing wealth, it increases the possibility of benefiting from the services of own property.

In order to test the impact that social networks and the share of liquid wealth have on health, we rely on the model of health production proposed by Grossman (1972). For simplicity reasons, and contrary to Grossman, we make a one-period analysis. The decision variables are adapted to the present study, particularly by encompassing social networks as well as the share of liquid wealth. An additive separable utility function on health, consumption of commodity goods (other than medical ones) and on the services obtained from assets is assumed. Without loss of generality, health is measured in utility levels. This extension of the Grossman model is novel and dictated by the question we address. The proposed model is:

$$Max_{\{t_H, t_N, C, M, \theta, N\}} U = H(M, t_H, N) + U_2(C) + U_3[W\theta + \alpha(1-\theta)W], \ \textit{for } \alpha>1 \quad (1)$$

s.t. $H = H(M,\ t_N);\ r\theta W + Y = pM + C$[1]$;\ \bar{T} = \bar{t_L} + t_H + t_N;\ N = N(t_N),\ N'>0;\ Y = \omega\bar{t_L}$

Which, after the appropriate substitutions have been made, can be reduced to[2]:

$$Max_{\{t_N, \theta, M\}} U = H(M, t_N) + U_2(r\theta W + \omega\bar{t_L} - pM) + U_3[\theta W + \alpha(1-\theta)W] \quad (2)$$

Where *H* is the stock of health; *M* is medical goods and services; *N* represents social networks; *C*, the *numéraire*, represents commodity goods other than medical ones; *W* is total net wealth; $0 \leq \theta \leq 1$ is the share of wealth which is liquid; α is a parameter that represents the greater value of the services associated with illiquid wealth; *r* is the interest rate attributed to liquid assets; *p* is the price of medical goods and services; *Y* is the fixed labour income; ω is the hourly wage; $\bar{T}$ is the endowment of time; $\bar{t_L}$ is the number of hours of work, which we assume to be

[1] If the problem is extended to a multi-period setting and since this is a steady state analysis, then $\theta_{t-1} = \theta_t$. Thus, we could write $r\theta W + Y = pM + C + \theta S + (1-\theta)S \Leftrightarrow r\theta W + Y = pM + C + S$, where S is savings. Assuming, without loss of generality, that S=0, we obtain the budget restriction that was used in this study.

[2] In case the entire wealth is liquid, *r* can be substituted by *1+r*, the share of liquid wealth (θ) can be omitted in the utility function of wealth (U_3) and α can be set equal to 1 – nothing in the conclusions of the model will change with this reformulation. The version of the model used (2) implies that only income accruing from liquid wealth enters the budget constraint and interpreting *r* as being *(1 + rate of remuneration)* does not change anything in the results.

fixed; t_H corresponds to the amount of time devoted to health-enhancing activities and, lastly, t_N is the time allocated to one's social networks.

Since (1) is a state-dependent utility function, we determine the responses that are expected after an adverse health shock. We first analyse the cases for which $0 < \theta < 1$ and then focus on the corner solution cases ($\theta = 0$ and $\theta = 1$). We study the corner solutions separately, because the equality restrictions imposed on the share of liquid wealth in those situations reduce the degrees of freedom in the adjustment process, which may imply different empirical formulations.

For the cases in which $0 < \theta < 1$, we analyse the responses to an adverse health shock, both when the individual has a supportive social network as well as in the absence of such network (or when social networks are not responsive to the needs of the individual). A comparative statics analysis (technical appendix 1) shows that in case the affected individual has a social network, then an expected health shock (or anything that decreases the his/her efficiency of health production) leads the individual to devote more of his/her time to social networks, to extend the liquidity of wealth and to engage in the purchase of more medical goods and services. On the other hand, if social networks do not provide great support, the model predicts that after the shock the individual should decrease the time spent with his/her social network and that a greater liquidity of wealth should be achieved.

The corner solution cases are analysed in the technical appendix 2. For individuals whose wealth is entirely illiquid ($\theta = 0$), and in face of an adverse health shock, the model predicts a similar response to that verified when $0 < \theta < 1$. Indeed, people are expected to increase the time spent with their social networks, allocate some wealth to liquid assets as well as to consume more medical goods and services. Concerning the cases in which $\theta = 1$, the responses to a negative health shock are exctly the same as above, with the exception of the share of liquid wealth, which remains unaltered ($\theta = 1$).

Regarding the relationship between social network contacts and the share of liquid wealth, the model is not able to provide a clear-cut implication (technical appendix 3), thereby implying that this is essentially an empirical question. What is possible to infer is that when the services accrued from illiquid assets are not very relevant, in the sense that liquid and illiquid wealth are close to perfect substitutes in the wealth utility function (U_3), then social network interactions and the share of liquid wealth behave as substitutes in the health production function. As the weight of illiquid wealth (α) increases, the degree of substitutability between social networks and liquid wealth decreases and they may even become complementary goods. In other words, the degree of substitutability between social networks and liquid wealth decreases as the opportunity cost of allocating wealth in liquid assets increases.

Based on the theoretical derivations, the following hypotheses can be tested:

Table 1 – Hypotheses and tests

$0 \leq \theta < 1$	Social network interactions have a positive marginal impact in the production of health. The share of liquid wealth has a positive marginal impact in the production of health. Given that the theoretical model does not point toward a particular relation between social networks and the share of liquid wealth, determine empirically if they are complements or substitutes.
$\theta = 1$	Social network interactions have a positive marginal impact in the production of health. Given that the theoretical model does not point toward a particular relation between social networks and the share of liquid wealth, determine empirically if they are complements or substitutes.

