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Health and income: testing for causality on European elderly people

Amélie Adeline, Eric Delattre

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Amélie Adeline* Eric Delattre†

Abstract

Socioeconomic status and health are positively related, also known as the "health-income gradient". However, when considering the causal impact of income on health, the reverse causality might be at play. Income inequalities are an important factor in health inequality such that policy makers who aim at improving general health or narrowing inequalities using public policies, need to understand the sources and the direction of the causality between income and health. We thus investigate bivariate causal effects between the two by highlighting the Granger causality. Using the Survey of Health, Aging and Retirement in Europe (SHARE), we find evidence of persistent causal effects running from income to health and from health to income. Results, using a Full Information Maximum Likelihood estimator (FIML), suggest that considering a simultaneous equations approach is required because there are unobservable factors common to both equations in the individual effects (statistically significant correlation between the two equations).

Keywords: Granger causality; income; simultaneity; self-assessed health; FIML.
JEL Classification: C32; C33; D31; I10; J14.

*Corresponding author. THEMA, University of Cergy-Pontoise - 33 boulevard du Port, 95000 Cergy. Email: amelie.adeline@u-cergy.fr

†THEMA, University of Cergy-Pontoise. Email: eric.delattre@u-cergy.fr

1 Introduction

A topic at the center of health economics is the relationship between health and individual income, with the consensus view among researchers being that higher socioeconomic status is associated with better health (Preston [1975]). This relationship has been reviewed using many health outcomes in different countries (e.g. Van Doorslaer et al. [1997] using self-assessed health). While this relationship appears to be well-known, this is not the case concerning its causal interpretation. There are many possible pathways through which earnings can impact health. Indeed, there is a causal relationship between socioeconomic status, or more specifically income, and health of the former on the latter (Frijters et al. [2005]; Apouey and Clark [2015]). However, we can also think of the reverse association, for instance stating that poor health status may influence income, by reducing the ability to work (Michaud and Van Soest [2008]). This lack of a clear understanding of causality is an important omission, and the direction of the causal effect of income on health does not seem obvious. Since income inequalities are an important factor in health inequalities (e.g. Carrieri and Jones [2016]), policy makers who aim at improving general health or narrowing health inequalities in a society, need to understand the sources and the true direction of the causality between income and health. The difficulty in disentangling cause and effect is due to endogeneity, more specifically whenever health and income mutually determine one another, there are simultaneity issues. Since simultaneous causality in both directions may exist, testing causal impacts require considering one one hand, the impact of income on health, and on the other, the impact of health on income. Different econometric methods have been used to fix this issue such as instrumental variables method or exogenous income shocks and health shocks, but without finding a common consensus about the direction of the causality (from income to health according to Halliday [2017] or from health to wealth according to Michaud and Van Soest [2008]). While these studies disagree about the direction of the causality between health and income, they provide interesting insights. However, majority of these studies do not adequately consider heterogeneity due to individual fixed effects that may be associated with both income and health. The two previous cited studies address this temporal concerns by employing dynamic panel techniques to investigate causality. Nevertheless, our paper deepens the link between health and income and is different from the latter since we explicitly bring to the forefront the Granger causality while taking into account other information and concerns. Indeed, on one hand, Halliday [2017]'s study differs from ours in two points. First, he only considers the impact of income on health, while we consider this relationship as well as the impact of health on income in order to highlight bidirectional causal links. Second, our database contains more information (specifically information on morbidity indicators) so that we can investigate more control variables and control variables in the estimates to make robust links. On the other hand, Michaud and Van Soest [2008] work on the

Health and Retirement Study, a population of U.S. couples aged 50 and older, a similar population than ours, but focus on wealth. However, instead of considering two univariate relationships (one considering the impact of income on health and the other considering the impact of health on wealth), we implement a simultaneous equations approach to consider the possible existence of unobservable factors common to both equations. Thus, we tackle endogeneity issues using a specific structure for error terms.

We choose to focus on self-perceived health, a subjective measurement of health status but considered to be a strong predictor of an individual's health (Benitez-Silva et al. [2004]). Indeed, individuals take into account several elements of their health when assessing their subjective measure of health. Diseases, diagnosed health problems, as well as interactions with health professionals are factors which influence self-rated health (Tubeuf et al. [2008]). Thus, it incorporates factors which are not always observed by health professionals because it integrates personal expectation of the level of health.

This paper contributes to these subjects by bringing the Granger causality to the forefront. We use European dynamic micro data, where the temporal dimension of the data is employed to evaluate and predict changes in self-perceived health status according to income and the reverse association. Full Information Maximum Likelihood estimator is implemented with the use of a simultaneous equations model to estimate causality between health and income on European elderly people with bivariate analysis.

In section 2 we present the theoretical framework of the causal relationship between income and health. Section 3 describes the Survey of Health, Ageing and Retirement in Europe. In section 4 we detail the econometric framework, as well as the results. Section 5 concludes the paper.

