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# Too late to get healthy? A behavioural analysis of the diet-health relationship in the older Italian population

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***Abstract:*** *The continuous aging of the EU population challenges the sustainability of welfare states. Part of the solution is to ensure that people not only live longer but also better (i.e., that they can function independently while remaining free of disease/disability), which may be achieved through better nutrition and adoption of healthier lifestyles. We test that proposition with a behavioural model of diet quality choice and health determination. The simultaneous equations model, which accounts for the endogeneity of lifestyle choices and is applied to a sample of older Italians, allows for bi-directional causality between diet and health. The health production function confirms that good quality diets and other healthy lifestyles (e.g., physical activity, smoking and drinking) improve self-assessed health. In turn, the elderly respond to illness by improving their diets and exercising more. Supporting healthy aging may be achieved through targeted policies aimed at promoting healthy eating and other healthy lifestyles.*

**Keywords:** Health; elderly; behavioural; nutrition; healthy eating

**JEL codes:** I1; I12; I18; Q18

## 1. INTRODUCTION

The European Union (EU) is currently undergoing a second demographic transition due to the low fertility and increase in life expectancy of its population. After reaching a post-war peak around 1965 (van de Kaa, 1987), the fertility rate of the EU 25 declined well below the replacement rate (2.1) to reach 1.46 in 2001, with only Ireland currently exceeding that threshold value (Vos, 2009). Meanwhile, life expectancy is lengthening almost linearly in the EU as in most developed countries, with no sign of deceleration. Although that evolution has been ongoing for almost 200 years, recent gains in life expectancy have largely been achieved by unprecedented reductions in old-age mortality, hence defying the limits to human longevity set by many scientists only three decades ago (Christensen et al., 2009). Altogether, those demographic changes imply that the EU population is aging rapidly, as indicated by the sharp increase in the share of the population in older age categories (Lanzieri, 2010).

In turn, the aging of the EU population raises a whole range of potential issues, including: the funding of pensions as the dependency ratio rises; difficulties for both governments and families to provide adequate care to the elderly; an increasing cost of health care as the expanding "oldest-old" population group is also the most susceptible to disease and disability; shortages of workers and skills; and even a decline in overall productivity and growth of the economy (Andreason & Miller, 2011). Although the importance of some of those problems may be exaggerated (Cutler et al., 1990), the consensus view considers that the evolution of mortality, disease and disability rates in elderly people represents a fundamental challenge to the sustainability of modern societies (Christensen et al., 2009). The good news is that scientific evidence is accumulating that aging processes are fundamentally modifiable rather than immutable (Christensen et al., 2009) and it is in particular believed that nutritional factors can be used to slow functional decline and the onset of age-related chronic diseases (Horwath, 2002).

That evidence, however, is not sufficient to conclude that the promotion of healthy eating to achieve healthy aging would be an effective policy for three reasons. First, the benefits from nutritional changes measured in strictly-controlled laboratory studies may be misleading, because unconstrained consumers urged or incentivized to improve their diets in one dimension may operate substitutions leading to a worsening of diet quality in another dimension, with an ambiguous overall effect on health. Although not specifically for the older population, this has been repeatedly found in relation to the impact of "fat taxes". Hence, Mytton et al. (2007) reported in a UK study that taxing the principle sources of saturated fat would, paradoxically, result in an increase in the incidence of cardiovascular diseases due to an unexpected rise in salt intake. Second, epidemiological models do not always appropriately account for the fact that diets and other lifestyle factors result from choices, hence leading to endogeneity issues, confounding, and biased inference (Zohoori & Savitz, 1997; Chen et al., 2002). Finally, the question of what obstacles older individuals might face when endeavoring to improve the quality of their diets remains largely unexplored.

Against this background, we propose to develop a behavioural model of diet quality choice and health determination in order to contribute to the current debate on the promotion of healthy eating for healthy ageing. The specific objectives are to: 1- analyse the influence of diet quality on health of older people; 2- identify the main drivers of diet quality in older populations; and 3- clarify the direction of causality between diet quality and health for that population group.

The paper makes several contributions to the existing literature. At an empirical level, we are not aware of any previous attempt at applying the household theory of health production specifically to older people. Given the particularities of that demographic group (e.g., low opportunity cost of time, short planning horizon), it is likely that older individuals behave differently from the general population in relation to nutritional health issues, which gives relevance to our inquiry. Further, at a more conceptual level, we extend the theoretical and empirical framework to allow for the possibility that while diet quality influences health, health may also influence diet quality, as the ubiquity of weight-reducing diets might suggest. Indeed, the relationship from health status to diet seems particularly relevant for the older population, as that demographic group is the most subject to food related chronic diseases (e.g., diabetes or high blood pressure). Although intuitively obvious, the influence of health status on dietary and other lifestyle choices has, surprisingly, not been properly addressed in published studies (e.g., Chen et al., 2002; Contoyannis & Jones, 2005; Balia & Jones, 2008). Hence, by estimating a simultaneous system of diet quality choice and health status determination, we are able to shed new light on the potentially bi-directional nature of the causal relationship between diet and health. Finally, we exploit a micro-level data set particularly rich in its description of the health status, lifestyles choices, environment and socio-demographic characteristics of the elderly.

The next section develops the theoretical framework for the analysis the diet-health relationship, presents the data, and proposes an empirical model as well as an estimation strategy. Section 3 discusses the results and is followed by a conclusion.

## 2. METHODS

### *2.1 THEORETICAL FRAMEWORK*

The dynamic nature of the diet-health relationship implies that time must be included in the modelling framework. However, the data used in the empirical section prevents us from estimating a fully dynamic model. As a compromise between realism and empirical tractability, we therefore consider a one-period optimization problem in which an older person's past health decisions are captured by an initial health stock. Our model of lifestyle and health production function represents an extension of that of Contoyannis & Jones (2004), and its specification starts with the utility maximization problem:

$$\max_{C,M} U(C,H,M) \qquad (1)$$

where U is a neoclassical utility function, which depends first on the consumption C of an aggregate of all market goods and services that do not influence health . Utility is also function of the commodity "good health", denoted by H, which depends itself on an initial health stock H0 and investments in J health inputs Mj as described by the health production function:

$$H = H(H_o, M) \qquad (2)$$

The J-vector M of health inputs can include medical care and lifestyle factors such as diet, smoking, alcohol consumption and physical activity. Those health inputs also enter the utility function (1) directly since it is likely that they influence well-being of the older consumer other than through health – for instance, it is evident that consumption of particular foods generates hedonic rewards. Taking the aggregate consumption good C as numeraire, the budget constraint is:

$$C + \sum_{j=1}^{J} p_j M_j \leq I \qquad (3)$$

where pj denotes the price of the j-th health input. This specification treats income as exogenous and departs from Grossman's original model of health investment (Grossman, 1972) in that the consumer does not choose to allocate time to wage-earning activities. This assumption is justified by the specific population of interest, which includes many retired individuals. Finally, it is assumed that consumption of market goods and health inputs requires time and a related constraint is therefore imposed:

$$\tau_c C + \sum_{j=1}^{J} \tau_j M_j \leq T \qquad (4)$$

Where and denote the amounts of time to consume the market goods and health inputs. The utility maximization problem is solved by defining the Lagrangian function:

$$\max_{C,M} L = U(C, H(H_o, M), M) + \lambda\left[I - C - \sum_{j=1}^{J} p_j M_j\right] + \mu\left[T - \tau_c C - \sum_{j=1}^{J} \tau_j M_j\right] \quad (5)$$