4. Data and Empirical Methodology

In order to develop the empirical analysis, we resorted to SHARE, which is a cross-national and multidisciplinary panel dataset, compiling micro data on health, psychological, economic, social support and social network variables for individuals with 50 or more years (Malter *et al.*, 2013). Despite the longitudinal nature of SHARE, we focused solely on wave 4, which data is from 2013, since this wave is the only one containing a social network module. We started by focusing on wave 4 data present in easySHARE, which is a simplified version of SHARE that aggregates in a single file information from all waves, over a restricted set of variables, and contains generated variables which are ready to use (Börsch-Supan *et al*., 2016). Given that not every information required for the present study was available in easySHARE, we imported additional variables of wave 4 following the procedures described by Gruber *et al.* (2014). In view of our interest in analysing the relation between an individual's wealth portfolio composition and his/her health, several financial variables had to be constructed following the methodology of Börsch-Supan *et al*. (2005).

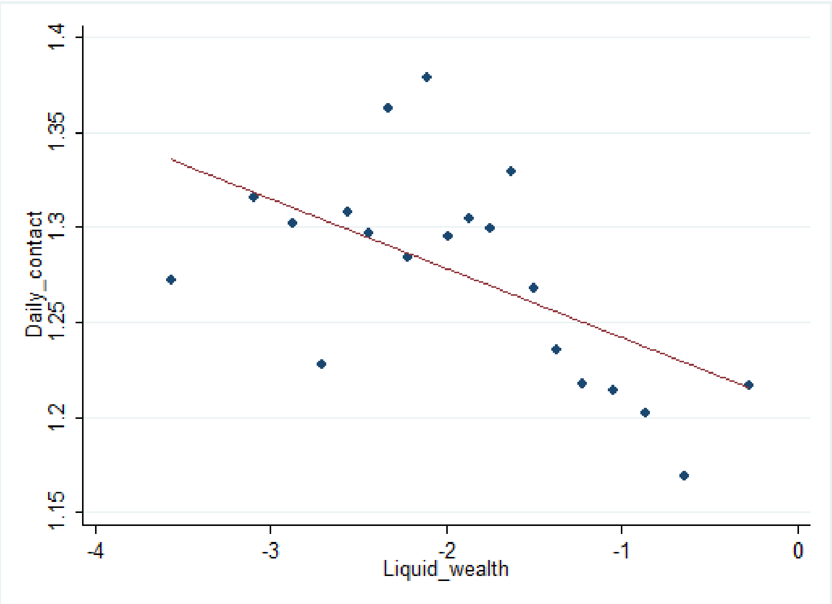
4.1. Descriptive statistics

After cleaning the dataset, we were left with 46170 observations of which approximately 57,9% were women, with an average age of 65 years, and 42,1% were men, with an average age of approximately 66 years. Those observations correspond to 16 countries (Austria, Belgium, Chez Republic, Denmark, Estonia, France, Germany, Hungary, Italy, Netherlands, Poland, Portugal, Slovenia, Spain, Sweden and Switzerland), being France the most represented, with 10,08% of the observations, and Poland the least, representing 2,48% of the observations.

Concerning social networks, the average size of an individual's social network is small in all countries, ranging from a minimum of 1,77 persons in Slovenia to a maximum of 2,92 individuals in Switzerland. In Switzerland and Belgium, which are the countries where people's social networks are less reliant on family, social networks are on average composed of 69,7% and 69,9% of kins, respectively. On the other side of the spectrum appears Hungary with an average of 89,2% and Poland with 89,4% of social networks represented by family members. In none of the countries the representativeness of formal helpers on social networks surpasses 1%, on average.

In all countries included in the analysis the greatest share of individuals is homeowner, with the remaining being either members of a cooperative, tenants, subtenants or enjoying free rents. Hungary is the country evidencing the highest homeownership rate (96,1%) and Austria the lowest (68,7%). Additionally, most individuals in the sample have a low share of liquid wealth, which is defined as the ratio between net financial assets and net worth. As a matter of fact, on average, liquid wealth represents 24,3% of net worth. However, the average share of liquid wealth can be as low as 9,7% in Hungary and reach a maximum of 33,7% in Switzerland. The liquidity position of individuals is considerably improved, though, if we consider the value of owned business and the value of cars as liquid, which is equivalent to say that the net illiquid wealth corresponds solely to the net value of the primary residence, net of mortgage, and the value of other real estate. In fact, with this approach the average share of liquid wealth is 41% of total net worth. Lastly, it is important to mention the relatively reduced expression that financial instruments have among the individuals in the sample. Indeed, while most individuals possess bank accounts (89,3%), few invest in bonds (7,5%), stocks (13,8%), mutual funds (10,1%), individual retirement accounts (42,1%), contractual saving for housing (14,3%) and life insurance policies (31,6%).

Figure 1 - Binned scatterplot between daily network contacts and the (Box-Cox transformed) share of liquid wealth.



A preliminary analysis of the relation between social network contacts and the share of liquid wealth (fig. 1) evidences that they are negatively related, which partially underpins our initial conjecture that liquidity contrained individuals tend to be more reliant on social networks. Given the inability of model (1) to arrive at a precise conclusion about the interaction between these two variables in the production of health, it remains to be empirically tested whether this negative association translates into a substitutability relation between social networks and the share of liquid wealth in health production.

4.2. Empirical analysis

In order to estimate the health production function for the cases in which $0 < \theta < 1$, a four-equation recursive system, where the errors follow a multivariate normal distribution, was developed[3]. The recursivity of the model allowed us to control for potential sources of endogeneity associated with the main variables of interest – social network contacts and share of liquid wealth – as well as for the endogeneity of health care demand. In the following equations, X represents a vector of socioeconomic variables – age, gender, marital status, number of children, years of education, employment status and income.