2 The causal relationship

The relationship between self-perceived health status and individual income is heavily documented in health economics. Self-perceived health status assesses the general perceived health of an individual. In order to collect this information, individuals are asked: "Would you say your health in general is..." and they have to choose between five answer categories ("excellent", "very good", "good", "fair" or "poor"). In this study, we consider a binary version of this information by grouping excellent, very good and good health. Self-perceived health status is an important predictor of an individual's health since it combines different elements that an individual knows about his own health. This subjective measure also integrates factors which are not always considered by health professionals such as individuals' beliefs and attitudes towards health commodity for instance. Thus, this subjective indicator is a good predictor of people's actual health status (Benitez-Silva et al. [2004]; DeSalvo et al. [2005] ; Bond et al. [2006]). Recent studies modeling the dynamics of health-income relationship question the existence of a causal effect of income or other socioeconomic status on health (see, for instance, recent studies by Kim and Ruhm [2012]; Apouey and Clark [2015] or Halliday [2017]). Direction of causality is considered to be an important issue much debated among economists, since the lack of a clear and true understanding constitutes a major shortcoming for policy makers, who aim to narrow health inequalities and improve health. In this paper, we want to investigate the direction of the causality by tackling the question of what happens to a person's health (*resp.* income) when they experience a variation in their income (*resp.* health). In the literature, some papers have already used instrumental variables methods or exogenous income shocks to investigate a causal link from income to health. Concerning instrumental variables method, authors investigate different kind of instruments and the majority find that income has a positive and significant effect on health (Ettner [1996]; Economou and Theodossiou [2011]; Halliday [2017]). Indeed, Ettner [1996] examines the effect of income on different health proxies, such as self-assessed health, daily activity limitations, proxies for alcohol abuse and others. She uses cross-sectional data from a number of US surveys collected in the 1980's. Depending on the health outcome, she uses ordered probit, probit or two-part models. The problem of reverse causality is addressed using parental education, work experience, spousal characteristics and unemployment rate as instruments. In each case, Ettner finds that income still has a significant impact on health. Economou and Theodossiou [2011] use European data and control for income endogeneity using inheritance, children's education and art collection as instruments. Results indicate a strong and positive relationship between household income and health. However, the use of cross-sectional data weakens the causal statement. More recently, Halliday [2017] employs data from the Panel Study of Income and Dynamics (US) to investigate the causal link of income on health. He implements a GMM procedure on a model in first-differences, and uses further lag variables as instruments. His results establish a causal link running from income to health in the case of married individuals. However, Michaud and Van Soest [2008] do not find a significant impact of wealth on health, using inheritances as instrument for wealth. They investigate the pathways of the health-wealth gradient using six waves of the Health and Retirement Study (US equivalent of SHARE database), implemented in a GMM framework. On the other hand, exogenous increases in income are investigated to identify a causal effect of wealth or income on health. These exogenous shocks result from lottery winnings (Lindahl [2005]; Gardner and Oswald [2007]; Apouey and Clark [2015]), inheritances (Meer et al. [2003]; Kim and Ruhm [2012]) or other economic changes (Frijters et al. [2005]; Adda et al. [2009]; McInerney et al. [2013]). Findings from these studies suggest that lottery wins have a positive effect on mental health. Indeed, Lindahl [2005] uses Swedish longitudinal data to account for the health-income relationship. In this paper, lottery prizes are used to provide exogenous variations in income. However, the identification of lottery winners is not ideal since it is not possible to establish when the individual wins in his lifetime. Lindahl runs the estimation on different aspects of health and the results are varied. He finds that lottery winnings have a positive impact on mental health and imply lower body mass index.[1] Gardner and Oswald [2007] explore the causality issue using medium-sized lottery wins (£1000+) as their instrument.[2] They find that mental health is positively affected by income. Apouey and Clark [2015] study the exogenous impact of income on different health outcomes with English data, using lottery winnings. They find that positive income shocks do not have a significant effect on general health, but do have an effect on mental health. Nonetheless, inheritances do not have a significant effect on health. Meer et al. [2003], on American data, use the amount of inheritances and gifts received over the last five years (amounts larger than US $10,000). Results suggest that wealth does not have a significant effect on health. The validity of inheritance information is also open to debate, as noted by the authors. Kim and Ruhm [2012], using eight waves of the Health and Retirement Survey, find that bequests (larger or equal to US $10,000) do not have a significant impact on health. Finally, variations in income due to changes in the economic environment suggest that health is positively impacted by exogenous income shocks. Frijters et al. [2005] analyze German data and their instrumental method is to use an exogenous change in income due to the fall of the Berlin wall. In other words, they investigate whether there was a causal effect of income changes on the health satisfaction of East and West Germans in the years following reunification. Results suggest a positive impact of income on health. Adda et al. [2009] model income and health as a stochastic process evolving over the life cycle, created using a synthetic cohort dataset which is based on successive years of micro data from several English cross-sectional surveys. They exploit the fact that, at the cohort level, over the eighties and nighties, there were sizable changes in income, mainly due to changes in the macroeconomic environment. According to their results, income variations have little effect on health, but affect health behaviors and mortality. McInerney et al. [2013] use exogenous variation in the interview dates of the 2008 Health and Retirement Survey to assess impacts of wealth losses on mental health. They find that feeling of depression and use of antidepressant drugs increase after the 2008 stock market crash.

Concerning literature on the impacts of health on income, there are less papers. Main idea is that having a bad health may reduce the ability to work efficiently such that it has a negative effect on health. Moreover, poor health can also be as-

[1] However, lottery winnings have no effect on other physical health problems.

[2] They use medium-sized lottery wins because individuals who get no win are almost indistinguishable in their responses from individuals with a small win.

sociated to important medical expenditures such that it might imply a decrease in income. Grossman [1972b]'s model of health production is a good starting-point of how health is a factor because it allows us to understand that health may be seen as a stock, and income might be related to saving motives. Smith [1999] explains that "arithmetically, savings may fall as current health deteriorates because it reduces current period income or increases either consumption or out-of-pocket medical expenses". Moreover, income might be affected by the onset of health events which might reduce the amount of labor supplied. As a result, we can consider that health is a form of human capital. Other things being equal, we expect healthier people to be more productive, and more productive workers tend to earn higher wages and work more. Using exogenous health shocks, this result is supported by Wagstaff [2007] and Halla and Zweimüller [2013]. Using a Vietnamese database, Wagstaff [2007] finds that some health shocks (particularly the death of a working-age household member) have a negative impact on earned income. Results also suggest that health shocks have more impact on incomes of urban households than of rural ones. Then, Halla and Zweimüller [2013] compare workers who get in an accident on the way to work with workers who don't (considered as health shocks) in order to implement a quasi-experimental experience. Using a fixed effects difference-in-differences approach on Australian data, they show a persistent negative causal effect of health shocks on employment and earnings. However, this negative impact of health shocks on income is not always found in studies. For instance, Charles [2003], using the Panel Study of Income Dynamics, studies the dynamic effects of a disability on earnings and finds that earnings have already dropped one year before the onset of the disability. On the other hand, Michaud and Van Soest [2008] use instrumental variables method to consider this relationship. They instrument health with the onset of critical health conditions (like cancer for severe condition or high blood pressure for mild condition). Using, the Health and Retirement Study with dynamic panel data models, they find strong evidence of causal effects from health of household members on household wealth.

Moreover, we should be aware that in the causal relationship from income to health[3], there are likely to be effects which need to be controlled. In figure 1, we notice that health status is a decreasing function of age.[4] When people get older, they tend to consider themselves as being less healthy. Changes in health status are thus partly due to the age. As a result, researchers need to control for this factor if they want to establish a causal link between income and health. This could be due to changes in behaviors on the one hand or changes in morbidity or technological progress, on the other. Indeed, self-rated health assimilates morbidity, which in turn depends on

[3]For the reverse association (from health to income), we consider an improved version of the Mincer [1974]'s equation.

[4]Figure 1 comes from data of the Survey of Health Ageing and Retirement in Europe, which contains five waves (each two years, from 2004 to 2015). See section 4.1 for further information.