The first-order conditions lead to the following equilibrium equations:

$$U_c = \lambda + \mu\tau_c$$
$$U_j + U_H H_j = \lambda p_j + \mu\tau_j \text{ for j=1,...,J}$$
$$\mu\left[T - \tau_c C - \sum_{j=1}^{J} \tau_j M_j\right] = 0;\ \mu \geq 0 \quad \text{(6 a,b,c)}$$

where Uc, Hj and Hj denote the partial derivatives of the utility and health production functions. The left hand-sides of equations (6 a-b) are the marginal utilities of the market goods and health inputs, the latter having both a direct component Uj and an indirect component UHHj that operates through the production of health. The marginal products are equated to the shadow prices corresponding to the right hand-sides of (6a-b). Those shadow prices are the sum of a monetary component ( or ) and a time component ( or ), which can disappear if the time constraint is not binding. Hence, the equilibrium conditions reflect the extension of the standard consumer model to include a time constraint and household production of health.

Under the assumption of non-satiation, the budget constraint (3) is always binding and we have a square system in J+3 variables (C, M, μ, λ) and J+3 equations (6 a-c & 3). The solution of that system is the set of Marshallian demand functions for the market goods and health inputs:

$$C(p, I, T, H_0)$$
$$M(p, I, T, H_0) \quad \text{(7a,b)}$$

Importantly, we note that demand for the health inputs depends on initial health stock Ho. Hence, focusing on the lifestyle factor of interest, diet influences health through the production function (2) but health influences diet through the Marshallian demand function (7b). The latter equation could for instance capture the situation of a diabetic person adopting a diet low in saturated fat and sugar as a way of managing his/her disease. Our theoretical model therefore gives a framework to investigate the potentially bi-directional relationship between diet and health. It represents an important departure from the other economic models of diet (or more generally lifestyle) and health of which we are aware (Chen et al., 2002; Contoyannis & Jones, 2004; Balia & Jones, 2008), as those consider that adoption of particular lifestyles is not a function of health. In fact, in making the choice of lifestyles and other health inputs dependent on health status, our analytical framework shares more similarities with the models used to analyse the demand for curative and preventive medical care (Gilleskie & Harrison, 1998).

### *2.2 DATA*

Empirical estimation of the theoretical model – and specifically of the production function (2) and demand equations in (7) – requires data on a variety of domains, covering dietary choices and quality, socio-economic factors such as income and prices, as well as health information. Data sets providing high-quality information on all these aspects at the individual level are virtually inexistent, which might explain the scarcity of empirical studies exploring the bi-directional diet-health relationship. For our purpose, we rely on data from the Italian Multipurpose Survey on Daily Life (MSDL), which – albeit not ideal – covers a large part of the required information set.

The MSDL is an annual survey on a multitude of aspects of daily life of the Italian population, which records information on social, cultural, environmental, health and economic characteristics of individual respondents and their households. Food consumption habits are measured through a food frequency questionnaire, which is limited to a selection of food categories. The survey is designed to be representative for sub-groups of the population. For our study, we employ three annual rounds of the Italian MSDL corresponding to years 2008, 2009, and 2010. Unfortunately, these repeated cross-sections do not have a longitudinal dimension as the same individuals are not followed through time. We consider the sub-sample of individuals aged 65 and over and retired from work, which, after a listwise deletion of incomplete observations, gives a final sample of 24970 respondents.

We now seek to relate each variable derived from the MSDL to the theoretical model described in section 2.1.

**Health variables.** Our measure of current health H in the theoretical model is based on the subjective self-assessment of the respondent's health status (SUBJHEALTH), relative to the health status of individuals of the same age. The health stock H0 is measured based on the number and nature of diseases with which the respondent has been diagnosed (ILLNESS). The survey includes information on 15 different disease groups, indicating whether the respondent has been diagnosed with each condition. In order to create a single indicator, we weighted each condition according to the disability weights applied to the 2004 Global Burden of Disease Project (WHO, 2008), and the resulting variable was rescaled to fit a range between zero (no conditions) and one (worst combination of conditions among those included in the survey). We opted for the 2004 GBD disability weights because those from the 2010 GBD study adopted a classification of diseases different from that in our data set, and the quality as well as international validity of those weights have been recently criticised (Nord, 2013). We also include in the empirical model explicit binary variables for two conditions that are most likely to affect weight control behaviours, namely diabetes (DIABETES) and hypertension (HYPER).

Finally, we also include the respondent's Body Mass Index (BMI) in two different ways: first, as a continuous variable measuring a health outcome that may also determine calorie intake; second, we derive a binary variable identifying obese individuals (OBESE) using the standard BMI threshold of 30, and use it as a factor explaining subjective health.

**Subjective well-being.** One of the distinguishing features of the MSDL survey is the availability of multiple self-reported measures of an individual's satisfaction with his/her income, health, family, friends, leisure, environment, and individual safety . These measures of different components of subjective well-being are derived through a micro-level adaptation of the country-level methodology proposed by the OECD (OECD, 2011) and are based on the recommendations produced by the Stiglitz-Sen-Fitoussi commission (Stiglitz et al., 2009). The individual variables on self-reported satisfaction are measured on a four-point Likert scale ("not satisfied at all", "little satisfaction", "reasonably satisfied", "very satisfied"), which are correlated with each other. Thus, they were summarized by means of a non-linear Principal Component Analysis (NL-PCA), i.e. an extension of traditional PCA to account for ordinal variables (Linting et al., 2007; Jöreskog and Moustaki, 2006). This resulted in two clearly distinguished indicators of subjective well-being (SWB). The first one (SWBPERS) mainly summarizes the personal dimensions of subjective well-being (health, family, friends, leisure), while the second one (SWBEXT) relates to factors which can be associated with societal trends (satisfaction with the environmental situation and with safety in the area of residence of the respondent). Interestingly, satisfaction with one's income loaded on both components, with a slightly larger weight for the former. There are strong grounds to consider subjective well-being as a potential determinant of health behaviours and health outcomes, and especially the personal dimensions and satisfaction with the social network (family, friend, leisure) have been recognised as an important explanatory factor of dietary choices of the elderly (Herne, 1995).

**Health inputs, lifestyles and habits.** The main health input (M) of interest in our study is dietary quality, which is measured using an index of departure from recommended nutrient intakes captured by the World Health Organisation (WHO) norms. Following Mazzocchi et al. (2008), we calculated the Recommendation Compliance Index (RCI), which is bounded between zero and one, where zero represents the maximum possible distance from WHO norms and one reflects perfect adherence to the norms. The index does not account for energy intake, which is however an important determinant of body weight and, hence, nutritional health. Given that the Italian MSDL only records food intakes for a selection of food categories, an absolute measurement of calorie intake is unfeasible, but an index (CAL) converting food frequencies into calories and normalized relative to the sample average provides an acceptable proxy. We also consider other variables related to eating habits. The MSDL includes an item on self-reported monitoring of salt intakes (FOODSALT) and another question about the use of iodized salt (IODIZED). These variables may act as a proxy for past attitudes towards eating healthily, and therefore form a potential substitute for lagged variables.