Social network interactions: $Daily\_contact_i = \alpha + \beta' X + \sum_{j=1}^{15} \beta_j Country_j + \beta_j SizeSN_i + \beta_j Very\_close_i + \beta_j FamilySN_i + \beta_j Proximity_i + \beta_j Mobility\_ind_i + \varepsilon_i$ (3)

Liquid wealth: $Liquid\_wealth_i = \gamma + \beta' X + \sum_{j=1}^{15} \beta_j Country_j + \beta_j Homeowner_i + \beta_j Bonds_i + \beta_j Stocks_i + \beta_j Mutual\_funds_i + \beta_j Retirement\_acc_i + \beta_j Contractual\_saving_i + \beta_j Life\_insurance_i + v_i$ (4)

Health care demand: $Doctor\_visits_i = \psi + \beta' X + \sum_{j=1}^{4} \beta_j Health\_system_j + \beta_j Chronic_i + \beta_j Mobility\_index_i + \beta_j Eurod_i + \beta_j Smoking_i + \sum_{j=1}^{3} \beta_j Sports_i + \beta_j OOP/lw_i + \beta_j Liquid\_wealth_i + \beta_j Daily\_contact_i + z_i$ (5)

Self-perceived health: $SP\_Health_i = \beta' X + \sum_{j=1}^{15} \beta_j Country_j + \beta_j Mobility\_index_i + \beta_j Chronic_i + \beta_j Eurod_i + \beta_j Smoking_i + \sum_{j=1}^{3} \beta_j Sports_i + \beta_j Daily\_contact_i + \beta_j Liquid\_wealth_i + \beta_j Doctor\_visits_i + \beta_j Daily\_contact\_lw_i + \tau_i$

(6)

[3] The empirical analysis must be done separately for the corner solution cases $\theta = 0/1$ and the interior cases $0 < \theta < 1$. This conclusion is obtained by linearizing the system of first order conditions of maximization problem (2) with a Taylor series approximation. For further explanations resort to technical appendix 4.

Table 2 – Description of the variables included in the model

Variable	Description
Age	Age of the individual in years.
Female	Dummy variable equal to 1 if the individual is a woman and 0 if the individual is a man.
i.Country	Corresponds to 15 dummy variables for the country of residence. The base group is "Austria".
i.Marital_status	Corresponds to 5 dummy variables. The base group is "married and living together with spouse" and the dummies are "registered partnerships", "married and living without spouse", "never married", "divorced", "widowed".
Children	Number of children.
Education	Years of education.
i.Employment	Creates 5 dummy variables for the job situation. The base group is "Retired" and the dummies are "(self-)employed", "unemployed", "permanently sick/disabled", "homemaker" and "other".
i.Income	Creates 9 dummies corresponding to income deciles. The base group corresponds to the first decile.
Daily_contact	Number of people in the social network with whom the individual has daily contact (from 0 to 7).
SizeSN	Number of people in the social network (from 0 to 7).
Very_close	Number of people in the social network with whom the individual feels emotionally very close or extremely close (from 0 to 7).
FamilySN	Percentage of people in the social network who belong to family.
Proximity	Number of elements in the social network that are within 5 km (from 0 to 7).
Liquid_wealth	Share of wealth which is liquid (only values >0 and <1 are considered), with a Box-Cox transformation.
Homeowner	Dummy variable equal to 1 if the individual is a homeowner; equal to 0 if the person is either member of a cooperative, tenant, subtenant or enjoys free rent.
Bonds	Dummy variable equal to 1 if the person has bonds; equal to 0 if he/she doesn't.
Stocks	Dummy variable equal to 1 if the person has stocks; equal to 0 if he/she doesn't.
Retirement_acc	Dummy variable equal to 1 if the person has a retirement account; equal to 0 if he/she doesn't.
Mutual_funds	Dummy variable equal to 1 if the person invests in mutual funds; equal to 0 if he/she doesn't.
Contractual_saving	Dummy variable equal to 1 if the person has contractual saving for housing; equal to 0 if he/she doesn't.
Life_insurance	Dummy variable equal to 1 if the person has a life insurance policy; equal to 0 if he/she doesn't.
Doctor_visits	Box-Cox transformation of the number of times the individual has seen a doctor in the previous 12 months.
i.Health_system	Creates 4 dummy variables for the type of healthcare system, based on Böhm *et al.* (2012) who propose 5 classifications: National Health Service, National Health Insurance, Social-based mixed-type, Social Health Insurance and Private Health Insurance. The base category corresponds to National Health Service.
OOP/lw	Box-cox transformation of the ratio between the average out-of-pocket expenses (for one's age, gender and health status) and the net liquid wealth.
Chronic	Number of chronic diseases.
Mobility_index	Mobility index (from 0 to 4; the higher the index, the lower the mobility of the respondent and greater difficulties exist in performing the following activities: "walking 100 meters", "walking across a room", "climbing several flights of stairs" and "climbing one flight of stairs").
Eurod	Depression scale Euro-D (from 0 to 12; high value is more likely to be depressed)
Smoking	Dummy variable equal to 1 if the individual smokes, 0 otherwise.
i.Sports	Creates 3 dummies related to the frequency with which the individual practices sports. The base category is "more than once a week". The other dummies are "once a week", "one to three times a month" and "hardly ever or never".
SP_Health	Self-perceived health (from 1 to 5; 1 is "poor", 2 is "fair", 3 is "good", 4 is "very good" and 5 is "excellent").
Daily_contact_lw	Interaction between the variables Daily_contact and Liquid_wealth.