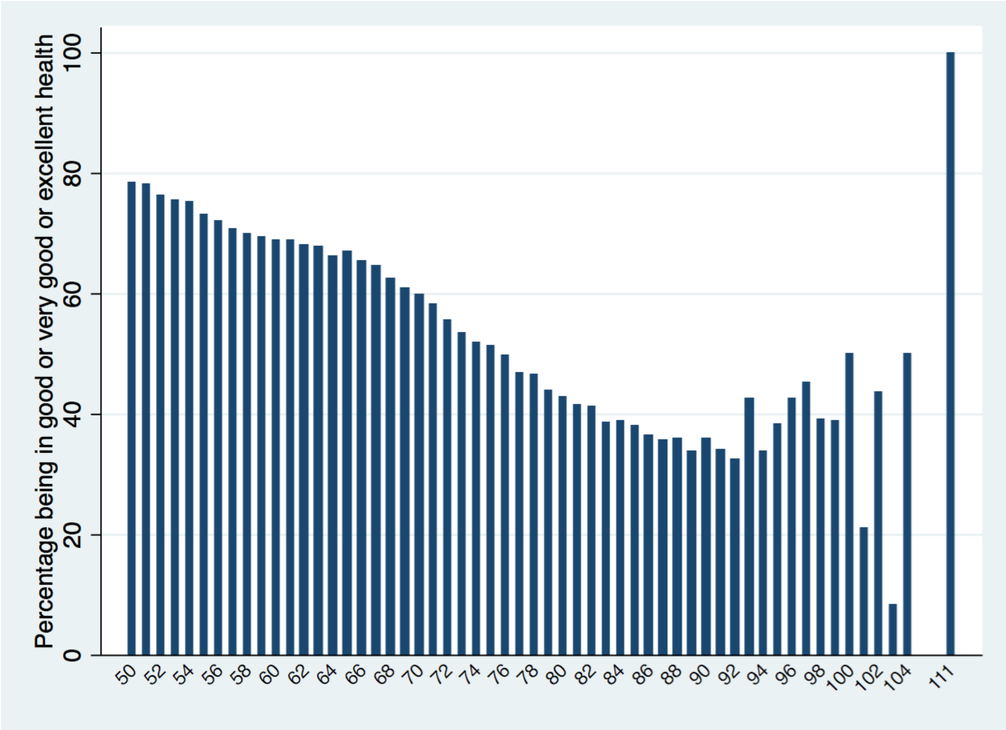

Figure 1: Health of individuals - SHARE survey

diagnosed health problems, interactions with health professionals, as well as diseases (Tubeuf et al. [2008]). Traditional measures of morbidity provide important information about levels of health. Morbidity corresponds to the incidence of diseases. It seems that morbidity is a good predictor of the self-assessment of health status, and this is why we control for its effect in the health-income relationship. We model for morbidity thanks to indicators characterized by chronic illnesses and disability. The last impact we need to be careful about is technological progress. Examining trends and patterns in mortality helps to explain changes and differences in health status, permitting evaluation of health strategies. Hoeymans et al. [2014] argue that technological applications arise in prevention, treatment and care. Benefits range from improved diagnostic skills to regenerative medicine facilitating the independent living. For example, research enables more targeted prescription of medicines, and sensor technology enables instruments that monitor health status and home automation devices. As a result, one anticipates that self-perceived health status will increase across the board in the future, thanks to technological and societal trends allowing an improvement in medical care. Empirically, technological trends can be modeled in two ways: using longevity as a proxy (since this informs us on the improvement of medicine); and using any variable which is homogeneous across individuals in a given year. Concerning the latter way to model technological trends, we suppose that everybody is affected in the same way by these trends.

In order to establish a causal relationship between health and income, the goal of this paper is to take into account all the previously enumerated effects. One should notice that when talking about causality in social sciences, experimental studies might be useful. However, in this research we do not make use of such methods because we think that it refers to a different approach and thus story, and we do not have the means necessary to develop these methods. However, since we have access to a rich panel database, we can investigate causal links between income and health.

3 SHARE Survey

The Survey of Health, Ageing and Retirement in Europe (SHARE) is a multidisciplinary and cross-national panel database of micro data on health, socio-economic status and social and family networks of more than 123,000 individuals aged 50 and over from many European countries and Israel. Since 2004, SHARE asks questions to a sample of households throughout Europe with at least one member who is 50 and older. These households are re-interviewed every two years in the panel. The first wave (2004-2005, around 27,000 individuals) and the second one (2006-2007, around 34,000 individuals) were used to collect data on health status, medical consumption, socio-economic status, and living conditions. The 2008-2009 survey (Wave 3) "SHARELIFE" was extended to life stories by collecting information on the history of the respondents. Since it does not contain the required information for our research, this wave is not taken into account in the pooled database used. The number of participants increased from 12 countries in wave 1 (Börsch-Supan [2017a]), to 15 (adding Ireland, Israel, Poland and Czech Republic) in wave 2 (Börsch-Supan [2017b]), while the third wave contains information about 13 countries. Wave 4 (2010-2011), is a return to the initial questionnaire of waves 1 and 2 (Börsch-Supan [2017c]). It collects data from 56,533 individuals in 16 European countries. The fieldwork of the fifth wave (Börsch-Supan [2017d]) was completed in November 2013. The following countries are included in the scientific release of 2015: Austria, Belgium, Switzerland, the Czech Republic, Germany, Denmark, Estonia, Spain, France, Israel, Italy, Luxembourg, Netherlands, Sweden, and Slovenia. This wave contains the responses of 63,626 individuals. Finally, the sixth wave is available since 2016 and contains information on 67,346 individuals from 18 countries (Börsch-Supan [2017e]). As a result, the pooled database contains almost 250,000 observations, and individuals are present on average 2.1 years in the panel. However, researchers should also be aware of the potential disadvantage of this database. Indeed, Börsch-Supan et al. [2013] explain that in some waves there are relative low response rates and moderate levels of attrition (even though the overall response rate is high compared to other European and US surveys with an average retention rate over the year of 81 %) which are presumably due to the economic crises faced by some of the countries implying a decrease in the participation rates. We choose to focus on this survey since it has all the information needed to carry out this research. Indeed, the dependent variable in our study is the binary transformation of self-perceived health status where individuals are asked to classify their health from “poor” to “excellent” (binary variable equals to 1 when individuals report being in good, very good and excellent health - see figure 2). Concerning, the

