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**ABSTRACT**

In old age, consumption can fluctuate because of shocks to available resources and because health shocks affect utility from consumption. We find that even temporary drops in income and health are associated with drops in consumption and most of the effect of temporary drops in health on consumption stems from the reduction in the marginal utility from consumption that they generate. More precisely, after a health shock, richer households adjust their consumption of luxury goods because their utility of consuming them changes. Poorer households, instead, adjust both their necessary and luxury consumption because of changing resources and utility from consumption.

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# 1 Introduction

To what extent are households subject to risks and to what extent are they insured by the government, themselves, their family, and their community? Given the importance of this question, it is not surprising that many papers have offered different perspectives on it, in the context of both developed and developing countries.

To answer this question, the vast majority of these papers focus on people of working age and study the effects of income shocks on consumption. The key idea is that income fluctuations that result in consumption fluctuations signal that households are imperfectly insured. While this is a very sensible approach, the population is aging, people across the world live much longer and, as they become older, health shocks assume an increasingly important role. This has two important implications. The first one is that health shocks are an additional important source of risk later in life. The second one is that health shocks might affect both resources and the marginal utility of consumption.

Disentangling the causes of consumption changes due to shocks crucially determines how we should best insure people. Consider, for instance, a person hit by a health shock that generates an income drop. Within this situation, there are two possible scenarios. In one, this person's marginal utility function does not change and any drop in consumption reflects a drop in resources. This can call for additional insurance to alleviate frictions that prevent people from smoothing out income fluctuations: this is the traditional view that has been tested. But under a different scenario, suppose that this person's health shock also reduces his or her marginal utility from consumption, for instance because the person no longer derives the same utility from traveling. This person's consumption might now fluctuate for two reasons. One pertains to the fluctuation in resources. The other one pertains to the fluctuation in the marginal utility caused by a change in health. It could well be, for instance if this person has a lot of assets, that he or she has no problem smoothing out income fluctuations as desired, and that all fluctuations in consumption come from a change in the utility of consumption resulting from a change in health.

The implications in terms of insurance in these two scenarios are different: if the person has no change in marginal utility from consumption as a result of these health and income shocks but experiences a large drop in consumption, it is desirable to give him or her transfers to smooth consumption and thus marginal utility fluctuations.

In contrast, if health mainly reduces the marginal utility of consumption, giving resources to a person affected by a negative health shock is not an effective policy (a benevolent planner maximizing total utility would allocate less consumption to a person whose marginal utility of consumption has decreased). Thus, optimal insurance depends on why consumption fluctuates.

In this paper, we measure the effects of both income and health shocks on consumption among households over age 65 and we decompose the consumption response to a health shock into its effect on resources (which can come from changes in both income and expenses on medical goods and services, a category that we distinguish from regular consumption), and its effect on the marginal utility from consumption of goods and services.

Our analysis requires observing, for the same household, income, health, and broad-based consumption measures; and such data has been notably difficult to find. To overcome this problem and pair income and health data together with consumption data, we use the Consumption and Activities Mail Survey (CAMS) that is sent to a subset of households enrolled in the Health and Retirement Survey (HRS) since 2001.

The HRS is a longitudinal panel study that is conducted every other year and is representative of the U.S. population over the age of 50 and their spouses. It collects information on health status and income over the past year. The CAMS is conducted on the off-years in between the main HRS years and collects information about consumption in the contemporaneous year, that is, over the same period as reported for health and income. Its consumption information is quite detailed and allows us to build and analyze several consumption categories: food, utilities, and car-related expenditures (repairs, insurance, and gasoline), which we classify as necessities; and leisure and equipment (house, garden, clothing, and personal care goods and services), which we classify as luxuries.

To compute our measure of health, we follow Blundell, Britton, Costa-Dias, and French (2017) and use the predicted value of a self-reported health index (the individuals' rating of their health status), regressed over a set of objective measures (dummies for reporting difficulties in activities of daily living and dummies for having certain health conditions, as diagnosed by a doctor). Because consumption data is at the household level, our level of analysis is the household, and we take average health of a household's members as an indicator of the health of that household.

We focus on temporary shocks, which given the frequency of our data refer to

changes in health that last at most two years. This allows us to cleanly sidestep the well-known difficulty of disentangling the health and income effects of a permanent health shock from its effect on expected lifespan and bequest motives.

To identify the consumption response to these temporary health and income shocks, we rely on a statistical decomposition method a la Blundell, Pistaferri, and Preston (2008) (BPP). That is, we model the household’s health and income as transitory-permanent processes, which can be represented as the sum of a permanent component that evolves as a random walk and of a transitory component that is a moving average. As we show in Appendix B, these assumptions are well supported for our age group. Our empirical strategy is to then instrument the effects of a current change in health with that of a future change in health, which correlates with the transitory part of a current health change but is uncorrelated with its permanent component.

Our method is more general than the original BPP estimator, in that we remain agnostic about how households make their consumption decision. In fact, by focusing only on the pass-through of transitory shocks, the assumption that log-consumption evolves as a random walk can be relaxed (Kaplan and Violante (2010), Commault (2020)). In addition, we do not need to assume that households know that the shock is temporary and they might thus be mistaken about the shocks’ duration.

Our analysis yields several important and novel findings. First, after age 65 households are subject to large temporary shocks in both income and health. In terms of magnitudes, the variance of the i.i.d. component of income explains 40% of the variance of changes in income, and the variance of the i.i.d. component of health explains 33% of the variance of changes in health (after we detrend all variables from the effect of observed demographic characteristics). The bulk of these shocks cannot be attributed to measurement error for two reasons: first, the HRS has been documented to be of excellent quality<sup>1</sup> and, second, we find that these transitory shocks have a significant impact on households’ decision variables.