A detailed description of the variables included in the model is available in table 2. The first equation estimates daily social network interactions ($Daily\_contact$), controlling for socioeconomic variables as well as for variables associated with the social network. Despite several variables measuring the frequency of contacts with social network members were available in SHARE - such as weekly network contacts, average contact with family members in the social network and the average contact with friends in the social network – we opted for using $Daily\_contact$ for two main reasons. On the one hand, this variable does not restrict the analysis to any subgroup of the social network (family, friends, children, etc.), thereby being more generic, on the other hand $Daily\_contact$ focus on very frequent relations, which we believe to be the most relevant for individuals subject to adverse health conditions and in need of greater support from their social networks.

The share of liquid wealth was estimated taking into consideration not only socioeconomic variables, but also homeownership and investment in bonds, stocks, mutual funds, individual retirement accounts, contractual saving for housing and life insurance policies.

Then, for a given choice of the optimal time allocated to social networks and the optimal share of liquid wealth, the occurrence of an adverse health shock determines the optimal level of consumption of medical goods and services. We proxied the demand for healthcare by the number of visits to a doctor in the previous 12 months. As for the determinants of healthcare demand, we included socioeconomic variables, mental and physical health variables, a variable controlling for the type of health system, out-of-pocket expenses as a share of liquid wealth, daily social network interactions and the share of liquid wealth. By controlling for the number of daily interactions we aimed at ascertaining whether the availability of one's social network mitigates the need for formal health care, as social networks may be able to address some of the needs of the individual. Concerning the share of liquid wealth, we conjectured that the greater the share of liquid wealth one has the greater is the ability of the individual to respond to adverse health shocks, given the increased leeway to pay for unexpected expenses associated with a medical appointment, such as the transportation cost, medication cost and/or the cost of the appointment itself.

In the last stage of the model, we estimated the overall health level of the individual using self-perceived health as the dependent variable. As regressors, we included socioeconomic variables, physical and mental health variables as well as the variables estimated in the previous stages of the model – daily social network interactions, share of liquid wealth and health care demand. Additionally, as we wanted to study how the marginal impact of daily social network interactions (share of liquid wealth) on self-perceived health varies with the share of liquid wealth (daily social network interactions), we included a term corresponding to the interaction of these two variables.

4.2.1. Technical considerations

The four-equation recursive system was estimated in Stata 13.0, using the “cmp” (conditional mixed process) command, developed by Roodman (2011), which resorts to maximum likelihood estimation. The first three regressions of the system are linear regressions, while the last one is an ordered probit regression. Given the assumption of a multivariate normal distribution, we had to ensure that the variables included in the regressions followed a normal distribution. The variable that generated more concerns in this matter was the share of liquid wealth. Indeed, the distribution of the initial variable associated with the share of liquid wealth was highly nonnormal, with a great concentration of observations both at 0 and 1 (appendix 1, fig.1). Hence, we created an alternative variable for the share of liquid wealth, which considered as illiquid wealth only real estate and not other illiquid property such as cars. The concentration of observations on both extremes of the distribution persisted (appendix 1, fig.2). Therefore, and in light of the need to analyse the interior and corner solutions separately, we opted for excluding the observations for which the share of liquid wealth was equal to 0 or 1. Then, both for the situation in which the illiquid wealth contained assets other than real estate and for the case in which it consisted only of immovable property, some transformations were applied in order to reduce the positive skewness of the distributions. Particularly, a natural logarithmic transformation (appendix 1, figs.3 and 4) and a Box-Cox transformation (appendix 1, figs.5 and 6) were employed, and it was possible to conclude that the later outperformed the former. For the Box-Cox transformed variables, the one considering only real estate as illiquid wealth followed a distribution more close to the normal, which implied this was the chosen variable to include in the empirical model. A Box-Cox transformation was also applied to the number of doctor visits and to out-of-pocket expenses as a percentage of liquid wealth, but all the other variables were included in the model without any transformation. Moreover, given that "cmp" produces inconsistent estimates under heteroskedasticity, robust standard errors were used. Lastly, standard errors were clustered at country-income groups.

4.2.2. Results

The full set of estimation results is presented in appendix 2 and in this section we highlight only the most relevant results.

Table 3 – Selected estimates for social network interactions

Variables	Daily_contact	p-value	Variables	Daily_contact	p-value
Age	-0.00856	(0.000)	FamilySN	0.00569	(0.000)
SizeSN	-0.0186	(0.018)	Proximity	0.327	(0.000)
Very_close	0.133	(0.000)	Mobility_index	0.0325	(0.000)

Considering the role of social network interactions, which we proxy by the number of members belonging to the social network with whom the individual has daily contact, they decrease with age. Individuals from higher income groups tend to relate more with their social networks. Additionally, individuals have more daily contacts with the social network if they feel emotionally connected to them, if the social network is mainly composed of family members and if the members live nearby. As for the size of social networks, once controlling for other features of the social network, it has a negative impact on the number of people with whom one contacts daily. Mobility impairments, which tend to be related with activities of daily living (ADL) disabilities (Jette *et al*., 1998), do predict more frequent contacts with the social network, which is in line with the evidence that social networks are an important source of instrumental support, namely in the recovery from ADL disabilities (de Leon *et al*., 1999)[4].