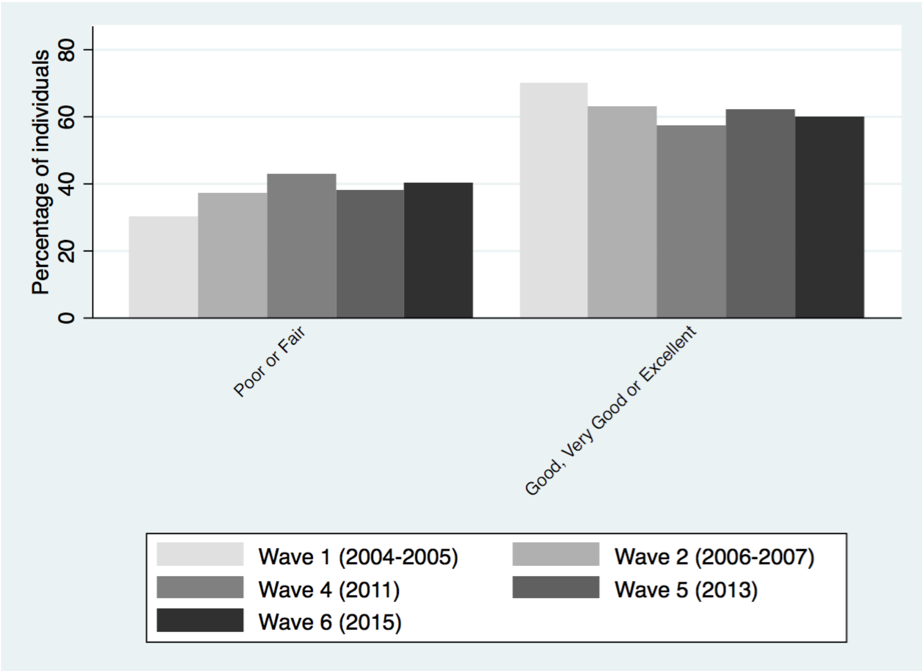

Figure 2: Distribution of self-perceived health status - SHARE

variables of control, we use quadratic age, education (quantitative version following the International Standard Classification of Education), marital status, current job situation and wave and country specific Gini coefficient[5] to have more variability in this measurement (see table 2 in appendix part for further information). We also use dummies for group of countries to capture regional effects.[6] Then, technical progress is modeled using life expectancy as a proxy. The OECD gives information for Europeans countries about life expectancy at 65 years of age. We distinguish women's life expectancy from that of men in each country, in order to have the most accurate information. Technological progress can also be viewed as a variable which is homogeneous for all individuals for a given year. As a result, we also add time dummy variables to the specification. Since, life expectancy is not completely collinear to time dummy variables, both variables are added into the specification, in order to capture the real trend implied by the technical progress.

In this database, income corresponds to the sum of individual imputed income for all household components. We use the logarithm of income to reduce impacts of

[5]The Gini coefficient goes from 0 to 1, with 0 representing the situation of perfect equality where incomes in a population are distributed completely equally.

[6]Dummies for countries are not included because of quasi-multicollinearity which can arise with the Gini coefficient.

outliers. We would also like to know what are the changes in health status following positive income shock. Thanks to data availability, we follow the intuition first introduced by Meer et al. [2003] using information about the amount of unexpected gift or inheritance (worth 5 000€ or more). This information is included as a dummy variable. We are mindful that inheritance might not satisfy all exclusion restrictions such that this is not a very strong income shock (a family member dying might signal something about the individual's health or other unobserved variables might drive both heath and inheritance using the idea of "privileged backgrounds"). However, the use of data on financial gifts creates a setting as close as possible to the idealized laboratory experiments.

It is important to measure health status in terms of non-fatal health outcomes since these are important for the burden of a disease. Morbidity indicators can be broadly defined by the prevalence or incidence of diseases, but also by the degree of disability and the risky behaviors of individuals, which can cause diseases. Morbidity is strongly correlated with the self-perceived health status (Manor et al. [2001]; Latham and Peek [2013]; Chan et al. [2015]). As a result, it has to be taken into account when one studies self-perceived health status. Dormont et al. [2006] use a French microeconomic dataset (Santé Protection Sociale, conducted by IRDES) in order to construct morbidity indicators. We base our construction of indicators on their method, since they produce these indicators with the help of general practitioners who assure their validity. As regards morbidity, we consider the last two indicators of the Mini European Health Module (MEHM), which represents three concepts of health.[7] The second indicator is the morbidity and it assesses the incidence or prevalence of a disease or of all diseases. This indicator gives information about people having long-standing illness or health problems. The last indicator is about activity limitation and disability, which assess self-perceived long-standing limitations in usual activities due to health problems. Thus, we use a vector of chronic illnesses and disability indicators for morbidity. Indeed, a variety of lifestyle factors and health-related behaviors, such as alcohol consumption, physical activity and dietary habits, can affect a person's health. An unhealthy lifestyle often results in a higher risk of chronic diseases. SHARE database has the advantage of providing information about many morbidity indicators which can be divided into three main parts.[8] The first part concerns the degree of invalidity of individuals and is represented using the following indicators: Activities of Daily Living (ADLs), Instrumental Activities of Daily Living (IADLs), the Global Activity Limitation In-

[7]The MEHM is included in several European survey programs (EU-SILC, SHARE, EHIS and Eurobarometer). The first one concerns the self-perceived health status which assesses general perceived health rather than the present state of health. This indicator, first recommended by the World Health Organization in 1988, seeks to incorporate different dimensions of health (i.e. physical, social, and emotional, as well as functional signs and symptoms). Despite its subjective nature, indicators of perceived general health have been found to be a good predictor of people's future health care use and mortality (DeSalvo et al. [2006]; Cox et al. [2009]).

[8]See the appendix part in order to have detailed statistics and definitions on the indicators.

dicator (GALI) and an indicator about mobility limitation. The second indicator is about chronic diseases and gives the number of chronic diseases of an individual. Finally, the third category of morbidity indicators concerns risky behaviors of individuals.[9] We choose the alcohol consumption variable which informs us on the drinking habits.