Second, these transitory shocks to income and health are correlated with each other, and this correlation is statistically significant, confirming that even short-run changes in health affect the resources available to households. Their magnitude im-

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<sup>1</sup>Hurd and Rohwedder (2009) discuss the CAMS data quality and show that spending totals are close to those measured in the Consumer Expenditures Survey (CEX) and the age profiles of wealth changes implied by spending and after-tax income are similar to the wealth change in the HRS data. French, Jones, and McCauley (2017) find that the HRS data are of high quality.

plies that a one standard-deviation decrease in health is associated with a 2% decrease in current income.

Third, income shocks affect non-durable consumption but not medical expenses. Our estimated average pass-through of a transitory income shock to consumption is 0.11. This means that a one unit increase in the transitory component of income (corresponding to a 100% increase, that is a doubling, of current income) is associated with an 11% increase in current non-durable consumption. This increase is roughly homogeneous across consumption good categories, with leisure activities responding more strongly. In addition, a positive transitory income shock raises the consumption of (all categories of) necessities among low-wealth households and the consumption of luxuries among high-wealth households.

Fourth, the effect of health shocks are concentrated on leisure activities, car maintenance, and out-of-pocket medical expenses. Our estimates of the pass-through coefficients imply that a one standard deviation decrease in current health is associated with a 9% decrease in leisure activities expenses, a 4% decrease in car maintenance expenses, and a 9% increase in out-of-pocket medical expenses. Across levels of wealth, a positive health shock raises the consumption of necessities and possibly of luxuries (although the latter is less precisely estimated) among low-wealth households and raises the consumption of luxuries among high-wealth households.

To further examine the sources of these consumption responses, we then specify a structural life-cycle model and estimate the respective contributions of the changes in resources and in the utility from consumption. In our model, a household's consumption decisions are the solution of an intertemporal problem in which utility is separable in different consumption categories and medical consumption and the utility derived from each consumption category can depend on the household's current health status. We show that, in this framework, the response of a given category of consumption to a transitory health shock can be written as the sum of the effect of the health shock on resources and on the shape of the utility function during the current period, and that it is possible to separately estimate the coefficients that govern the effect of the change in resources and in health through the dependence of the utility function on health.

Our last main finding is that the effects of a health shock on consumption of non-durable goods mainly come from a change in the utility of consuming them, rather than from the effect of health on income, medical expenses, and other resources; and

especially so for wealthier households. More specifically, looking into consumption composition, we find that health has only a small effect on consumption of necessary goods and that this effect comes from the impact of health on resources, rather than its effect on the utility of consuming necessities. In contrast, health shocks significantly impact the consumption of luxury goods, and this effect only comes from the utility of consuming them, rather than from a change in resources driven by a change in health. Splitting our sample into low- and high-wealth households, we find that the effect of health on necessary goods (which is generated by a change in resources) is only present among low-wealth households.

By making several contributions, our paper relates to several important strands of previous literature: the literature studying the impact of economic shocks on key economic outcomes, the literature striving to identify the effects of health on the utility function, the literature on household insurance, and the literature on old age savings and risk. We turn to discussing our paper's contributions in the context of each of these branches of the literature in the next section.

## 2 Our contributions in the context of the previous literature

The motivation of our paper builds on the **literature on consumption insurance**. Cochrane (1991) shows that under perfect insurance and absent preference shocks, the log-consumption growth of an individual should be constant. Therefore, a variable that is independent of preference shifts should have no impact on consumption growth. Attanasio and Davis (1996) test his hypothesis using systematic shifts in the hourly wage structure of households. More recent studies allow for endogenous labor supply and thus for social insurance to generate labor distortions from insurance (Farhi and Werning (2013), Golosov, Troshkin, and Tsyvinski (2016)).

Krueger and Perri (2005) further analyze this question by studying the extent to which empirically observed consumption smoothing (with respect to total income) is consistent with two consumption models and Krueger and Perri (2006) find a lesser increase in consumption inequality than in total income inequality over time. Blundell and Preston (1998), Blundell, Low, and Preston (2013), and Blundell, Pistaferri, and Preston (2008) derive expressions for the degree of consumption insurance to

transitory and permanent shocks that are implied by a life-cycle model and estimate it empirically. Gourinchas and Parker (2002) and Kaplan and Violante (2010) rely on numerical simulations to quantify the degree of precautionary saving and consumption insurance in realistically calibrated life-cycle models, respectively. Heathcote, Storesletten, and Violante (2009) provide a review on other work studying the degree of consumption insurance implied by a standard life-cycle model.