Table 4 – Selected estimates for the share of liquid wealth

Variables	Liquid_wealth	p-value	Variables	Liquid_wealth	p-value
Female	-0.141	(0.000)	Mutual_funds	0.253	(0.000)
Homeowner	-0.284	(0.000)	Retirement_acc	0.208	(0.000)
Bonds	0.157	(0.000)	Contractual_saving	0.191	(0.000)
Stocks	0.174	(0.000)	Life_insurance	0.118	(0.000)

In regards to the share of liquid wealth, we conclude that individuals from higher income groups tend to allocate a greater share of their wealth in liquid assets. Moreover, and in accordance with the findings of Brunetti *et al*. (2015), who conclude that homeownership increases an individuals' probability of being subject to financial fragility, we find that homeowners have a statistically significant lower share of liquid wealth than members of cooperatives, tenants, subtenants or people who enjoy free rents. [5]

Table 5 – Selected estimates for health care demand

Variables	Doctor_visits	p-value	Variables	Doctor_visits	p-value
Mobility_index	0.123	(0.000)	**Health_system**		
Chronic	0.156	(0.000)	National Health Service	-	(.)
Eurod	0.0559	(0.000)	National Health Insurance	0.409	(0.000)
OOP/lw	0.0685	(0.000)	Social-base mixed-type	0.0047	(0.909)
Daily_contact	0.0462	(0.000)	Social Health Insurance	0.260	(0.000)
Liquid_wealth	0.0639	(0.000)	Private Health System	0.236	(0.000)

Concerning the demand for medical goods and services, it increases with the number of chronic diseases, mobility difficulties and depression sympthoms. As expected, the share of liquid wealth has a positive impact on the demand for health care, since it gives more leeway to pay for medical services that are totally uncovered or only partially covered by health insurance.

[4] We also tested for the effect of chronic conditions, though no statistical significant effect was found.
[5] The role of risk aversion and the performance in a numeracy test were also taken into consideration as possible predictors of the share of liquid wealth, but no statistically significant effects were obtained.

Manning *et al.* (1987), with data from the Rand Health Insurance Experiment, showed that the demand for health care services varies negatively with the co-insurance rate (fraction of price paid by the patient, out-of-pocket (OOP)). Note, however, that the positive impact that the variable *OOP/lw* has on the number of doctor visits does not necessarily contradict that evidence. Indeed, to obtain *OOP/lw* we relied on information about co-payments, not on co-insurance rates. Since the value of out-of-pocket expenses[6] depends on the consumption of health care services, the estimated positive relation between *OOP/lw* and health care demand is likely to be due to the fact that the number of doctor visits appears in both sides of the equation – as the dependent variable and as part of *OOP/lw*.

The dummy variables associated with the type of health system are all significant, with the exception of the social-based mixed-type, which is only present in Slovenia. However, such result was expected, given that Böhm *et al.* (2012), who apply a deductive approach to classify health systems based on the analysis of three dimensions – finacing, service provision and regulation – conclude that "Only the Slovenian healthcare system currently resembles a combination which we deductively described as implausible" (Böhm *et al.* 2012, p.18).

The positive relation between the number of social network members with whom one has daily contact and the number of doctor appointments appears to contradict the evidence that social networks can mitigate the need for formal health care. As a matter of illustration, Wang *et al.* (2005) developed a 3-year follow-up study with middle-aged women diagnosed with coronary artery disease and concluded that women who were social isolated and who had a shortage of social support experienced a faster deterioration of coronary atherosclerosis. Nevertheless, the positive relationship between daily social network contacts and the number of doctor visits may result from the fact that social networks can potentially decrease the price of medical services, particularly by providing help with transportation. Syed *et al.* (2013) stress

[6] Out-of-pocket expenditure=(Coinsurance rate)*Price*Quantity

that transportation is commonly mentioned as a significant barrier to health care access, particularly for individuals with chronic diseases and/or for people who do not own a car. Though, Arcury *et al.* (as cited in Syed *et al*., 2013) highlight that individuals who have friends or relatives who are able to provide them with frequent transport are more likely to resort to health care services.

Table 6 - Selected estimates for self-perceived health

Variables	SP_Health	p-value	Variables	SP_Health	p-value
5th decile	0.111	(0.030)	Daily_contact	0.0191	(0.388)
6th decile	0.113	(0.009)	Liquid_wealth	0.0730	(0.000)
7th decile	0.150	(0.001)	Doctor_visits	-0.572	(0.000)
8th decile	0.158	(0.000)	Daily_contact_lw	-0.0254	(0.012)
9th decile	0.228	(0.000)			
10th decile	0.238	(0.000)			

Despite the absence of a statistical significant effect of income on the number of doctor visits, the higher income deciles (5th – 10th) have a positive and statistically significant relation with self-perceived health. This result underpins the literature on the income-health gradient, which consistently registers a positive relation between income and health status, despite the direction of the causal effect remains unclear. Proponents of a causal impact of income on health highlight that high-income individuals tend to live in less polluted and crowded areas, to engage in a more balanced diet, to practice more physical exercise and to have more job security – behaviours and conditions that enhance health (Adler *et al*., 2002). A negative relation between the utilization of health care services and the health status arises because individuals usually resort to medical care when they are in poorer health (Wagstaff, 1986).

Social network interactions are not directly related to self-perceived health in a significant way, which may seem to contradict the literature underpinning a positive relationship between active social networks and health. Considering that more frequent social interactions facilitate the use of health care services (Arcury *et al.* as cited in Syed *et al*., 2013), then social network contacts potentially mitigate unmet health care needs. Therefore, even if the model does not register a direct link between social networks and self-perceived health, an indirect positive link between these variables probably arises through the mediator effect of greater use of necessary health care services.[7]

A greater share of liquid wealth is positively related with health. In fact, the higher the fraction of wealth which is liquid, the easier it becomes to keep a smooth consumption pattern in face of unexpected health expenses or a sudden negative income shock, with positive consequences for health. Moreover, the marginal impact of the share of liquid wealth decreases with the number of daily contacts, thereby suggesting that social network interactions and the fraction of liquid wealth behave as substitutes in the production of health. This result underpins our initial hypothesis that for social network constrained individuals it is more efficient to rely on a greater share of liquid wealth to produce health, while for liquidity constrained people social network interactions are a relatively more important input for health production.