Other consumption and lifestyle choices affecting health include smoking, drinking and physical activity. Only generic measures of those are available. Smoking status (SMOKER) is based on a three-level classification (never smoked, smoked in the past but not currently, and currently smoke). Alcohol consumption (ALCOHOL) is characterised using the same classification. A physical activity measure (PHYS) is also available, and – as for subjective well-being – it was obtained by extracting a single factor from separate ordinal items measuring the intensity of physical activity for domestic and leisure activities. Finally, the only measure on the consumption of medicaments (MEDIC) is a binary variable reporting whether the respondent has taken any pharmaceutical over the two days before the interview.

**Economic variables.** Income – or broader economic status – enters the theoretical model and is recognized as a major explanatory factor in the literature on diet quality of the elderly (Herne, 1995). Our measure of economic status is based on the self-reported financial resources of the family (INCOME), classified in four categories. A binary variable recording whether a pension is the main source of income of the respondent is also included.

However, one of the main obstacles to the empirical estimation of behavioural models of health determination is often the lack of price information, and in this regard our data set is no exception. Thus, we used separate regional price indices for food, alcohol and tobacco together with one overall regional consumer price index for each region and year, based on the standard assumption that prices only vary across regions and over time (see e.g. Deaton, 1988). The (real) price indices (PRICES) are then formed as the ratio of the food (or alcohol, or tobacco) price index and the consumer price index for each of the 20 Italian regions and survey year (all indices are produced by the Italian National Statistical Institute), so that each individual price variable may assume 60 different values depending on the region and survey year of the respondent. Unfortunately prices of leisure physical activities and pharmaceutical products are not provided at the regional level, but they were proxied by the consumer price index.

**Accessibility and mobility.** Among the variables in our data set which are likely to have an impact on behaviours, there are several indicators which can be used to proxy the ease of access of a healthy diet, or measures of other factors facilitating or constraining daily life activities. The variable measuring difficulties in accessing a healthy diet relates first to a more specific question about access to supermarkets (ACCESS), the lack of which has been linked to nutritional risks (Wilson et al., 2004). Furthermore, there are explicit questions about health impairments (HIMPAIR) affecting ordinary daily activities (no limitations, minor limitations, major limitations). The quality of public transport (PUBTRANS) and whether the respondent drives or not (DRIVING) are also two potential factors influencing accessibility of healthy lifestyle choices. Among the determinant of physical activity, the time spent watching television (TV) may also be treated as an explanatory variable.

**Demographics and other variables.** Based on the wide literature on the determinants of food choices of the elderly, a set of additional social and demographic variables is introduced in the empirical analysis. The first obvious candidates are age (AGE) and gender (GENDER). Because age effects may be non-linear, the age variable was broken down into four binary dummies (age classes 65 to70, 71 to75, 76 to 80, and 81 and above). Dummy variables identifying individuals living alone (ALONE), married (MARRIED) and living far away from their family (FAMILYFAR) are also available. The education variable (EDUC) considers various levels of educational attainments. Consumption of cultural/leisure goods (CULT) and services is summarized by the frequency (days per year) of relevant events (i.e., trips/visits to cinemas, theatres, music concerts, museums, monuments, sport events, dancing). Similarly, religious involvement (RELIG) is measured through a variable capturing the number of days per year that the respondent visited a church or another place of worship. Social and political participation (POLIT) is a dummy variable which takes the value one if the respondent participates in any activity with a political party, trade union, social/cultural society or volunteer organization. Finally, the dataset includes binary variables for geographical areas (AREA).

Table 1 below reports the sample's descriptive statistics for all of the variables of the empirical model.

### *2.3 SPECIFICATION OF THE EMPIRICAL MODEL AND ESTIMATION STRATEGY*

The structural system to be estimated consists of two health production functions (8a and 8b) reflecting the theoretical specification of equation (2), one for subjective health and one for the body-mass index seen as a health outcome, and three demand functions for health inputs (8c to 8e), mirroring equation (7b). A sixth equation (8f) translates lifestyle choices into subjective (personal) well-being. The structural specification shown in equation (8) is necessarily incomplete, due to the lack of information on demand and prices for other market goods, including both health inputs and goods not influencing health. Separate estimation for the male and female sub-samples allows for potentially different psychological, behavioural and biological relationships.

SUBJHEALTH=f(RCI,OBESE,ILLNESS,PHYS,HIMPAIR,SMOKER,ALCOHOL,MEDIC,DEMO,SWB) (8a)

BMI=f(CAL,PHYS,DIABETES,HYPER,DEMO) (8b)

CAL=f(PRICE,INCOME,BMI,PHYS,DEMO,ILLNESS,HEIGHT) (8c)

RCI=f(PRICE,INCOME,FOODSALT,IODIZED,ACCESS,DEMO,ILLNESS) (8d)

PHYS=f(PRICE,INCOME,PUBTRANS,DRIVING,TV,DEMO,ILLNESS) (8e)

SWBPERS=f(INCOME,DEMO,ILLNESS,CULTURE,RELIGION,POLITICS) (8f)

The variable names are those listed in Table 1, while DEMO is a set of demographic variables, which includes age, gender, education, geographic area, living alone, and living far from one's family.

The health commodity (H in equation (2)) is measured through the variables SUBJHEALTH and BMI. The health stock H0 is proxied by the variables ILLNESS, DIABETES, HYPER and HIMPAIR. Among health inputs (M) we include diet quality (RCI), calorie intake (CAL), smoking status (SMOKER), alcohol consumption status (ALCOHOL), medicaments (MEDIC) and physical activity (PHYS). In our initial specification, all health inputs (including smoking and alcohol consumption) are treated as endogenous, although we only explicitly estimate the demand for calories, dietary quality and physical activity for which we have continuous dependent variables. Stated behaviours related to salt use (FOODSALT, IODIZED) were also treated as endogenous, since salt can also be considered a health input.

In equation (8a) (subjective) health depends on diet-quality (RCI), health stock (ILLNESS, HIMPAIR), other health inputs (PHYS, SMOKER, ALCOHOL, MEDIC) and obesity (OBESE), which is a health risk factor. We also include subjective well-being (SWB) to test whether it has a direct effect on perceived health status. A set of demographic variables completes the specification.

In equation (8b) BMI is itself a function of specific health stocks (DIABETES, HYPER), but obviously also of energy intakes (CAL) and energy expenditure (PHYS).

The demand equations (8c), (8d) and (8e) all include on the right-hand side socio-economic status (INCOME), the relevant input prices (PRICE), and the health stock (ILLNESS). Calorie demand is also influenced by the body-mass index (BMI) and the intensity of physical activity (PHYS). Food preference variables referring to past behaviours and health consciousness (FOODSALT, IODIZED) and difficulties in accessing supermarkets (ACCESS) are specific to the dietary quality demand equation. The variables specific to the demand for physical activity are the quality of public transport (PUBTRANS), whether the respondent drives (DRIVING) and the number of hours spent watching television (TV). Demographic variables (DEMO) such as AGE, enter all demand equations, while education (EDUC), living alone (ALONE) and distance from the family (FAMILYFAR) are specific to the demand for diet quality.