In this paper, we find that a change in resources during old age affects the consumption of necessities, in particular for households with low levels of wealth, which confirms that even when controlling for changes in preferences, consumption is not perfectly insured. Our approach is complementary to that of solving numerically a structural model. The first four of our five main results rely on very few assumptions about household decision making and reveal that transitory income and health shocks, which have been largely ignored by much of the structural literature so far, are very important, are correlated with each other, and affect both consumption and medical expenses. Our last result, that transitory health shocks affect the utility of consumption does require us to make more assumptions on the household's decision problem, but these assumptions are still more general than those adopted in the existing structural models that allow for health (and income) shocks. The large response of consumption to changes in income and health that we observe is consistent with the increasing earnings and consumption inequality over the life-cycle documented in Storesletten, Telmer, and Yaron (2004)

Our paper helps understanding the risks affecting savings and thus relates to studies on **savings and risk during retirement**. Love, Palumbo, and Smith (2009), De Nardi, French, and Jones (2010), Poterba, Venti, and Wise (2018), and Blundell, Crawford, French, and Tetlow (2016),<sup>2</sup> study the rate of dissaving during retirement, which is much slower than what is implied by the standard life-cycle model. The two main explanations brought forward in this literature highlight the importance of precautionary saving motivated by the risks that the elderly face late in life, particularly uncertain life spans and out-of-pocket medical and long-term-care (LTC) expenses. Kopecky and Koreshkova (2014) estimate the share of savings explained by the need to finance future out-of-pocket medical and nursing home expenses in a calibrated life-cycle model, and find this share to be large. Braun, Kopecky, and Koreshkova (2016) find that social insurance programs that help insure these risks,

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<sup>2</sup>For a review of this literature, De Nardi, French, and Jones (2016)



such as Medicaid and Supplemental Security Income, have a substantial impact on welfare.

Most of the literature on old age savings and risk ignores temporary shocks in income and health and assumes that health does not affect a household utility from consumption. In contrast, we find that these temporary shocks are important and that they influence both households' resources and utility from consumption. It is thus essential to evaluate the implications of our findings not only in terms of optimal household insurance, but also in terms of their implications for savings and exposure to risk and the extent to which current government taxes and transfers help insure these risks.

Our work is also related to the literature that tests for the possible **dependence of utility from consumption on health status** (Viscusi and Evans (1990), Evans and Viscusi (1991), Finkelstein, Luttmer, and Notowidigdo (2009), Finkelstein, Luttmer, and Notowidigdo (2013)). Although they yield a fairly wide range of estimates, most of these studies find that such a dependence cannot be rejected when measured using self-reported compensating differentials for exposure to health risk or questions about general happiness as a proxy for utility.

Like many of these studies, we find that bad health tends to reduce household's marginal utility from consumption. We make this result sharper by looking into the effects of temporary shocks, which allows us to abstract from the confounding effects that permanent or persistent health shocks have on one's life expectancy (and thus also strength of a potential bequest motive) and by avoiding using happiness or self-reports rather than observed economic outcomes. We also find that this health-consumption dependence is largest for luxury goods, as we are able to disentangle the share of the response of consumption that comes from the dependence of the utility function on health for each type of consumption separately.

Finally, more generally, our paper relates to the literature that examines **the impact of health shocks on economic outcomes**. Several studies analyze the impact of permanent or persistent shocks such as the diagnosis of a chronic disease, an hospital admission, or a car crash (Dobkin, Finkelstein, Kluender, and Notowidigdo (2018), Morrison, Gupta, Olson, Mstat, and Keenan (2013)), or shocks to a composite measure of health or ability (Meyer and Mok (2016), Poterba, Venti, and Wise (2015), Poterba, Venti, and Wise (2017)). They find that permanent (or persistent) bad health shocks are significant and have a large and negative effect on impor-

tant economic outcomes such as earnings, medical expenses, and the probability of bankruptcy. Compared with these papers, we also find evidence of large and transitory health and income shocks that have effects on consumption and out-of-pocket medical expenses.

Other papers study the impact of one-time income shocks to consumption decisions. Most empirical studies find that these shocks have an effect on consumption, whether the change comes from a tax rebate, a lottery gain (Fagereng, Holm, and Natvik (2018)), or a change in current assets—which is equivalent to a transitory change in income—(Mian, Rao, and Sufi (2013) Cloyne, Huber, Ilzetzki, and Kleven (2019)). We confirm this result for households over age 65, whose consumption significantly responds to transitory income shocks.

Some works examine the impact of health on food and housing consumption. Chung (2013) finds that the onset of an initial chronic illness is associated with a drop in food expenses, although these expenses recover over time. Similarly, Meyer and Mok (2016) find that becoming disabled is associated with a drop in food and housing consumption, and their results suggest some role for the effect of health on resources, such as individual savings and family support, and that social insurance helps households mitigate this drop. We complement this literature looking at the effect of transitory health and income shocks and in finding that a transitory change in resources only affect the consumption of necessities of poorer households.

Compared with the papers on the impact of health shocks on economic outcomes, our paper deepens our understanding of the risks faced by older households in that it also finds evidence of large transitory health and income shocks, of out-of-pocket medical expenses rising when health temporarily worsens, and of a positive correlation between transitory health and income shocks. Our findings thus suggest that, even though households over age 65 are covered by Medicare, the income and health risks that they face during old age are even larger than previously assumed.

### **3 The data and our variables of interest**

Our data come from the Health and Retirement Study (HRS), a longitudinal survey that is representative of the U.S. population over the age of 50 and their spouses. We combine information from the HRS core interviews and from the Consumption and Activities Mail Survey (CAMS), a supplementary study collecting data on house-

hold spending that is administered to a subset of HRS respondents. Both surveys are biennial, and our merged sample covers the years 2001 to 2013. Appendix A describes our sample selection in detail.

### 3.1 Consumption and medical expenses

Consumption		
Necessities	Food	Food at home, food away from home
	Utilities	Electricity, water, heat, phone and internet
	Car-related	Car insurance, car repairs, gasoline
Luxuries	Leisure	Trips and vacations, tickets, sport equipment, hobbies equipment, contributions to charities, gifts
	Equipment	House supplies, house services, yard/garden supplies, yard/garden services, clothing, personal care equipment and services
Medical exp.		
	Drugs	Drugs
	Medical serv. and sup.	Medical services
		Medical supplies

**Table 1:** Consumption and medical expenses categories

Both consumption and medical expenses come from CAMS. The top panel of Table 1 lists the 21 items that we include in non-durable consumption and shows how we construct non-durable consumption subcategories by aggregating the original 21 categories. The bottom panel of the table lists the three items that we include in out-of-pocket medical expenses.