4.2.3. Model extensions

For the corner solution cases $\theta = 0/1$, the share of liquid wealth is determined exogenously (technical appendix 1). As such, the empirical model consists of a system of three recursive equations – social network interactions, health care demand and self-perceived health. A dummy variable $(\theta = 0/1)$ accounts for the differences between the two situations. Social network interactions have a positive impact in the demand for health care. Concerning the share of liquid wealth, nothing can be concluded about its effect on self-perceived health, neither about its complementarity/substitutability relation with social networks.

[7] The unavailability of data related to unmet health care needs in wave 4 of SHARE precluded us from testing if, for the analysed sample, daily social network contacts significantly predicted a lower probability of registering unmet health care needs.

5. Conclusion

The present study aimed at widening the knowledge on health production factors. Particularly, we were concerned in comprehending how social network contacts and the share of liquid wealth interact in the production of health, for individuals aged 50 years or more. A novel extension of the Grossman model, which encompasses the role of social network interactions as well as that of wealth portfolio's composition, predicts that both the time allocated to social networks and the share of liquid wealth positively impact the production of health. In order to empirically test these hypotheses, we estimated the health production function with a recursive system of equations, which allowed us to control for potential sources of endogeneity associated with the main variables of interest – social network contacts and share of liquid wealth – as well as for the endogeneity of health care demand. The empirical results endorse the theoretical preditions and unveil a substitutability relation between social networks and the share of liquid wealth in the production of health.

In light of the Health in All Policies, which "is an approach to public policies across sectors that systematically takes into account the health and health systems implications of decisions [...] in order to improve population health" (Leppo *et al*. 2013, p.6), and given the aforementioned results, policies that promote social ties and facilitate social network interactions (such as incentives attributed to informal carers) as well as policies that improve the functioning of the rental housing market may have positive repercussions in population health.

Lastly, it is worth mentioning that the cross-sectional nature of this study constitutes a major limitation. Future work that extends this approach to a longitudinal setting may bring important insights to better grasp how individuals adapt their social network ties and wealth composition in face of health shocks. Possible extensions would be to analyse other age groups and to focus on distinct wealth portfolio compositions, namely that of risky and safe assets.

Appendix 1

Figure 3 – Distribution of the share of liquid wealth

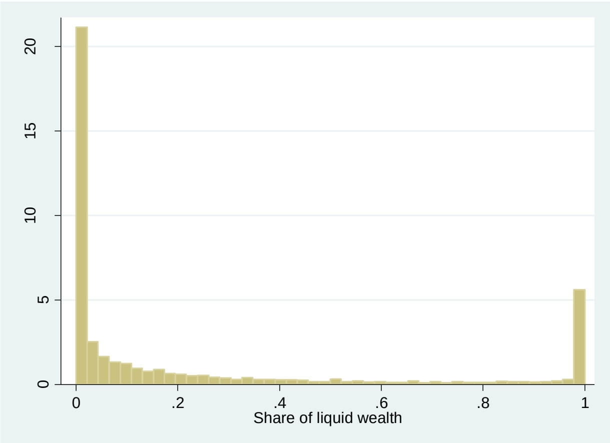


Figure 2 – Distribution of the share of liquid wealth (assuming that illiquid wealth is only composed of real estate assets)

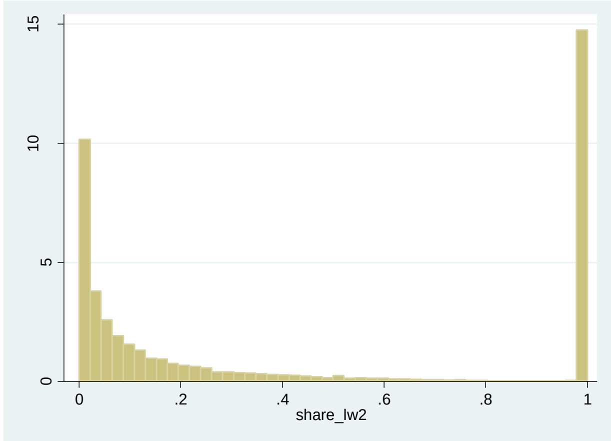


Figure 4 – Distribution of the natural logarithmic transformation of the share of liquid wealth (considering only values above 0 and below 1)

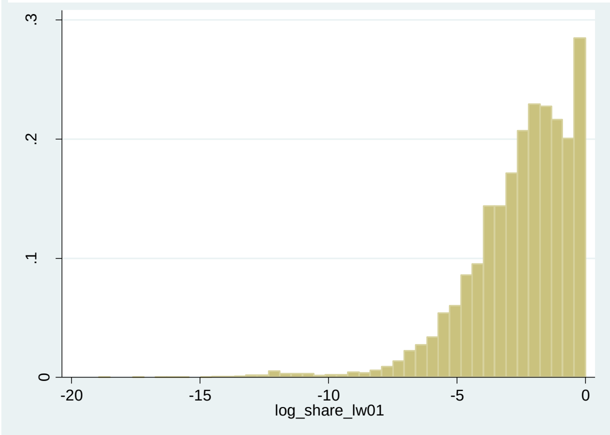


Figure 5 - Distribution of the natural logarithmic transformation of the share of liquid wealth (assuming that illiquid wealth is only composed of real estate assets and considering only values above 0 and below 1)