Finally, equation (8f) explores the potential determinants of the personal dimension of subjective well-being (SWBPERS). Those intutiely include the health stock (ILLNESS), some demographic variables (AGE, FAMILYFAR, MARRIED), the economic situation of the respondent (INCOME), his/her social and political involvement (POLIT) and the frequency of cultural consumption (CULT) and religious participation (RELIG).

Given the specification of the six-equation system (8), the variables to be treated econometrically as endogenous are SUBJHEALTH, BMI (including OBESE), CAL, RCI, PHYS, SWBPERS, SMOKER, ALCOHOL, FOODSALT, IODINE and MEDIC, which represent the health inputs and outputs considered in the structural model. Meanwhile, we assume that the health stock (ILLNESS, DIABETES, HYPER, HIMPAIR), economic variables (PRICES, INCOME), and the other determinants (ACCESS, DEMO, CULT, RELIG, POLIT, PUBTRANS, TV, DRIVING) can be treated econometrically as exogenous variables, in that they are determined outside of our structural model or in previous periods. The same applies to the SWBEXT measure of subjective well-being, which depends on factors over which individuals have little control (e.g., environment, crime) and are determined outside of the behavioural model.

The cross-sectional nature of the data set places some limitations on the analysis, as dynamics (i.e., lagged variables derived from repeated observations) would provide a precious set of exogenous variables, which would allow us to capture longer-term effects and account for omitted (unobservable) variables in a better way. However, it is reasonable to assume that within the time span covered by the surveys there is no immediate effect of food choice on health stocks. Further, we have some information on past behaviours, habits and lifestyles (e.g. smoking, drinking, salt use in the past, etc.), which may prove useful to capture some dynamic effects and serve as instrumental variables.

Our system meets the necessary condition for identification in terms of exclusion restrictions, that is, each equation does not contain the same set of exogenous variables, which allows to distinguish among the structural equations of the system. Furthermore, all equations are overidentified, which opens the way to two-stage least squares (2SLS) and three-stage least squares (3SLS) estimation, using as instruments all exogenous variables in the system. This allows to overcome the simultaneity bias which generates biased and inconsistent OLS estimates of the structural coefficients. We provide OLS estimates to assess the extent of such simultaneity bias, which derives from ignoring endogeneity.

The estimation approach is also motivated by the fact that, while exogeneity tests exist for covariates in instrumental variables regressions, these are intrinsically unreliable since they need to rely on the assumption that some of the regressors are indeed exogenous (Doko and Dufour, 2008). Although we did perform Hausman-type tests on the regressors to confirm or reject their endogeneity, our results are obviously conditional on the validity of our theory-driven structural specification. A comforting finding is that our estimates are quite robust in terms of direction and significance to changes in assumptions on the endogeneity or exogeneity of those variables that are not explicitly endogeneous (i.e. they do not appear on the LHS of the equations of our system).

Two-stage least squares is a limited-information estimation method, as it ignores cross-equation correlations. The gain in efficiency brought by full information methods such as 3SLS must be weighed against the risk of misspecification of the system, as in this case misspecification in one equation has implication for all estimated equations. Since neither method is superior a priori, we report estimation from both in the following section.

## 3. RESULTS

System (8) was estimated using OLS, 2SLS and 3SLS and the estimates of standardised coefficients are shown in Tables 2, 3 and 4. While we present the results separately for health outcomes (Table 2), health input demands (Table 3), and well-being (Table 4) for ease of presentation, the six equations were considered jointly in 2SLS and 3SLS estimation.

### *The production of health*

The first equation represents the main health production function, and the measured health outcome is the subjective perception of health status. In general, the direction of the effects is consistent with a priori expectations, regardless of the estimation method, with some notable exceptions that we will discuss in a second step while addressing the endogeneity issue. When focusing on the 2SLS and 3SLS models, the estimation results strongly support the view that investment in health through adoption of healthy lifestyles results in improvement in self-assessed health of elderly individuals, although there are substantial differences between genders and across lifestyles. Adoption of higher quality diets as measured by the RCI improves self-stated health of elderly females, although we find no evidence that compliance with nutrition recommendation has a direct impact on males' subjective health (i.e., the relevant coefficient is not statistically significant). The level of physical activity also influences health positively, with a particularly large standardised coefficient for elderly males, but the relationship is not statistically significant for women. Smoking (currently) lowers self-stated health, although the relationship is only statistically significant for elderly males in the 2SLS model. The adverse health effects of current alcohol consumption are much more robustly established, both for men and women.

The results also reveal that, unsurprisingly, many factors other than current lifestyles influence the health of elderly individuals. Health stock (illness index) has obviously a large and significant impact on subjective health, and freedom from major health-related impairments has a significant positive impact on self-assessed health, as should be expected. Excess weight has a significant and negative effect, especially for women, for whom the largest negative determinant of health corresponds to obesity. We also confirm that subjective well-being, and especially the factor related to social networks and personal satisfaction, is by itself an important driver of health, especially for elderly women. Altogether, and given the micro-level and cross-sectional nature of the data, the explanatory power of the health production equations is relatively high as indicated by R-squared values in excess of 0.41 for both genders and all estimation methods.

Comparison of the OLS results with those from 2SLS and 3SLS estimation makes clear that accounting for endogeneity is important to the determination of the health production function. For instance, the statistical significance and magnitude of the adverse effects of alcohol consumption and smoking only become evident in the 2SLS and 3SLS results, while the OLS results erroneously suggest that those two lifestyle factors actually improve health. The magnitude of the statistically significant coefficients associated with diet quality and physical activity is also much larger in the 2SLS/3SLS models than in the OLS equivalent, so that ignoring endogeneity of lifestyle factors would lead to a severe underestimation of the influence of those lifestyles factors on health.

The second health production equation explores the determinants of BMI. Again, addressing endogeneity improves the interpretability of the results. The OLS model does not find any association between BMI and calorie intake, and only indicates a weakly significant negative relationship between BMI and physical activity. When endogeneity is considered in the female sub-sample, the expected signs emerge for calorie intake and physical activity, although that is not the case for males. Furthermore, BMI drops significantly with age and is higher for those living in the south of Italy. It is positively associated with diabetes and hypertension, which is consistent with the view that both diseases are part of a broader metabolic syndrome that also includes obesity (Grundy et al., 2004). Besides these well-known associations, causal factors generating excess weight are still difficult to identify.