In Table 2, we present the level and composition of these different categories of expenses. The average level of expenses in nondurable consumption is 25,004 per year in 2015\$. We break it down into five categories that represent at least ten percent of the households' expenses in nondurables. The table shows that the two most prominent categories, which each gather a little more than one quarter of nondurable expenses, are food and leisure activities. Among low-wealth households, expenses in food, utilities, and car maintenance, are higher than in the whole sample, which is why we consider them necessities. Among high-wealth households, expenses in

	All	Low wealth	High wealth
All nondurables, mean	25,004	15,335	27,718
Food, mean	6,574	4,821	7,064
Food, share	28.6%	32.5%	27.5%
Utilities, mean	5,592	4,335	5,948
Utilities, share	24.7%	28.5%	23.6%
Car maintenance, mean	3,504	2,580	3,754
Car maintenance, share	16.1%	17.6%	15.6%
Leisure activities, mean	6,607	1,908	7,926
Leisure activities, share	20.3%	11.5%	22.8%
Equipment, mean	2,761	1,775	3,046
Equipment, share	11.1%	11.7%	10.9%
All medical expenses, mean	3,071	2,554	3,186
Drugs, mean	1,417	1,362	1,438
Drugs, share	53.9%	59.3%	52.3%
Services and supplies, mean	1,658	1,198	1,752
Services and supplies, share	48.9%	45.2%	49.9%

**Table 2:** Consumption and medical expenses composition, means in 2015 dollars and shares in percentages

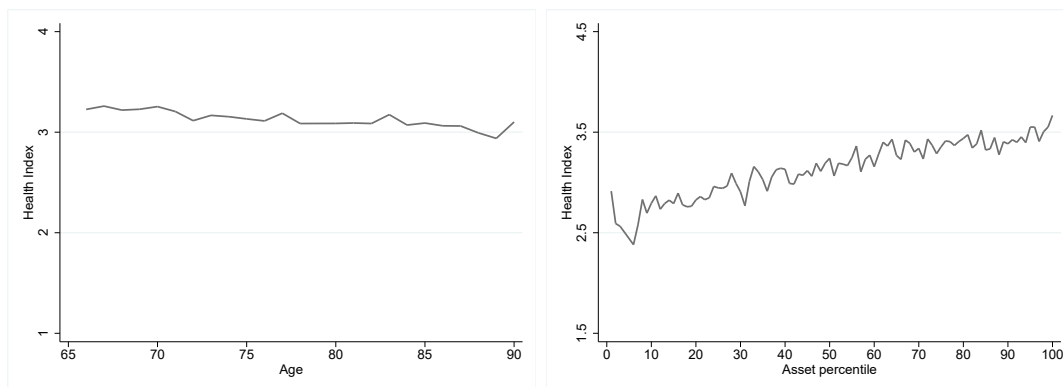
luxuries represent a higher share of the budget than in the whole sample, and the share of expenses in equipment is almost the same as in the whole sample, which is why we consider them luxuries. In the bottom part of the table, we report medical expenses. Their average level is 3,071 per year in 2015\$, almost evenly split between drugs and medical services and supplies.

### 3.2 Health index

The construction of our health index follows a similar strategy to that used by Blundell, Britton, Costa-Dias, and French (2017): we instrument self-reported health by objective health measures. This means that the changes in our health index stem from the changes in self-reported health that are driven by underlying changes in objective measures or health. Thus, we are eliminating the changes in self-reported health that are not caused by any objective change and we are not considering changes in objective measures that do not translate into changes in self-reported health.

More specifically, the health index that we construct for each person is the predicted value from a regression of the self-reported health status of that person on objective health measures, which are dummies for reporting difficulties in activities

of daily living (ADLs) and dummies for having had certain health conditions diagnosed by a doctor.<sup>3</sup> Our regression also includes age dummies, year dummies, education dummies, and initial health status. To obtain a household health index for couples, we average the two instrumented self-reported health indices computed for husbands and wives separately.



**Figure 1:** Health index by age (left panel) and wealth (right panel)

We construct our health measure so that a higher health index corresponds to a better health. The left panel of Figure 1 displays our health index by age and highlights that, although the average health index decreases as households age, the change is modest: it goes down from 3.2 at age 65 to 3.0 at age 90. This modest decrease is consistent with selection, that is, that healthier households live longer, but also it is also consistent with a large share of the changes in health being transitory rather than permanent: as their effect fades after one period, they do not generate a decrease in health over the life-cycle.

The right panel of Figure 1 shows our health index by wealth percentiles, where the gradient is much larger than by age. It highlights a steady increase from the 10th to the 100th wealth percentile—the first 10 percentiles corresponding to households with debt but, often, with the income potential to repay it, while households around the 10th percentile have no debt but no wealth and no means to repay it—. This

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<sup>3</sup>Our ADLs measures refer to whether the head and spouse experience difficulty walking across the room, dressing up, bathing or showering, eating, getting in or out of bed, using the toilet, walking several blocks, walking one block, sitting for two hours, getting up from a chair after sitting for long periods, climbing several flights of stairs without resting, climbing one flight of stairs without resting, lifting or carrying weights over 10 pounds, stooping kneeling, or crouching, reaching arms above shoulder level, pushing or pulling large objects, and picking up a dime from the table. The health conditions are a cancer, diabetes, high blood pressure, arthritis, a psychological illness, lung problems, heart problems, and a stroke.

change and the classic idea that households with less wealth might be less able to self-insure against shocks motivate our choice to break down our sample by wealth and examine how differently households with different amounts of wealth respond to transitory health shocks.