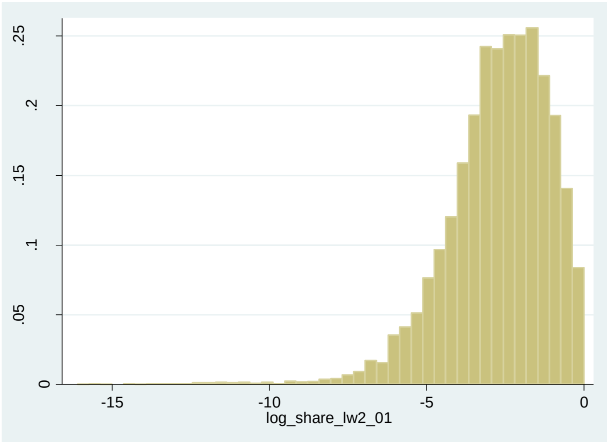


Figure 7 - Distribution of the Box-Cox transformation of the share of liquid wealth (considering only values above 0 and below 1)

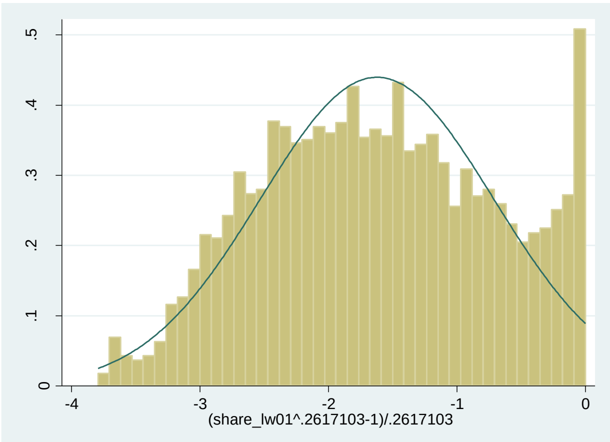
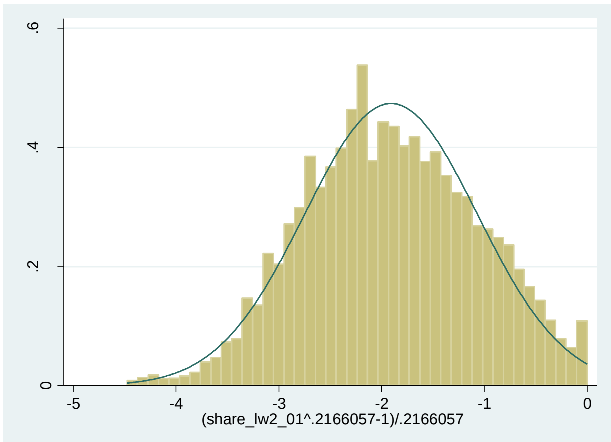


Figure 6 - Distribution of the Box-Cox transformation of the share of liquid wealth (assuming that illiquid wealth is only composed of real estate assets and considering only values above 0 and below 1)



Appendix 2

Table 7 - Full set of estimation results, for interior solutions ($0 < \theta < 1$)

	Daily_contact		Liquid_wealth		Doctor_visits		SP_Health	
Age	-0.00856***	(0.000)	-0.00300**	(0.008)	0.00256*	(0.023)	-0.000490	(0.726)
Female	0.0132	(0.197)	-0.141***	(0.000)	0.0253*	(0.048)	0.155***	(0.000)
Country								
Austria	-	(.)	-	(.)			-	(.)
Germany	-0.00778	(0.740)	0.273***	(0.000)			-0.453***	(0.000)
Sweden	0.00717	(0.730)	0.401***	(0.000)			-0.302***	(0.000)
Netherlands	-0.185***	(0.000)	0.193***	(0.001)			-0.319***	(0.000)
Spain	0.317***	(0.000)	-0.111**	(0.003)			-0.394***	(0.000)
Italy	0.410***	(0.000)	-0.0872*	(0.017)			-0.107*	(0.042)
France	-0.00606	(0.749)	-0.0219	(0.437)			-0.234***	(0.000)
Denmark	-0.0269	(0.360)	0.519***	(0.000)			0.117*	(0.040)
Switzerland	-0.0617**	(0.006)	0.243***	(0.000)			0.0744*	(0.048)
Belgium	-0.0602**	(0.004)	0.0147	(0.673)			-0.0124	(0.775)
Czech Republic	0.0529*	(0.019)	-0.244***	(0.000)			-0.418***	(0.000)
Poland	0.224***	(0.000)	-0.0982	(0.055)			-0.631***	(0.000)
Hungary	0.420***	(0.000)	0.122**	(0.003)			-0.624***	(0.000)
Portugal	0.405***	(0.000)	0.00635	(0.893)			-0.876***	(0.000)
Slovenia	0.178***	(0.000)	-0.231***	(0.000)			-0.573***	(0.000)
Estonia	0.134***	(0.000)	-0.0715	(0.089)			-1.209***	(0.000)
Marital_status								
Married (living with spouse)	-	(.)	-	(.)	-	(.)	-	(.)
Registered partnership	-0.0664	(0.063)	0.133**	(0.005)	-0.0464	(0.402)	0.0611	(0.366)
Married (living w/ spouse)	-0.104*	(0.035)	-0.114*	(0.043)	0.0171	(0.744)	0.0251	(0.729)
Never married	-0.213***	(0.000)	0.0111	(0.756)	-0.000107	(0.997)	-0.00211	(0.959)
Divorced	-0.194***	(0.000)	0.0173	(0.535)	0.0349	(0.133)	0.149***	(0.000)
Widowed	-0.197***	(0.000)	0.00665	(0.785)	0.00215	(0.936)	0.0630	(0.055)
Children	0.00432	(0.294)	-0.0202***	(0.001)	-0.00286	(0.580)	0.00495	(0.478)
Education	-0.00423**	(0.004)	-0.000372	(0.842)	0.00802***	(0.000)	0.0244***	(0.000)
Employment								
Retired	-	(.)	-	(.)	-	(.)	-	(.)
(Self-)Employed	0.0967***	(0.000)	0.00814	(0.720)	-0.113***	(0.000)	0.0776**	(0.005)
Unemployed	0.00482	(0.890)	-0.125*	(0.013)	-0.00697	(0.880)	-0.0196	(0.690)
Permanently sick/disabled	0.0837**	(0.009)	-0.0821	(0.064)	0.317***	(0.000)	-0.495***	(0.000)
Homemaker	-0.00494	(0.825)	-0.0642	(0.071)	-0.0196	(0.427)	-0.0394	(0.235)
Other	0.0788	(0.077)	-0.0426	(0.499)	0.0695	(0.262)	0.147	(0.067)
Income								
1st decile	-	(.)	-	(.)	-	(.)	-	(.)
2nd decile	0.0198	(0.570)	-0.0580	(0.122)	0.000221	(0.997)	0.0686	(0.262)
3rd decile	0.0655*	(0.019)	0.0282	(0.417)	0.0547	(0.362)	0.0215	(0.671)
4th decile	0.0183	(0.472)	0.0240	(0.464)	0.0392	(0.488)	0.0394	(0.380)