4 Econometric framework and results

4.1 Identification strategy

In order to assess the real impact of (i) income on health and (ii) health on income, we focus on the concept of Granger causality, which takes into account the temporal dynamic of the relationships. The definition of causality by Granger [1969] distinguishes lag causality from instantaneous one. Granger [1969]'s concept of causality assesses a better predictability of one variable based on another one. In this case, while the latter is different from a "cause-effect" relationship concept, it still helps us to give insights concerning public policies. As a result, we investigate the causal impact of past income (*resp.* health) on current health status (*resp.* income). This approach includes the phenomenon of persistence of health status (*resp.* income) in the relationship. Self-perceived health status is a qualitative variable such that:

$$h_{it} = \begin{cases} 1 & \text{if} \quad h^*_{it} > 0 \\ 0 & \text{otherwise} \end{cases}$$

in which h^*_{it} is a latent variable and implies a latent variable specification of the model. We intend to estimate the following equations simultaneously to highlight permanent causal links:

$$\forall i = 1...N \quad \& \quad \forall t = 1...T_i$$

$$\begin{cases} h^*_{it} = \alpha_0 + \lambda h_{i,t-1} + \delta linc_{i,t-1} + X_{it}\beta + c_{jt} + \epsilon^1_{it} \\ linc_{i,t} = \beta_0 + \Lambda h_{i,t-1} + \Omega linc_{i,t-1} + Z_{it}\alpha + c_{jt} + \epsilon^2_{it} \end{cases} \tag{1}$$

where T_i corresponds to the number of observations for an individual i; h^*_{it} is a latent variable for which h_{it} equals to 1 when individual i reports being in good, very good or excellent health[10] at date t; $linc_{it}$ denotes log income[11] of individual i at date

[9] We do not include information about smoking since this variable contains a lot of missing information such that it would considerably reduce the number of observations. However, we did the entire microsimulation method with the inclusion of this variable and find similar results. The results are not reported here but available upon request.

[10] This binary variable is derived from self-perceived health status. Individual reporting their health as being excellent, very good, or good were categorized as "healthy" such that h_{it} equals 1; in contrast, individuals reporting their health as fair or poor were categorized as "unhealthy" where h_{it} equals 0.

[11] We use log transformation of income to reduce effects of outliers, as done by Michaud and Van Soest [2008] or Halliday [2017].

t; c_{jt} represents technological trend of country j at date t, thus corresponding to cross-country and time fixed effects; X_{it} is a set of observed variables representing age, age squared, gender, marital status, a dummy for the retired status, schooling, a country-specific indicator of income inequalities (Gini coefficient) and dummies for group of countries. To be sure of correctly assessing the true impact of income on health, we also add an exogenous income shock to the equation (included in X_{it}). Then, Z_{it} corresponds to age, age squared, gender, education, job status, marital status and dummies for group of countries. Moreover, error terms are assumed to be normally distributed and can be decomposed into two terms such that:

$$\begin{cases} \epsilon_{it}^1 = \eta_i^1 + \zeta_{it}^1 \\ \epsilon_{it}^2 = \eta_i^2 + \zeta_{it}^2 \end{cases} \tag{2}$$

We have a variance-covariance matrix for individual effects such that :

$$\Sigma_\eta = \begin{pmatrix} \sigma_1^2 & \rho\sigma_1\sigma_2 \\ \rho\sigma_1\sigma_2 & \sigma_2^2 \end{pmatrix}$$

with $\rho = \text{corr}(\eta_i^1, \eta_i^2)$. Then, variance-covariance matrix for idiosyncratic errors is given by:

$$\Sigma_\zeta = \begin{pmatrix} 1 & \rho_1\sigma \\ \rho_1\sigma & \sigma^2 \end{pmatrix}$$

where η and ζ are independent. Whether $\rho\sigma_1\sigma_2$ is statistically significant or not gives us insight on the necessity to conduct bidirectional simultaneous analyses or univariate ones. A simultaneous equations approach allows us to consider unobservable factors which may be common to both equations. For instance, these factors can correspond to the physical maturity (some individuals are "physically stronger" than others due to their genetics) or to intellectual capacity (some individuals have intellectual abilities). As a result it is important to consider these correlations when considering the health-income relationship. Moreover, since we correctly consider heterogeneity into the fixed effects of both equations using a simultaneous equations model, estimated with a Full Information Maximum Likelihood (FIML) estimator, we do not need to specifically instrument health and income.

Concerning the likelihood function, Roodman [2011] specifically discusses conditions for consistency and identification in simultaneous equations model. We consider a bivariate case with one binary outcome (health) and a linear one (income), such that we can introduce a notation:

$$q_{it}^1 = 2 * h_{it} - 1$$

in which h_{it} corresponds to the binary outcome, ie. health. Thus we can first write the contribution of individual i to the likelihood function as:

$$\begin{aligned} L_i &= \int_{\mathbb{R}^2} \left\{ \prod_{t=1}^{T_i} f_\zeta(\zeta_{it}^1, \zeta_{it}^2 | \eta) \right\} f_\eta(\eta_i^1, \eta_i^2) \mathrm{d}\eta_i^1 \mathrm{d}\eta_i^2 \\ &= \int_{\mathbb{R}^2} \left\{ \prod_{t=1}^{T_i} \ell_{it} \right\} f_\eta(\eta_i^1, \eta_i^2) \mathrm{d}\eta_i^1 \mathrm{d}\eta_i^2 \end{aligned}$$

in which ℓ_{it} is:

$$\ell_{it} = \phi_1 \left(\zeta_{it}^2, 0, \sigma^2 \right) \Phi_1 \left(\frac{q_{it}^1 x_{it} - \frac{\rho_1}{\sigma} \zeta_{it}^2}{\sqrt{1 - \rho_1^2}} \right)$$

in which $x_{it} = X_{it}\Gamma + \eta_i^1$ with X_{it} for the explanatory variables in the health equation. In this way, the likelihood function is a multiple dimensions integral such that we use the adaptative Gauss-Hermite quadrature method as an approximation (as proposed by Liu and Pierce [1994]).[12]

Simultaneous equations modeling is feasible only if both equations are identified which is the case here. Indeed, both equations contain two endogenous equations (i.e. $h_{i,t-1}$ and $linc_{i,t-1}$) such that at least two exogenous variables must be specified in each equations and must be different from one equation to another. On one hand, different morbidity indicators are estimated only in the health equation because there can be considered as important determinants of self-perceived health status. On the other hand, different job status are estimated in the income equation which is important when considering a Mincer equation.

One limitation of this study is due to the concept of causality chosen here which is the one of Granger. Indeed, Granger causality corresponds to a weak causality test which allows to solve simultaneity issues but not issue associated to a possible omitted variable bias. For instance, since we focus on Europe, we might think of different social security systems specific in all countries, but the latter is difficult to access in the data. Thus, we include group of countries to try to capture such biases. However, there might still be other missing components causing an omitted variables bias.

We now detail our approach concerning the endogeneity status of the other variables. First of all, in the estimation of system 1, we consider the exogeneity of what we are calling, hereafter, the variables of control (i.e. X_{it} for the health equation, and

[12] For accuracy of the method and to reduce computing time, we derive the gradient of the log-likelihood and the Hessian of the respective integrand. The estimation method has been implemented using the *d1* method of STATA software (see Gould et al. [2010] for further details).