### 3.3 Income and wealth

Wealth is the sum of all assets less all debt. We categorize as low-wealth the households in which the real wealth per adult equivalent (one adult is worth one, two or more adults are worth the square root of 2, and other minor family members are not counted) is below 75,000 in 2015\$. This corresponds to the first 20th percentile of the wealth distribution. We categorize as high-wealth the remaining households.

Our measure of income includes earnings (wages, salaries, bonuses), capital income (business or farm income, self-employment, rents, dividend and interest income, and other asset income), private pensions (income from employer pension or annuity), benefits (social security retirement income, income from transfer programs and workers' compensations), and other income (alimony, other income, lump sums from insurance, pension, and inheritance), of both household's head and spouse, if present.

Figure 2 shows the evolution of various income components by age and for our two wealth groups.<sup>4</sup> It highlights that, while benefits (which include social security and other government transfers programs) are the most important income component for households over age 65, earnings and pensions are also substantial, and especially so for high-wealth households.

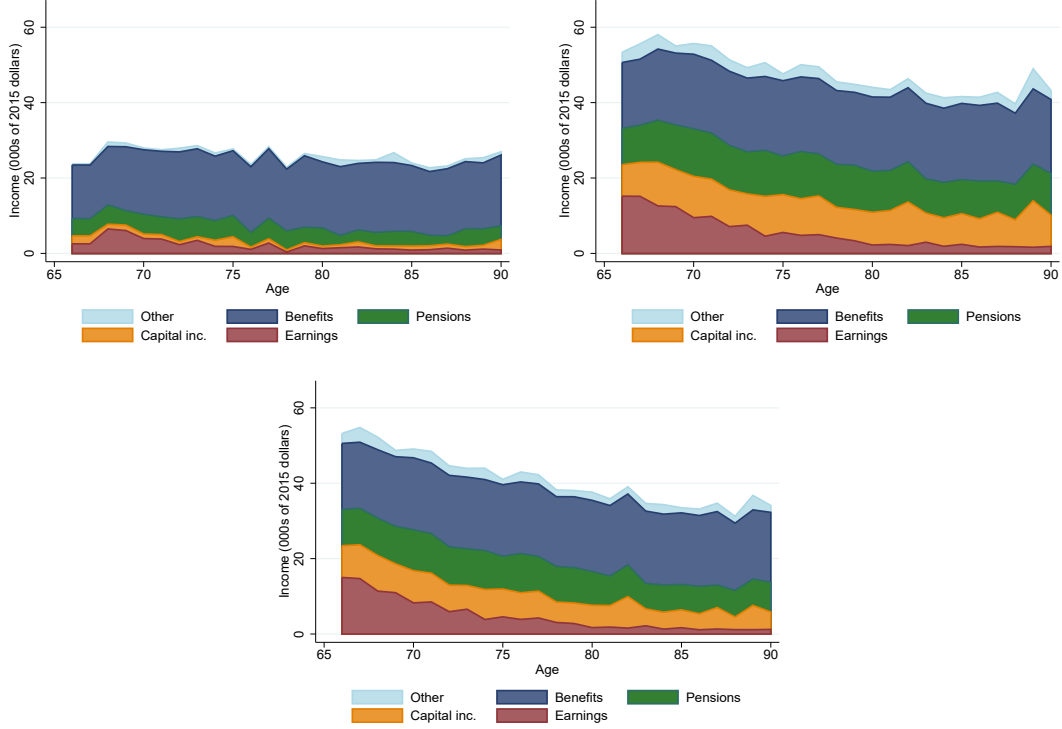
## 4 Income and health risks

We assume that the evolution of both health and income are exogenous and that, after the elimination of demographics, detrended health and log-income (which we denote with a tilde) can be represented as a transitory-permanent process,<sup>5</sup> that is, as the sum of a permanent component that evolves as a random walk, and of a transitory component that is an i.i.d. shock, that is, an MA(0) process. Our

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<sup>4</sup>For this graph, we equalize income by dividing couples' income by the square root of two. In addition, we draw the age pattern relative to the cohort born in 1940-1949.

<sup>5</sup>With the same abuse of notation as with consumption, we put the tilde on  $y$ , while it is log-income  $\ln(y_t)$  that is detrended from the effect of demographics.