### *Lifestyle choices and their determinants*

Table 3 reports the estimates of the equations describing demand for the three health inputs, and confirms broadly the theoretical proposition that health is an important determinant of lifestyle choices in general and dietary quality in particular. More diagnosed illnesses, as captured by the illness index, induce elderly individuals to raise the quality of their diets and their level of physical activity (although the latter result does not apply to women). Further, diabetic males also make relatively healthier food choices (the relationship is not significant for women), although the reverse is true for those diagnosed with hypertension, which is difficult to explain. Demand for calories is not found to be influenced by the health stock variable (the coefficients are all zero for the 2SLS and 3SLS estimates). Overall, however, the results are consistent with the view that individuals respond to a deterioration of their health capital by adopting healthier lifestyles. Here again, this conclusion would not have been reached without having accounted for the simultaneity of health determination and lifestyle choices. Taking elderly males as an example, the effect of an increase in the number of diagnosed illnesses on diet quality is nil in the OLS model but positive and strongly significant in the 2SLS/3SLS models. Similarly, the OLS results suggest that a rise in the illness indicator results in a significant decrease in the level of physical activity of elderly females, but IV-based models indicate the opposite.

We find that economic characteristics of the environment in which the elderly live also influence lifestyle choices. The results clearly show that food prices matter in determining calorie intake and dietary quality. Given that no price data are available for physical activity, we proxied the price of such activities with the general price index, and find a strong negative relationship between that index and the intensity of physical activity. Table 4 translates the price coefficients into elasticities, although some caution is needed given that both diet quality and the intensity of physical activity are measured through indicators. The values are similar across genders, a 10% increase in prices leading to a 3% reduction in calorie intake, but also in a 6% reduction in the diet quality index. Significant substitutions emerge between calorie intake, alcohol consumption and especially smoking.

Resource availability is often stressed in the literature as an important determinant of food choices and their healthiness, but the estimation results indicate that income has little influence on dietary quality and demand for calories. The lower energy intake of the elderly belonging to the lowest of the four income categories represents the only robust result. Resource availability is, however, a significant determinant of physical activity, with the well-off elderly choosing to exercise less.

Our analysis identifies many other socio-demographic factors influencing lifestyles choices. With reference to diet quality, we find a relatively strong positive association between habits revealing health-consciousness (e.g., monitoring salt content, and use of iodized salt) and demand for dietary quality, suggesting some persistence of virtuous habits. Difficulties in accessing supermarkets create a (weak) barrier to consuming a healthy diet. However, there is no strong evidence of an educational gradient in the choice of dietary quality, and age also has little impact on healthy eating decisions.

Even at older ages, physical activity remains a key health input, as demonstrated by its major role in improving subjective health and reducing the body-mass index. However, demand for physical activity (leisure or at home) rapidly decreases with age. The intensity of physical activity is also driven by the availability of transport means, especially autonomous transport. Males driving a car show on average higher levels of physical activity. Subjective well-being, in its personal dimension (capturing satisfaction with one's social networks, health status, income), generates significantly higher levels of physical activity, adding a further positive indirect effect on health beyond the direct effect shown in the health production equation.

Finally, table 5 reports the estimates for the subjective well-being equation. The estimates are fairly similar for males and females (with the exception of the low but significant coefficient of the MARRIED variable) and conform with expectations. Subjective well-being increases with income, and decreases with illness. A more intense social and cultural life, as well as regular religious practices, improve the perception of personal well-being. Interestingly, once these factors are accounted for, age does not imply less satisfaction.

## 4. CONCLUSION

We developed a theoretically consistent behavioural model of dietary (and other lifestyle) choices and health determination allowing for the possibility that while eating habits may influence health, the reverse is at least equally likely to hold a priori (i.e., people diagnosed with diabetes or other chronic diseases adjust their diets, possibly in response to official medical advice). Even if this idea appears fairly intuitive, it has not been captured by the existing models of health behaviour published to date. Estimation of a corresponding simultaneous equations structural model was performed using a large individual-level data set describing in detail the choices, health status, environment, social networks and satisfaction with multiple aspects of the daily lives of elderly Italians.

The results support the proposition that, even for the elderly, the causal relationship between diet and health is bi-directional. First, we establish, in line with most of the epidemiological literature on the subject, that healthy eating habits influence health positively, and the estimated health production function further reveals that other lifestyles choices, such as smoking, drinking, and physical activity are important determinants of health. While this does not represent a particularly controversial conclusion, it is worth stressing that the analysis was carried out exclusively on individuals over 65 years of age, and that health was self-assessed. Thus, the results imply that adoption of healthy diets and other healthy lifestyles generates rapid health rewards even in older age and after controlling for diagnosed illnesses, or, in other words, that it is never too late to get healthy (or healthier). This encouraging conclusion also means that promotion of healthy eating and other healthy lifestyles among the elderly represents a promising avenue to foster the healthy aging of the Italian population.

In the reverse direction, we find that the health stock as measured by an index of diagnosed diseases has a significant influence on decisions to adopt a healthy diet and, more generally, invest in health inputs. Overall, elderly individuals diagnosed with diseases respond by adopting better-quality diets and raising their level of physical activity. These behavioural adjustments, as well as the true nature of the health production function, are only clearly established after addressing the issue of endogeneity econometrically, which confirms the importance of developing fully structural models of lifestyle choices and health as emphasized by other authors previously (Contoyannis & Jones, 2004; Chen et al., 2002).

Our model also identifies the determinants of healthy eating and other healthy lifestyles, and it is therefore worth reflecting on the nature of possible policy interventions and how effective these might be in influencing diet quality, BMI and health among older people. Broadly speaking there are two main types of intervention (see Mazzocchi, Traill and Shogren, 2009); the first, may be called information measures and include education, social marketing and nutrition labelling that, in principle, permit consumers to make more informed choices. The second group of policies changes the market environment more directly, by modifying relative prices (e.g. 'fat taxes') or changing food availability (e.g. reformulation to reduce the levels of 'harmful' nutrients like salt or trans fatty acids in foods). While our model does not permit direct explicit examination of the impact of many of these policy measures, it generates nonetheless some relevant insights.

Hence, raising the relative price of food to non-foods worsens diet quality, which may argue against imposing VAT on food; it may also argue for measures to reduce the severity of food price spikes which have become a common phenomenon in recent years. However, we also find that higher relative food prices result in lower intakes of calories, which represents a positive change for a majority of elderly individuals given the prevalence of obesity and overweight in that age group. In view of this trade-off, we conclude that manipulation of the VAT rate of foods is too blunt of an instrument to improve the nutritional health of the elderly. The analysis does not allow us to go further and assess whether taxes applied differentially to foods or nutrients according to their healthiness may be more effective in promoting healthy eating.

We find little evidence that poor diets and unhealthy lifestyles result from low income among the elderly. This is consistent with a recent analysis of determinants of diet quality in four European countries (Irz et al., 2013), including Italy, but unlike the conclusion of that study, ours was reached on the basis of a fully structural model which is superior for an analysis of causal relationships. It is important in that it suggests that, at least among the elderly, poor diet quality is not primarily an economic issue – a view that is often popular in public health circles (e.g., Drewnosky & Darmon, 2005). This is encouraging since it implies that promotion of healthy eating among the elderly could potentially be achieved through specific policy interventions rather general macroeconomic adjustments (an example of the latter would be to address income poverty in old age ).

Concluding about the potential effectiveness of informational measures for the promotion of health eating is more difficult. To the extent that there is an association between the level of a person's general education (which we do model) and their willingness and ability to assimilate new information on nutrition, we might expect that information measures would improve diet quality of the better educated. However, given our finding that there is little educational gradient in the adoption of healthy lifestyles among the elderly, this should not be considered a major problem of informational policies.