Z_{it}, for the income equation):

$$E(X'_{it}.\epsilon^1_{it}) = 0 \quad \forall t$$

$$E(Z'_{it}.\epsilon^2_{it}) = 0 \quad \forall t$$

Concerning schooling, a higher level allows an individual to have better access to health systems and jobs, and therefore one's subjective health and income should improve. Education shapes future occupational opportunities and earnings potential. Thus, it also provides knowledge that allows better educated persons to gain more access to information, which in turn promotes health. Grossman [1972a] proposes, in addition, that variables such as age and education influences the optimum level of health. As a result, if one decides to control for age, then we should also control for education. Then, we are focusing on the health-income gradient such that we need to consider an indicator for income inequalities in a country since these play a role and have an impact on individual current health status (Adeline and Delattre [2017]). Finally, when focusing on individuals aged 50 and older, one need to control for their current job status (retired, employed or other statuses) since it influences their income levels.

Moreover, Granger causality involves a delayed causality of income on health in a manner that income creates disparities throughout time. Moreover, income affects health and might also affect other unobservable variables (such as lifestyle or food expenditures) which in turn might influence health status. In health economics literature concerning causality, due to endogeneity issues, the difficulty is to distinguish causes and effects. From an early stage in the debate, it was argued that higher income causes better health (Preston [1975]). Smith [1999] explains that this positive relationship leads to a number of interpretations: causality may go from income to health (high economic resources lead to better health status for many reasons such as: more resources devoted to health or better knowledge about what improves health), from health to income (poor health may restrict a family's capacity to earn income or to accumulate assets by limiting work or by raising medical expenses), or both may be determined by other common factors. For instance, η_i^1 and η_i^2 (system 2) might contain common factors to both h^*_{it} and $linc_{it}$, implying:

$$\begin{cases} E(\epsilon^1_{it}|linc_{it}) & \neq 0 \\ E(\epsilon^2_{it}|h^*_{it}) & \neq 0 \end{cases}$$

Similarly, Wooldridge [2010] brings two issues to the forefront which need to be taken into account in solving this endogeneity problem:

1. The issue of reverse-causality is a concern when one studies income-related health relationship: a positive income shock can lead to an improvement in health status through, for example, better access to medical services. However,

we can also think of the reverse relationship where people in good health are likely to be more economically productive and thus have higher incomes.

2. Some individual characteristics which are not identified by the researcher may determine both income and self-assessed health status. A biased estimation between income and health results from a failure to control for these effects.

Finally, both equations in system 1 are auto-regressive forms, which are due to the data generating process underlying by Granger causality. These auto-regressive forms imply biased estimates if we have:

$$E(h^*_{i,t-1}.\epsilon^1_{it}) \neq 0 \qquad \forall t$$
$$E(linc_{i,t-1}.\epsilon^2_{it}) \neq 0 \qquad \forall t$$

As a result, these endogeneity issues further justify the use of a simultaneous equations model to correctly consider correlation in the error terms. Even if each identified equation can be estimated by two-stage least squares (2SLS), system estimation methods, such as Full Information Maximum Likelihood (FIML) are more efficient since they take into account the possible correlation of errors of all equations (ϵ^1_{it} and ϵ^2_{it}) resulting from the simultaneous determination of health and income. Moreover, because we have a non linear equation and a linear one, 2SLS estimator does not adequately consider such specifications.

4.2 Results

Since we want to highlight Granger causal links, we include lagged variables for income and health in both equations (persistence and effects of persistence). As a result, we lose observations due to these delayed variables, because all individuals are not always interviewed during the five waves of the panel.[13] We thus estimate the health and income equations simultaneously with a Full Information Maximum Likelihood estimator, while correctly considering the panel structure of system 1 and correlations between error terms.

Results in column (1) of table 1, corresponding to the health equation, display a strong phenomenon of persistence in health status. More specifically, when turning to the average marginal effects (AME - table 1, column (1')), it appears that moving from bad to good health at the previous period $(t-1)$ increases the probability of being in good health at date t by 6.7%. Thus, individuals in good health at the previous date have a higher propensity to be in good health today, compared to individuals who are in bad health at the previous date. Then, past income is positively related to the feelings of individuals concerning their current health. This

[13] Thus, this analysis (system 1) gives us access to 90,684 observations corresponding to almost 50,000 individuals. Indeed, in the panel we have 116,388 individuals, including 42,986 individuals who are present only once in the panel, 33,912 present twice, 25,955 present during three waves, 7,384 individuals are interviewed during four waves, and only 6,151 individuals are followed during the five waves.

result is significant and has the intuitive sign according to the literature, where it is said that a higher income is positively associated to health status. Thus an increase in income in the past has a positive effect on current health status. Especially, looking at the average marginal effect of this variable (table 1, column (1')), we can say that a 1% increase in income at the previous date implies a 1.2% increase in the probability of being in good health today (at date t). Moreover, the latter results is also supported with the income shock added to the estimation (financial gift of 5,000€ or more). This shock is positive, meaning that an expected amount of money has a positive effect on health. The average marginal effect for this variable is also positive and significant and further details that having received a financial gift increases the probability of being in good health by 0.3%. Concerning morbidity indicators which represent the prevalence or incidence of a disease, results imply that being affected by a disease, or by limitations, is negatively correlated to self-rated health status. Individuals do consider these effects when rating their health. For technical progress, we include both life expectancy and cohort fixed effects (wave 1 is not included since the analysis has been performed using lagged variables). Individuals feel better when life expectancy increases. We include an indicator of income inequalities in a country (Gini coefficient) which is negatively related to current health status, meaning that when inequalities increase, health status decreases. We also include dummies for group of countries to capture specific country effects. These dummies are negatively related to health status when compared to individuals who live in Western Europe. Finally, we control for the retirement status in this equation with a dummy, but the latter does not have a significant effect on health. Average marginal effects for this equation are reported in table 1 column (1'), and confirm the results such that the latter are considered as robust.

On the other hand, results in column (2) correspond to the income equation. Granger causality seems to be at play too since there is a strong phenomenon of persistence in income (a 1% increase in income at the previous date increases current income by 0.31%), and health has a positive and permanent impact on current individual income (switching from being in bad health to being in good health at the previous period implies an increase of 0.215% in income). This supports the idea that health might determine earnings on the labor market or that health might induce costs (such that being healthy means no costs). Technical progress also improves individual income whereas living in Eastern, Northern and Southern Europe decreases income when compared to countries of Western Europe. We control for marital status, and results suggest that being never married, divorced or widowed has a negative impact on income. Indeed, in these cases, there are not insurance effect between partners concerning income. Then, we also control for the job status of individuals because this study considers a population aged 50 and older, and results suggest that being employed compared to retired (reference category) has a positive impact on income. Indeed, incomes from employment are generally higher than other sources of income for individuals who do not work or are retired.