**Figure 2:** Equivalized income components by age, in thousands of 2015 dollars for cohort born in 1940-1949. Top left panel: low wealth households ( $< 75k$  equivalized wealth); top right panel: high wealth households ( $\geq 75k$  equivalized wealth); bottom panel: whole sample.

assumptions are supported by Appendix B, which reports the autocovariances of both health and log-income growth, and highlights that these covariances are consistent with our assumptions (and inconsistent with the permanent components being an AR(1) processes with coefficients very different from one and with the transitory components being MA(1) processes).

$$\tilde{h}_t = \pi_t^h + \varepsilon_t^h, \quad \pi_t^h = \pi_{t-1}^h + \eta_t^h, \quad (1)$$

$$\ln(\tilde{y}_t) = \pi_t^y + \varepsilon_t^y, \quad \pi_t^y = \pi_{t-1}^y + \varepsilon_t^y. \quad (2)$$

Given these assumptions, we can express health growth and log-income growth as

$$\Delta \tilde{h}_t = \eta_t^h + \varepsilon_t^h - \varepsilon_{t-1}^h \quad (3)$$

$$\Delta \ln(\tilde{y}_t) = \eta_t^y + \varepsilon_t^y - \varepsilon_{t-1}^y. \quad (4)$$

We make the following assumptions about the distribution of the shocks in the economy

- i The shocks  $\varepsilon^h, \eta^h, \varepsilon^y, \eta^y$ , are drawn independently over time and across households; however, they are not necessarily drawn from the same distributions during each period and for each household.
- ii The contemporaneous household's transitory and permanent shocks are independent of one another, but the transitory health and income shocks can be correlated, and the permanent health and income shocks can be correlated.

## 4.1 Identification and estimation

The identification problem stems from the fact that we observe changes in health,  $\Delta\tilde{h}$ , and in log-income,  $\Delta\ln(\tilde{y})$ , but we do not observe the changes in their transitory and permanent components. To overcome the problem, our identification strategy follows that of Meghir and Pistaferri (2004).

Using equations (3) and (4), and variance and covariance formulas, we obtain the following formulas for the variance of transitory shocks

$$\text{var}(\varepsilon_t^h) = \text{cov}(\Delta\tilde{h}_t, -\Delta\tilde{h}_{t+1}), \quad (5)$$

and

$$\text{var}(\varepsilon_t^y) = \text{cov}(\Delta\ln(\tilde{y}_t), -\Delta\ln(\tilde{y}_{t+1})). \quad (6)$$

The intuition is that changes in health (or log income) at  $t + 1$  are independent of the changes in the permanent component of health (or log income) at  $t$ , which affect health (or log-income) at period  $t$  and  $t + 1$  in the same way, but vary negatively with the change in the transitory health (or log income) shock at  $t$ , which affect health (or log-income) at period  $t$  more than at  $t + 1$ .

We can express the variance of permanent shocks as

$$\text{var}(\eta_t^h) = \text{cov}(\Delta\tilde{h}_t, \Delta\tilde{h}_{t-1} + \Delta\tilde{h}_t + \Delta\tilde{h}_{t+1}), \quad (7)$$

$$\text{var}(\eta_t^y) = \text{cov}(\Delta\tilde{y}_t, \Delta\tilde{y}_{t-1} + \Delta\tilde{y}_t + \Delta\tilde{y}_{t+1}). \quad (8)$$



Indeed, the change in health (or log-income) between  $t + 1$  and  $t - 2$  is independent of transitory shocks that occur at  $t - 1$  and at  $t$ , which have not yet realized at  $t - 2$  and already dissipated at  $t + 1$ , but captures the permanent shock at  $t$ , which is not yet realized at  $t - 2$  and still affects health at  $t + 1$ .

We can also identify the covariance between the transitory income and health shocks from the two following moments (the covariance is thus overidentified):

$$\text{cov}(\varepsilon_t^h, \varepsilon_t^y) = \text{cov}(\Delta \tilde{y}_t, -\Delta \tilde{h}_{t+1}), \quad (9)$$

$$\text{cov}(\varepsilon_t^h, \varepsilon_t^y) = \text{cov}(\Delta \tilde{h}_t, -\Delta \tilde{y}_{t+1}). \quad (10)$$

We construct detrended health and income, that is, net from observed demographic characteristics, as detailed in Appendix A. We then use equations (7), (8), (9), and (10) to estimate the variances and covariances with a generalized method of moments (GMM). All observations are pooled together in the estimation, but the residuals are clustered at the household level and allow for arbitrary correlation between the observations from the same household. The weighting matrix of the GMM is robust to heteroskedasticity.

## 4.2 Income and health risk results

We use a measure of income is “net income” and includes all income, net of taxes and transfers. Thus, it reflects any household self-insurance through savings and labor supply and all government insurance through taxes and transfers.

Table 3 highlights that, even at advanced ages, households face substantial net income risk. The magnitude of transitory income risk is large, with a variance of 0.088, statistically significant at 1%. Because the variance of detrended net (log) income growth,  $\text{var}(\Delta \ln(\tilde{y}_t))$ , is the sum of  $\text{var}(\varepsilon_t^y)$ ,  $\text{var}(\varepsilon_{t-1}^y)$ , and  $\text{var}(\eta_t^y)$ , it means that  $\text{var}(\varepsilon_t^y)$  explain 41% of the variance of total net income growth.<sup>6</sup> High-wealth households face higher variances of both transitory and permanent income shocks.

To further explore the sources of income risk for older households, Table 4 shows the standard deviation of the change of unexplained (log) net income components (upper panel) and of total income excluding some income components. The upper

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<sup>6</sup>Assuming  $\text{var}(\varepsilon_t^y) \approx \text{var}(\varepsilon_{t-1}^y)$ , which is not a strong assumption when we pool all years together, current and past transitory shocks explain 82% of the variance of log-income growth.