Finally, we must acknowledge some limitations of the study, and particularly the difficulties linked to the cross-sectional nature of the data for an analysis of health investment that may take time to generate effects. Panel data with repeated observations on food choices and health over a long time spam would permit a better treatment of unobserved heterogeneity, but we must emphasize that the cross-sectional nature of our data set should be weighed against the particularly rich description of the daily lives of the Italian elderly that it provides.

## Table 1. Descriptive statistics

| Variable | Description | Mean | Std. Dev. | Variable | Description | Mean | Std. Dev. |
|---|---|---|---|---|---|---|---|
| ACCESS | Difficulty to access supermarkets | 0.47 | 0.67 | GENDER | Gender: female | 0.58 | 0.49 |
| AGE_1 | Aged 66-70 | 0.27 | 0.44 | HIMPAIR_1 | Limitation in daily life activities because of health: none | 0.44 | 0.50 |
| AGE_2 | Aged 71-75 | 0.24 | 0.43 | HIMPAIR_2 | Limitation in daily life activities because of health: minor | 0.36 | 0.48 |
| AGE_3 | Aged 76-80 | 0.20 | 0.40 | HIMPAIR_3 | Limitation in daily life activities because of health: major | 0.20 | 0.40 |
| AGE_4 | Aged 81 or above | 0.24 | 0.43 | HYPER | Hypertension | 0.49 | 0.50 |
| ALCOHOL | Drinks alcohol | 0.45 | 0.50 | ILLNESS | llness indicator | 0.13 | 0.12 |
| ALCOHOL_QUIT | Quit alcohol | 0.05 | 0.22 | INCOME_1 | Income - extremely low | 0.06 | 0.23 |
| ALONE | Living alone | 0.29 | 0.45 | INCOME_2 | Income - low | 0.42 | 0.49 |
| AREA_1 | Living in the North-West | 0.22 | 0.42 | INCOME_3 | Income - adequate | 0.51 | 0.50 |
| AREA_2 | Living in the North-East | 0.20 | 0.40 | INCOME_4 | Income - high | 0.01 | 0.12 |
| AREA_3 | Living in Central Italy | 0.20 | 0.40 | INCOME_PENS | Pension as main source of income | 0.91 | 0.29 |
| AREA_4 | Living in the South | 0.28 | 0.45 | IODIZED | Iodised salt use | 0.37 | 0.48 |
| AREA_5 | Living in Islands | 0.10 | 0.31 | MARRIED | Respondent is married | 0.57 | 0.49 |
| BMI | Body mass index (continuous) | 26.05 | 3.86 | MEDIC | Makes use of medicaments | 0.81 | 0.39 |
| BMI_1 | Underweight (BMI<18.5) | 0.02 | 0.12 | PHYS | Physical activity level | 0.63 | 0.43 |
| BMI_2 | Normal weight (18.5<BMI<25) | 0.38 | 0.49 | POLIT | Social and political participation | 0.64 | 1.33 |
| BMI_3 | Overweight (25<BMI<30) | 0.46 | 0.50 | PRICE - CPI | Consumer price index | 127.43 | 2.21 |
| BMI_4 | Obese (BMI>30) | 0.14 | 0.35 | PRICE_ALC | Price of alcohol (real) | 0.01 | 0.00 |
| CAL | Calorie intake | 1468.65 | 364.24 | PRICE_FOOD | Price of food (real) | 1.02 | 0.03 |
| CULT | Frequency of cultural activities | 2.56 | 6.80 | PRICE_TOB | Price of tobacco (real) | 0.01 | 0.00 |
| DIABETES | Has diabetes | 0.17 | 0.38 | PUBTRANS | Quality of public transport | 0.92 | 0.99 |
| DRIVING | Drives a car | 0.40 | 0.49 | RCI | Recommendation compliance index | 0.73 | 0.11 |
| EDU_1 | Education - no title, can't read/write | 0.03 | 0.17 | RELIG | Frequency of religious attendance | 52.07 | 73.13 |
| EDU_2 | Education - no title, read and write | 0.14 | 0.35 | SMOKE_QUIT | Quit smoking | 0.59 | 0.49 |
| EDU_3 | Education - primary school | 0.52 | 0.50 | SMOKER | Current smoker | 0.09 | 0.29 |
| EDU_4 | Education - lower secondary | 0.16 | 0.37 | SUBJHEALTH | Perceived health status | 3.04 | 0.79 |
| EDU_5 | Education - upper secondary and above | 0.11 | 0.32 | SWBEXT | Subjective well-being (external factors) | -0.01 | 1.09 |
| FAMILYFAR | Living far from family | 0.20 | 0.40 | SWBPERS | Subjective well-being (personal factors) | -0.02 | 1.05 |
| FOODSALT_1 | Salt content - reduced | 0.44 | 0.50 | TV | Hours spent watching TV | 13.24 | 29.10 |
| FOODSALT_2 | Salt content - always monitored | 0.37 | 0.48 | | | | |