Finally, one important result is the correlation between error terms which is statistically significant, meaning that one should consider these correlations when studying health-income gradient since simultaneity between health and income is at play. Thus, considering a simultaneous equation model is necessary in our case where we study causal links between health and income on elderly Europeans. In other words, there might be unobservable factors common to both equation. Thus, thanks to this method, our results ensure the Granger causality of income on health on one hand, and of health on income on the other hand. These two relationships, which highlight permanent causal links and persistence in the relationship, should be considered simultaneously.

Table 1: Results of the simultaneous equations model

Variables	**Coefficients**		
	(1)	(2)	(1')
Equation:	**Health**$_t$	**Income**$_t$	**AME - Pr(Health**$_t$**=1)**
<u>Granger causality</u>			
Health$_{t-1}$	0.814*** (0.015)	0.215*** (0.007)	0.067*** (0.001)
Log of income$_{t-1}$	0.132*** (0.006)	0.319*** (0.003)	0.012*** (0.0004)
<u>Exogenous income shocks</u>			
Financial gift (5000€ or more)	0.051* (0.029)	-	0.003* (0.002)
<u>Morbidity Indicators</u>			
ADL	−0.044*** (0.013)	-	−0.003*** (0.001)
IADL	−0.017* (0.009)	-	−0.001* (0.001)
GALI	−1.005*** (0.015)	-	−0.079*** (0.001)
Mobility indicator	−0.186*** (0.004)	-	−0.014*** (0.0004)
Chronic diseases	−0.235*** (0.006)	-	−0.016*** (0.0004)
Drinking	−0.048*** (0.016)	-	−0.003*** (0.001)
<u>Technical progress</u>			
Wave 2	0.061** (0.027)	0.307*** (0.011)	0.001 (0.002)
Wave 4	0.025 (0.021)	0.661*** (0.009)	−0.015*** (0.001)
Wave 5	0.031* (0.018)	0.579*** (0.007)	−0.001 (0.001)
Wave 6	*Reference*		
Life Expectancy	0.046*** (0.009)	-	0.003*** (0.001)
<u>Co-variables</u>			

Table 1: Results of the simultaneous equations model (continued)

Variables	**Coefficients**		
	(1)	(2)	(1')
Equation:	**Health**$_t$	**Income**$_t$	**AME - Pr(Health**$_t$**=1)**
Age/10	-0.682^{***} (0.110)	0.437^{***} (0.047)	-0.002^{**} (0.001)
Age squared/100	0.046^{***} (0.008)	-0.028^{***} (0.003)	-
Gender (=1 if women)	-0.058 (0.038)	-0.048^{***} (0.007)	-0.004^{*} (0.002)
Gini	-1.032^{***} (0.138)	-	-0.066^{***} (0.009)
Education	0.086^{***} (0.005)	0.069^{***} (0.002)	0.007^{***} (0.004)
Married		*Reference*	
Living with partner	0.008 (0.058)	0.157^{***} (0.024)	0.0004 (0.004)
Living as a single	0.015 (0.032)	0.068^{***} (0.014)	0.001 (0.002)
Never married	-0.105^{***} (0.032)	-0.218^{***} (0.013)	-0.013^{***} (0.002)
Divorced	0.047^{*} (0.026)	-0.174^{***} (0.011)	-0.001 (0.002)
Widowed	0.038^{*} (0.021)	-0.211^{***} (0.009)	-0.003^{**} (0.001)
Retired	0.024 (0.019)	*Reference*	0.002 (0.001)
Employed	-	0.202^{***} (0.011)	0.001^{*} (0.0004)
Unemployed	-	-0.285^{***} (0.022)	-0.009^{***} (0.001)
Permanently sick	-	-0.028 (0.018)	-0.0004 (0.0005)
Homemaker	-	-0.183^{***} (0.012)	-0.005^{***} (0.0006)
Other	-	-0.178^{***} (0.025)	-0.005^{***} (0.001)
Western Europe		*Reference*	
Eastern Europe	-0.118^{***} (0.038)	-1.034^{***} (0.011)	-0.075^{***} (0.002)
Northern Europe	-0.441^{***} (0.025)	-0.229^{***} (0.008)	-0.034^{***} (0.002)
Southern Europe	-0.032 (0.021)	-0.579^{***} (0.009)	-0.027^{***} (0.001)
Constant	1.681^{***} (0.438)	4.428^{***} (0.173)	-
$\rho\sigma_1\sigma_2$: correlation	0.022^{***} (0.009)		-
Numb. of obs.		90,684	
***: 1% significant; **: 5% significant; *: 10% significant.			
Standard deviations are into parentheses below coefficients.			

5 Conclusion

A heavily researched topic in health economics is the relationship between income and health and more specifically the direction of causality between the two. While it seems well-known that people with higher incomes enjoy better health, it is far more difficult to establish the direction of the causality. This paper sheds light on the question of causal effects of health on socioeconomic status and vice versa, for elderly individuals in Europe. All waves of the SHARE survey, which follows a statistically representative sample of European people aged 50 and older from 2004 to 2015, are used. The definition of causality chosen here is that of Granger which includes a persistence phenomenon in relationships, as well as permanent causal links thanks to lagged variables. Factors such as morbidity or technical progress are controlled in the health equation, since they could influence the specific impact of income on health. We implement a simultaneous equations model to highlight bidirectional causal links. This enables us to identify components of the health-income relationship and to control for endogeneity by considering a specific error terms' structure. The originality of this paper is the simultaneous bivariate analysis settled, which, to the best of our knowledge, has not yet been done.

Since researchers need a clear understanding of the direction of the causality in this relationship, results presented here contribute to a central point in the analysis of health and income. Our dynamic method and results suggest that, on one hand, income has a permanent effect on subjective health status, and on the other hand, health has a permanent effect on income. Especially, individuals in good health at the previous date have a higher propensity to be in good health today, compared to individuals who are in bad health at the previous date. Moreover, switching from being in bad health to being in good health at the previous date implies an increase of 0.215% in income. Results also suggest that a 1% increase in income at the previous date implies a 1.2% increase in the probability of being in good health today (at date t), and an increase in the current income by 0.319%. More precisely, our results imply that simultaneity between income and health is at play such that it is essential to consider bidirectional analyses. Indeed, one should correctly tackle endogeneity since there might be unobservable components common to both equation.