	All	Low wealth	High wealth
$var(\varepsilon_t^y)$	.088***	.067***	.093***
	(.005)	(.009)	(.005)
Obs.	5105	1000	4105
$var(\eta_t^y)$	.029***	.018*	.031***
	(.005)	(.01)	(.006)
Obs.	3494	655	2839
$var(\Delta \ln(\tilde{y}_t))$	.215***	.167***	.226***
	(.007)	(.013)	(.008)
Obs.	5105	1000	4105

Standard errors in parentheses. \* at 10%, \*\* at 5%, \*\*\* at 1%

**Table 3:** Variance of the transitory and permanent shocks to net income

panel of the table shows that benefits display (unsurprisingly) very little variation and that the vast majority of households in our sample do receive them (8,855 out of a total of 9,132). Pensions display more variation than benefits and less than half of our households receive them. Capital income displays the largest variation and is received by over half of our households. The bottom part of the table shows that removing various income components in turn tends to raise the variation in gross income, with the exception of other income. For the bottom portion of the table, we do not report the number of observations by row, because it is, by construction, the same as the observations for total net income (and total gross income).

Turning to our results for the health shocks, Table 5 highlights that households face substantial health risk. The variance of the transitory health shocks is 0.02 and is statistically significant at 1%. The variance of the permanent shocks, estimated on a smaller sample because the identification requires a longer panel, is also significant at 1%, and its magnitude is very similar, at 0.019. Because the variance of changes in health,  $var(\Delta \tilde{h}_t)$ , is the sum of  $var(\varepsilon_t^h)$ ,  $var(\varepsilon_{t-1}^h)$ , and  $var(\eta_t^h)$ , it means that  $var(\varepsilon_t^h)$  explain 31% of the variance of total net income growth.<sup>7</sup> Contrary to income shocks, low-wealth households are the ones facing higher variances of both transitory and permanent health shocks: the variance of the transitory health shocks

<sup>7</sup>As in the case of income, this is true assuming  $var(\varepsilon_t^h) \approx var(\varepsilon_{t-1}^h)$ , which is not a strong assumption when we pool all years together. Relaxing this assumption to compute them separately, and restricting the sample to the observations over which the variance of permanent shocks is estimated, and relaxing does not change our results. In that case, the variance of the change in health over time is 0.06, the variance of current transitory shocks is 0.019, and the variance of past transitory shocks is 0.022.

	Total	Low wealth	High wealth
Benefits	0.42	0.44	0.41
	( 8,855 )	( 2,381 )	( 6,474 )
Pensions	0.79	0.68	0.81
	( 4,242 )	( 764 )	( 3,478 )
Capital income	2.27	2.53	2.24
	( 5,200 )	( 501 )	( 4,699 )
Earnings	1.11	1.04	1.13
	( 1,735 )	( 389 )	( 1,346 )
Other	1.31	0.59	1.39
	( 106 )	( 15 )	( 91 )
Total gross income	0.52	0.46	0.54
Gross income excluding pensions	0.63	0.53	0.66
Gross income excluding capital	0.56	0.47	0.58
Gross income excluding Earnings	0.64	0.60	0.66
Gross income excluding Other	0.50	0.44	0.52
Net income including capital	0.47	0.43	0.49
	( 9,132 )	( 2,457 )	( 6,675 )

**Table 4:** Standard deviation of the change of unexplained (log) income components. Upper panel: income components. Lower panel: gross income minus various income components. Number of observations with non-zero income in parentheses.

is twice as large among low-wealth households than for high-wealth households, 0.035 compared with 0.017 and permanent health risk is also almost twice as large among low-wealth households than high-wealth households, 0.032 versus 0.017. Thus, this table, in conjunction with the right panel of Figure 1 reveals that not only low-wealth households are less healthy than high-wealth households but also experience more health fluctuations, both transitory and permanent.

The third line of the table indicates that there is a significant covariance between the transitory income and health shocks, with a point estimate of 0.03. Given our estimate of  $var(\varepsilon_t^h)$ , this means that the pass-through of a transitory health shock to income,  $\frac{cov(\varepsilon_t^h, \varepsilon_t^y)}{var(\varepsilon_t^h)}$ , is close to 0.15. Thus, a one standard deviation change in health, that is a 0.141 level change in the health index, is associated with a  $0.14 * 0.15 = 0.02$  percentage change in income. The covariance between the transitory health and income shocks has the same magnitude among low-wealth and high-wealth households, but is only precisely estimated among the high-wealth.

To further investigate the determinants of a change in our health index, Table 6

**Table 5:** Variance of the transitory and permanent health shocks

	All	Low wealth	High wealth
$var(\varepsilon_t^h)$	.020*** (.001)	.035*** (.004)	.017*** (.001)
Obs.	5105	1000	4105
$var(\eta_t^h)$	.019*** (.002)	.032*** (.005)	.017*** (.002)
Obs.	3494	655	2839
$cov(\varepsilon_t^h, \varepsilon_t^y)$	.003** (.001)	.003 (.003)	.003** (.001)
Obs.	5105	1000	4105
$var(\Delta \tilde{h}_t)$	.064*** (.002)	.104*** (.007)	.054*** (.002)
Obs.	5105	1000	4105

Standard errors in parentheses. \* at 10%, \*\* at 5%, \*\*\* at 1%

presents the results from a regression of our health index (net of the effect of demographics) over dummies for the occurrence of a change in our objective measures of health that lasts only one period. We select only the objective measures for which we can observe at least 20 events of a one unit decrease-then-increase-back change (or increase-then-decrease-back).<sup>8</sup> The results show that all types of temporary deterioration in health have a negative impact on our health index and that most of these effects are statistically significant. In terms of magnitudes, Table 6 shows that, everything else equal, reporting decreased ability to climb several flights of stairs for one period implies a reduction in one's health index of 0.07, decreased ability to climb one flight of stairs a 0.096 decrease, decreased ability to lift and carry 10 lbs a 0.152 decrease, decreased ability to push or pull large objects a 0.184 decrease, scoring one unit worse on the CESD (Center for Epidemiological Studies Depression) scale (that goes from 0 to 5) a 0.045 decrease, decreased ability of the spouse to push or pull large objects a 0.154 decrease, and finally, the spouse scoring one unit worse on the CESD scale, implies a 0.055 decrease. Note that the variance of transitory shocks is 0.02, which implies that a transitory shock of one standard deviation corresponds to a 0.141 change in the health index.