## Table 2. Estimation results: health outcomes (standardized coefficients)

| | Estimation method | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OLS | | | | 2SLS | | | | 3SLS | | | |
| **Determinant** | Males | | Females | | Males | | Females | | Males | | Females | |
| | Health outcome (Perceived health status) | | | | | | | | | | | |
| Diet quality (RCI) | 0.03 | *** | 0.04 | *** | -0.16 | | 0.17 | * | -0.06 | | 0.23 | *** |
| Physical activity | 0.10 | *** | 0.10 | *** | 0.43 | *** | 0.09 | | 0.56 | *** | 0.09 | |
| Obese | -0.01 | | -0.02 | *** | -0.15 | * | -0.41 | *** | -0.14 | * | -0.46 | *** |
| Illness index | -0.23 | *** | -0.22 | *** | -0.22 | *** | -0.19 | *** | -0.22 | *** | -0.17 | *** |
| Current smoker | 0.00 | | 0.01 | | -0.48 | *** | -0.15 | | -0.18 | | -0.07 | |
| Drinks alcohol | 0.03 | *** | 0.04 | *** | -0.19 | *** | -0.14 | *** | -0.23 | *** | -0.15 | *** |
| Aged 71-75 | -0.03 | *** | -0.03 | *** | -0.04 | *** | -0.03 | *** | -0.02 | | -0.03 | *** |
| Aged 76-80 | -0.04 | *** | -0.03 | *** | -0.05 | *** | -0.04 | *** | -0.01 | | -0.03 | ** |
| Aged 81 or above | -0.04 | *** | -0.01 | | -0.05 | ** | -0.04 | | 0.01 | | -0.02 | |
| Makes use of medicaments | -0.14 | *** | -0.13 | *** | -0.16 | *** | -0.11 | *** | -0.15 | *** | -0.13 | *** |
| Quit smoking | 0.00 | | -0.02 | ** | -0.13 | *** | -0.09 | | -0.06 | | -0.06 | |
| Quit alcohol | -0.03 | *** | -0.01 | | -0.09 | *** | -0.03 | *** | -0.09 | *** | -0.03 | *** |
| Subjective well-being (personal factors) | 0.16 | *** | 0.13 | *** | 0.18 | *** | 0.31 | *** | 0.09 | | 0.38 | *** |
| Subjective well-being (external factors) | 0.06 | *** | 0.05 | *** | 0.07 | *** | 0.06 | *** | 0.07 | *** | 0.05 | *** |
| Limitation in daily life activities because of health: none | 0.44 | *** | 0.47 | *** | 0.42 | *** | 0.42 | *** | 0.37 | *** | 0.41 | *** |
| Limitation in daily life activities because of health: minor | 0.23 | *** | 0.26 | *** | 0.21 | *** | 0.25 | *** | 0.17 | *** | 0.23 | *** |
| $R^2$ | *0.42* | | *0.43* | | *0.41* | | *0.41* | | *0.41* | | *0.41* | |
| | BMI Health outcome | | | | | | | | | | | |
| Calorie intake | 0.00 | | 0.01 | | 0.04 | | 0.15 | ** | -0.05 | | 0.24 | *** |
| Physical activity level | -0.02 | * | -0.02 | * | -0.02 | | -0.27 | *** | 0.00 | | -0.29 | *** |
| Diabetes | 0.09 | *** | 0.11 | *** | 0.09 | *** | 0.11 | *** | 0.10 | *** | 0.12 | *** |
| Hypertension | 0.12 | *** | 0.11 | *** | 0.12 | *** | 0.11 | *** | 0.11 | *** | 0.10 | *** |
| Ilnness index | 0.00 | | 0.05 | *** | 0.00 | | 0.02 | ** | 0.00 | | 0.03 | *** |
| Aged 71-75 | -0.02 | ** | 0.00 | | -0.02 | ** | -0.01 | | -0.02 | ** | -0.01 | |
| Aged 76-80 | -0.09 | *** | -0.03 | *** | -0.09 | *** | -0.07 | *** | -0.09 | *** | -0.07 | *** |
| Aged 81 or above | -0.14 | *** | -0.12 | *** | -0.14 | *** | -0.22 | *** | -0.14 | *** | -0.23 | *** |
| Living in Central Italy | 0.03 | ** | 0.06 | *** | 0.03 | ** | 0.05 | *** | 0.03 | ** | 0.06 | *** |
| Living in Islands | 0.04 | *** | 0.06 | *** | 0.04 | *** | 0.04 | *** | 0.04 | *** | 0.06 | *** |
| Living in the North-East | 0.04 | *** | 0.04 | *** | 0.04 | *** | 0.06 | *** | 0.04 | *** | 0.05 | *** |
| Living in the South | 0.08 | *** | 0.13 | *** | 0.08 | *** | 0.10 | *** | 0.07 | *** | 0.11 | *** |
| $R^2$ | *0.04* | | *0.06* | | *0.04* | | *0.07* | | *0.04* | | *0.06* | |

## Table 3. Estimation results: demand for health inputs (standardized coefficients)

| | Estimation method | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OLS | | | | 2SLS | | | | 3SLS | | | |
| **Determinant** | Males | | Females | | Males | | Females | | Males | | Females | |
| | Demand for calories | | | | | | | | | | | |
| Price of food (real) | -0.10 | *** | -0.07 | *** | -0.04 | ** | -0.03 | * | -0.04 | ** | -0.03 | ** |
| Price of alcohol (real) | 0.13 | *** | 0.07 | ** | 0.10 | ** | 0.05 | | 0.12 | *** | 0.06 | ** |
| Price of tobacco (real) | 0.14 | *** | 0.09 | *** | 0.09 | ** | 0.06 | ** | 0.11 | *** | 0.07 | *** |
| Income - extremely low | -0.08 | *** | -0.07 | *** | -0.06 | *** | -0.07 | *** | -0.06 | *** | -0.06 | *** |
| Income - low | -0.06 | | -0.06 | * | -0.03 | | -0.05 | | -0.03 | | -0.05 | |
| Income - adequate | -0.01 | | -0.02 | | 0.01 | | -0.01 | | 0.00 | | -0.01 | |
| Pension as main source of income | -0.01 | | 0.00 | | -0.01 | | 0.01 | | -0.01 | | 0.01 | |
| Aged 71-75 | 0.00 | | -0.02 | * | 0.01 | | -0.01 | | 0.01 | | -0.01 | |
| Aged 76-80 | -0.01 | | -0.02 | ** | -0.01 | | 0.00 | | -0.01 | | 0.00 | |
| Aged 81 or above | -0.02 | | -0.03 | *** | 0.01 | | 0.02 | | 0.00 | | 0.02 | |
| Physical activity level | 0.06 | *** | 0.07 | *** | 0.25 | *** | 0.23 | *** | 0.26 | *** | 0.22 | *** |
| Body mass index | 0.00 | | 0.01 | | -0.17 | *** | -0.10 | ** | -0.20 | *** | -0.08 | * |
| Illness indicator | -0.03 | *** | -0.02 | *** | 0.00 | | 0.00 | | 0.00 | | 0.00 | |
| $R^2$ | *0.03* | | *0.03* | | *0.04* | | *0.03* | | *0.04* | | *0.03* | |
| | Demand for dietary quality | | | | | | | | | | | |
| Price of food (real) | -0.09 | *** | -0.09 | *** | -0.11 | *** | -0.11 | *** | -0.12 | *** | -0.10 | *** |
| Income - extremely low | 0.00 | | -0.06 | *** | 0.03 | | -0.04 | | 0.03 | | -0.04 | |
| Income - low | 0.02 | | -0.06 | * | 0.07 | | -0.04 | | 0.07 | | -0.03 | |
| Income - adequate | 0.07 | * | -0.04 | | 0.10 | * | -0.05 | | 0.10 | * | -0.04 | |
| Pension as main source of income | 0.01 | | -0.01 | | 0.01 | | -0.02 | * | 0.01 | | -0.02 | ** |
| Aged 71-75 | 0.03 | ** | -0.01 | | 0.02 | | 0.01 | | 0.02 | | 0.00 | |
| Aged 76-80 | 0.01 | | -0.05 | *** | 0.00 | | -0.01 | | -0.01 | | -0.01 | |
| Aged 81 or above | -0.01 | | -0.08 | *** | 0.00 | | -0.02 | | -0.01 | | -0.03 | * |
| Education - no title, read and write | -0.01 | | -0.01 | | 0.00 | | 0.01 | | 0.00 | | 0.00 | |
| Education - primary school | 0.00 | | 0.00 | | -0.02 | | -0.03 | ** | -0.02 | | -0.04 | *** |
| Education - lower secondary | 0.04 | *** | 0.02 | ** | 0.01 | | 0.00 | | 0.01 | | -0.01 | |
| Education - upper secondary and above | 0.04 | *** | 0.04 | *** | 0.00 | | 0.00 | | 0.00 | | 0.01 | |
| Living alone | -0.04 | *** | 0.00 | | -0.01 | | -0.01 | | 0.00 | | 0.01 | |
| Living far from family | 0.01 | | -0.01 | | 0.01 | | -0.01 | | 0.01 | | -0.01 | |
| Salt content - always monitored | 0.06 | *** | 0.08 | *** | 0.65 | *** | 0.84 | *** | 0.62 | *** | 0.83 | *** |
| Salt content - reduced | 0.09 | *** | 0.10 | *** | 0.93 | *** | 1.05 | *** | 0.95 | *** | 0.96 | *** |
| Iodised salt use | 0.05 | *** | 0.05 | *** | 0.13 | | 0.30 | *** | 0.11 | | 0.33 | *** |
| Illness index | 0.00 | | 0.02 | * | 0.04 | * | 0.05 | *** | 0.04 | * | 0.04 | ** |
| Diabetes | 0.03 | *** | 0.01 | | 0.03 | ** | 0.00 | | 0.05 | *** | 0.01 | |
| Hypertension | 0.04 | *** | 0.02 | ** | -0.03 | | -0.05 | ** | -0.04 | ** | -0.03 | * |
| Perceived health status | 0.07 | *** | 0.08 | *** | 0.18 | *** | 0.16 | *** | 0.18 | *** | 0.16 | *** |
| Difficulty to access supermarkets | -0.03 | *** | -0.02 | ** | -0.01 | | -0.01 | | -0.01 | | -0.02 | * |
| $R^2$ | *0.04* | | *0.04* | | *0.04* | | *0.04* | | *0.04* | | *0.04* | |
| | Demand for physical activity | | | | | | | | | | | |
| Consumer price index | -0.11 | *** | -0.11 | *** | 0.00 | | -0.03 | *** | -0.02 | * | -0.05 | *** |
| Income - extremely low | -0.03 | | 0.00 | | 0.13 | *** | 0.07 | *** | 0.24 | *** | 0.13 | *** |
| Income - low | -0.06 | | 0.02 | | 0.28 | *** | 0.16 | *** | 0.52 | *** | 0.27 | *** |
| Income - adequate | -0.02 | | 0.03 | | 0.20 | *** | 0.08 | ** | 0.35 | *** | 0.12 | *** |
| Pension as main source of income | 0.02 | ** | -0.02 | *** | 0.02 | | -0.04 | *** | 0.02 | | -0.06 | *** |
| Aged 71-75 | -0.03 | ** | -0.04 | *** | -0.05 | *** | -0.07 | *** | -0.07 | *** | -0.07 | *** |
| Aged 76-80 | -0.06 | *** | -0.13 | *** | -0.08 | *** | -0.14 | *** | -0.06 | *** | -0.13 | *** |
| Aged 81 or above | -0.13 | *** | -0.34 | *** | -0.17 | *** | -0.36 | *** | -0.14 | *** | -0.34 | *** |
| Subjective well-being (personal factors) | 0.09 | *** | 0.10 | *** | 1.10 | *** | 0.87 | *** | 1.78 | *** | 1.36 | *** |
| Subjective well-being (external factors) | -0.02 | ** | 0.00 | | 0.01 | | 0.00 | | 0.01 | | 0.00 | |
| Drives a car | 0.17 | *** | 0.09 | *** | 0.08 | *** | 0.04 | *** | 0.10 | *** | 0.03 | *** |
| Hours spent watching TV | -0.04 | *** | -0.04 | *** | 0.02 | | 0.01 | | 0.01 | | 0.00 | |
| Quality of public transport | -0.04 | *** | -0.01 | * | 0.04 | *** | 0.04 | *** | 0.02 | ** | 0.03 | *** |
| Illness index | -0.01 | | -0.04 | *** | 0.03 | ** | -0.01 | | 0.10 | *** | 0.05 | *** |
| Limitation in daily life activities because of health: none | 0.22 | *** | 0.28 | *** | 0.14 | *** | 0.18 | *** | 0.15 | *** | 0.20 | *** |
| Limitation in daily life activities because of health: minor | 0.16 | *** | 0.23 | *** | 0.19 | *** | 0.25 | *** | 0.17 | *** | 0.22 | *** |
| $R^2$ | *0.17* | | *0.27* | | *0.20* | | *0.29* | | *0.15* | | *0.26* | |