5th decile	0.0648*	(0.011)	0.0647	(0.069)	0.0402	(0.493)	0.111*	(0.030)
6th decile	0.0751**	(0.003)	0.0338	(0.349)	0.0417	(0.471)	0.113**	(0.009)
7th decile	0.0771**	(0.003)	0.0564	(0.092)	0.0365	(0.484)	0.150***	(0.001)
8th decile	0.0756**	(0.006)	0.0855*	(0.017)	0.0579	(0.251)	0.158***	(0.000)
9th decile	0.0962***	(0.000)	0.115**	(0.002)	0.0406	(0.438)	0.228***	(0.000)
10th decile	0.104***	(0.000)	0.116**	(0.003)	0.0482	(0.413)	0.238***	(0.000)
SizeSN	-0.0186*	(0.018)						
Very_close	0.133***	(0.000)						
FamilySN	0.00569***	(0.000)						
Proximity	0.327***	(0.000)						
Mobility_index	0.0325***	(0.000)			0.123***	(0.000)	-0.353***	(0.000)
Homeowner			-0.284***	(0.000)				
Bonds			0.157***	(0.000)				
Stocks			0.174***	(0.000)				
Mutual_funds			0.253***	(0.000)				
Retirement_acc			0.208***	(0.000)				
Contractual_saving			0.191***	(0.000)				
Life_insurance			0.118***	(0.000)				
Health_system								
National Health Service					-	(.)		
National Health Insurance					0.409***	(0.000)		
Social-base mixed-type					0.00470	(0.909)		
Social Health Insurance					0.260***	(0.000)		
Private Health System					0.236***	(0.000)		
Chronic					0.156***	(0.000)	-0.154***	(0.000)
Eurod					0.0559***	(0.000)	-0.116***	(0.000)
Smoking					-0.0598***	(0.000)	-0.139***	(0.000)
Sports								
>once a week					-	(.)	-	(.)
Once a week					0.0208	(0.200)	-0.111***	(0.000)
One to three times a month					0.0315	(0.134)	-0.117***	(0.000)
Hardly ever or never					0.100***	(0.000)	-0.263***	(0.000)
oop_lw_bc					0.0685***	(0.000)		
Daily_contact					0.0462***	(0.000)	0.0191	(0.388)
Liquid_wealth					0.0639***	(0.000)	0.0730***	(0.000)
Doctor_visits							-0.572***	(0.000)
Daily_contact_lw							-0.0254*	(0.012)
_cons	0.451***	(0.000)	-1.646***	(0.000)	0.705***	(0.000)		

p-values in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

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Final Acknowledgements

This paper uses data from SHARE Wave 4 (DOIs: 10.6103/SHARE.w4.500), see Börsch-Supan et al. (2013) for methodological details, and from the generated easySHARE data set (DOI: 10.6103/SHARE.easy.500), see Gruber et al. (2014) for methodological details. The easySHARE release 5.0.0 is based on SHARE Waves 1, 2, 3 (SHARELIFE), 4 and 5 (DOIs: 10.6103/SHARE.w1.500, 10.6103/SHARE.w2.500, 10.6103/SHARE.w3.500, 10.6103/SHARE.w4.500, 10.6103/SHARE.w5.500). The SHARE data collection has been primarily funded by the European Commission through FP5 (QLK6-CT-2001-00360), FP6 (SHARE-I3: RII-CT-2006-062193, COMPARE: CIT5-CT-2005-028857, SHARELIFE: CIT4-CT-2006-028812) and FP7 (SHARE-PREP: N°211909, SHARE-LEAP: N°227822, SHARE M4: N°261982). Additional funding from the German Ministry of Education and Research, the U.S. National Institute on Aging (U01_AG09740-13S2, P01_AG005842, P01_AG08291, P30_AG12815, R21_AG025169, Y1-AG-4553-01, IAG_BSR06-11, OGHA_04-064) and from various national funding sources is gratefully acknowledged (see www.share-project.org).