This paper contributes to a better understanding of the health-income relationship and of the direction of the causality between the two in this literature. This is important for policy makers who want to reduce health inequalities in which income is shown to be an important lever. Finally, this is the first study analyzing the health-income relationship, with a simultaneous equations model, using the SHARE database and establishing strong and permanent Granger causal links.

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Authors' contributions

The authors did the research jointly. Both authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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[14]See www.share-project.org

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A Descriptive Statistics

A.1 Variables of interest and control variables

Table 2: Descriptive statistics of the variables of interests and some covariates

Variables	Mean	Std. dev.	Min.	Max.	Nb. of obs.
Self perceived health	2.833	1.083	0	5	248,966
Binary health =1 (%)	61.49				
Log of income	9.9695	1.328	-6.389	16.122	247,731
Exogenous inc. shock:	%				
Financial gift 5000€ or more	13.83				171,027
Age	66.637	10.108	50	111	248,966
Gini	0.392	0.069	0.273	0.772	248,966
Job situation:	%				246,123
Retired	55.62	*Reference*			
Employed	26.10				
Unemployed	2.80				
Permanently sick	3.47				
Homemaker	9.52				
Other	1.35				
Missing	1.14				
Education:	%				248,736
Without diploma	4.78				
Primary	19.97				
Lower secondary	18.17				
Upper secondary	35.90	*Reference*			
First Stage of tertiary	20.33				
Second stage of tertiary	0.75				
Marital Status:	%				246,510
Married living with spouse	68.18	*Reference*			
Married living single	7.03				
Registered partnership	2.04				
Never married	4.15				
Divorced	6.47				
Widowed	11.15				
Missing	0.98				

A.2 Morbidity indicators

As explained earlier, the morbidity indicators have been chosen following the selection of Dormont et al. [2006]. Our morbidity indicators are divided into three main parts corresponding to the indicators of the Minimum European Health Module (MEHM). The first category concerns the degree of invalidity of individuals and contains information on four health aspects. ADLs consist of “basic activities that are necessary to independent living (e.g. walking, bathing, dressing, toileting, brushing teeth and eating)”, according to the World Health Organization (WHO). This concept determines an individual’s ability to perform the activity with or without assistance. IADLs, according to the World Health Organization, are “activities with aspects of cognitive and social functioning, including shopping, cooking, doing housework, managing money and medication, and using the telephone or the computer”. These tasks support an independent lifestyle. GALI belongs to the family of disability indicators, targeting situations in which health disorders and conditions have impacted people’s usual activities (number of limitations with mobility, arm function and fine motor skills). It is a single-item survey instrument where individuals are asked: “ For at least the last 6 months, have you been limited because of a health problem in activities people usually do?” and they have to answer: “1) Yes, strongly limited, 2) Yes, limited, or 3) No, not limited”. Moreover, in the SHARE survey, individuals are asked to give the number of their limitations concerning mobility (from 0 to 10). The second category of indicators, corresponding to the chronic disease, gives the number of chronic diseases an individual suffer from (heart problem, high blood pressure/high blood cholesterol, stroke or cerebral vascular disease, diabetes, cancer...). Finally, we also take into account the risky behavior with a drinking variable. The World Health Organization recommendations for a reasonable consumption is a maximum of two glasses of alcohol per day.[15]

Table 3: Morbidity Indicators

Variables	Mean	Std. dev.	Min.	Max.	Nb. of obs.
ADLs	0.257	0.882	0	6	248,966
IADLs	0.407	1.243	0	9	248,966
GALI	0.462	0.499	0	1	248,966
Mobility	1.657	2.371	0	10	248,679
Chronic diseases	1.746	1.572	0	14	248,653
Drinking	0.289	0.453	0	1	248,035

[15]However, the WHO also states to abstain from alcohol at least one day in the week, and not to consume more than four drinks on an one-time opportunity.

A.3 Technical progress

Table 4: Life expectancy at 65 years old for all waves and individuals (females and males)

Country	**Mean**	**Std. dev.**	**Min.**	**Max.**	**Nb. of obs.**
Austria	20.003	1.689	17.3	21.7	15,344
Germany	18.622	2.683	11.9	21.2	16,954
Sweden	19.868	1.459	17.4	21.5	16,033
Netherlands	19.289	1.776	16.3	21.2	12,306
Spain	20.943	2.158	17.2	23.4	19,880
Italy	20.436	1.879	17.3	22.6	18,365
France	21.374	2.258	17.7	23.8	19,757
Denmark	18.769	1.538	15.9	20.7	14,091
Greece	19.379	1.546	16.9	21.3	10,449
Switzerland	20.745	1.547	18.2	22.6	11,767
Belgium	19.605	1.842	16.5	21.6	23,173
Israel	20.303	1.092	18.7	21.3	6,685
Czech Republic	17.674	1.803	14.3	19.3	18,453
Poland	17.608	2.226	14.5	20.1	5,918
Luxembourg	20.531	1.422	18.9	21.9	3,138
Hungary	16.547	1.985	14.3	18.3	2,974
Portugal	19.973	1.867	17.8	21.7	3,586
Slovenia	19.569	2.009	16.9	21.4	9,723
Estonia	18.217	2.573	14.3	20.7	17,923
Croatia	18.414	2.884	15.2	21	2,447
Total	19.565	2.276	11.9	23.8	248,966

A.4 Exogenous Shock

Table 5: Exogenous shock of income per country

Country	Gift 5,000€ or more		
	Yes (%)	No (%)	Nb. of obs.
Austria	11.38	88.62	11,062
Germany	17.51	82.49	11,382
Sweden	22.74	77.26	11,374
Netherlands	17.50	82.50	8,533
Spain	7.72	92.28	13,023
Italy	8.31	91.69	12,158
France	11.72	88.28	13,775
Denmark	21.56	78.44	9,818
Greece	14.68	85.32	7,185
Switzerland	19.73	80.27	8,466
Belgium	21.13	78.87	12,928
Israel	4.83	95.17	3,955
Czech Republic	9.73	90.27	12,560
Poland	8.41	91.57	4,008
Luxembourg	19.73	80.27	2,347
Hungary	15.32	84.68	1,952
Portugal	9.44	90.56	2,256
Slovenia	10.06	89.94	6,931
Estonia	6.12	93.88	12,262
Croatia	13.66	86.34	1,588
Total	13.83	86.17	171,027