## Table 4. Price elasticities

| Demand response | Price | | | |
|---|---|---|---|---|
| | Food | Alcohol | Tobacco | General |
| | | Males | | |
| Calories | -0.34 | 0.16 | 0.80 | |
| | (0.14) | (0.05) | (0.23) | |
| Diet quality | -0.62 | | | |
| | (0.07) | | | |
| Physical activity | | | | -0.77 |
| | | | | (0.01) |
| | | Females | | |
| Calories | -0.26 | 0.09 | 0.57 | |
| | (0.13) | (0.05) | (0.21) | |
| Diet quality | -0.55 | | | |
| | (0.06) | | | |
| Physical activity | | | | -1.89 |
| | | | | (0.01) |

Note: standard error in brackets (Delta method)

## Table 5. Estimation results: subjective well-being (standardized coefficients)

| Determinant | Estimation method | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OLS | | | | 2SLS | | | | 3SLS | | | |
| | Males | | Females | | Males | | Females | | Males | | Females | |
| | | | | | Well-being | | | | | | | |
| Income - extremely low | -0.15 | *** | -0.09 | *** | -0.15 | *** | -0.09 | *** | -0.16 | *** | -0.10 | *** |
| Income - low | -0.32 | *** | -0.19 | *** | -0.32 | *** | -0.19 | *** | -0.33 | *** | -0.20 | *** |
| Income - adequate | -0.20 | *** | -0.06 | * | -0.20 | *** | -0.06 | * | -0.21 | *** | -0.06 | * |
| Pension as main source of income | 0.00 | | 0.02 | ** | 0.00 | | 0.02 | ** | 0.00 | | 0.03 | *** |
| Aged 71-75 | 0.03 | *** | 0.02 | ** | 0.03 | *** | 0.02 | ** | 0.03 | ** | 0.02 | ** |
| Aged 76-80 | 0.01 | | 0.01 | | 0.01 | | 0.01 | | 0.00 | | 0.01 | |
| Aged 81 or above | 0.01 | | 0.01 | | 0.01 | | 0.01 | | 0.00 | | 0.01 | |
| Attendance of cultural events | 0.07 | *** | 0.07 | *** | 0.07 | *** | 0.07 | *** | 0.07 | *** | 0.07 | *** |
| Involved in politics | 0.07 | *** | 0.11 | *** | 0.07 | *** | 0.11 | *** | 0.06 | *** | 0.08 | *** |
| Religious | 0.02 | ** | 0.02 | ** | 0.02 | ** | 0.02 | ** | 0.02 | *** | 0.04 | *** |
| Married | 0.02 | ** | 0.01 | | 0.02 | ** | 0.01 | | -0.02 | *** | 0.03 | *** |
| Living far from family | -0.07 | *** | -0.05 | *** | -0.07 | *** | -0.05 | *** | -0.01 | | -0.01 | |
| Illness indicator | -0.07 | *** | -0.09 | *** | -0.07 | *** | -0.09 | *** | -0.08 | *** | -0.09 | *** |
| $R^2$ | *0.06* | | *0.06* | | *0.06* | | *0.05* | | *0.06* | | *0.06* | |

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