<sup>8</sup>For the questions about the difficulty of doing certain tasks, the range of values goes from 1 ('Not at all difficult') to 4 ('Very difficult/can't do'). For the CESD (Center for Epidemiological Studies Depression), the range of values goes from 0 to 5, and an increase in the score corresponds to a higher intensity of depression.

	Change in health index
Diff. climb sev. flt stair - head	-.07** (.033)
Diff. climb one flt stair - head	-.096** (.049)
Diff. lift/carry 10 lbs - head	-.152*** (.05)
Diff. push/pull large obj. - head	-.184*** (.034)
CESD score (for depression) - head	-.045*** (.013)
Diff. climb sev. flt stair - spouse	-.083 (.052)
Diff. push/pull large obj. - spouse	-.154*** (.042)
CESD score (for depression) - spouse	-.055*** (.018)
Observations	4,922

**Table 6:** Temporary health changes and the health index

## 5 The pass-through of health and income shocks to consumption and medical expenses

While we continue to assume that income and health evolve according to the processes that we have specified and estimated in the previous section, we now turn to describing our assumptions for the growth of our other variables of interest, which are consumption and medical expenses and their subcomponents. For brevity, we formalize our assumptions for consumption, with the understanding that we make the same kind of assumptions for medical expenses (and the subcomponents of both consumption and medical expenses).

We allow for the growth in log-consumption to follow a very general specification. After detrending log-consumption from the effects of demographic characteristics and denoting the resulting variable with a tilde<sup>9</sup>, we assume it to be a flexible function of current and past realizations of transitory and permanent shocks to income and health, and of current and past realizations of other shocks  $\zeta^c$  that may capture

<sup>9</sup>With an abuse of notation, we put the tilde on  $c$ , while we assume that it is log-consumption  $\ln(c_t)$  that is linear in demographic characteristics and detrended.

measurement error or consumption-specific shocks

$$\Delta \ln(\tilde{c}_t) = f_t(\varepsilon_t^y, \dots, \varepsilon_1^y, \varepsilon_t^h, \dots, \varepsilon_1^h, \eta_t^y, \dots, \eta_1^y, \zeta_t^c, \eta_t^h, \dots, \eta_1^h, \zeta_t^c, \dots, \zeta_{t-1}^c). \quad (11)$$

It is important to note that this specification encompasses the consumption functions derived from many structural life-cycle models as special cases. For instance, in a simple life-cycle model with only one risk-free asset, consumption is a function of assets, permanent income, and the current transitory shock (plus past transitory shocks when they are persistent), which is encompassed by our specification: iterating backwards, because the level of assets is a function of past consumption, past assets, past permanent income, and past transitory shocks, and because permanent income, under our assumptions, is a function of the current permanent shock and past permanent income, consumption can be written as a function of all of the current and past permanent and transitory shocks of the household, as in equation (11). The same reasoning extends to the presence of health shocks.

We define the pass-through of transitory shocks to consumption ( $\phi^\varepsilon$ ) as the ratio of the covariance between log-consumption growth and a contemporaneous transitory shock in either income or health over the variance of the same shock:

$$\phi^{\varepsilon^h} = \frac{\text{cov}(\Delta \ln(\tilde{c}_t), \varepsilon_t^h)}{\text{var}(\varepsilon_t^h)} = \frac{\text{cov}(\ln(\tilde{c}_t), \varepsilon_t^h)}{\text{var}(\varepsilon_t^h)} \quad (12)$$

$$\phi^{\varepsilon^y} = \frac{\text{cov}(\Delta \ln(\tilde{c}_t), \varepsilon_t^y)}{\text{var}(\varepsilon_t^y)} = \frac{\text{cov}(\ln(\tilde{c}_t), \varepsilon_t^y)}{\text{var}(\varepsilon_t^y)}. \quad (13)$$

The right hand side of the equalities derives from the assumption that shocks at  $t$  are orthogonal to variables at  $t - 1$ . Thus, the covariance between  $\ln(c_{t-1})$  and  $\varepsilon_t$  is zero, so the pass-through rewrites as a ratio of the covariance between the levels of log-consumption and the shocks over the variance of the shocks.

An interpretation of the pass-through coefficients popularized by Kaplan and Violante (2010) is that they represent the share of the variance of the transitory shocks that is passed to log-consumption, net of the effect of demographics. The pass-through coefficient also coincides with the average elasticity of consumption to a transitory shock,  $E[\frac{d \ln(\tilde{c}_t)}{d \varepsilon_t^h}]$ , when log-consumption is linear in the shocks (Blundell, Pistaferri, and Preston (2008)) or when log-consumption is quadratic in the shocks and the distribution of the shocks is not skewed, or when the shocks are normally distributed (Commault (2020)).

## 5.1 Identification and implementation

Our identification strategy follows that developed in Blundell, Pistaferri, and Preston (2008) but relaxes the assumption that log-consumption is a random walk (as in Kaplan and Violante (2010), Commault (2020)). It relies on the intuition that future changes in health (or in income), only covary with current expenses through current transitory shocks

$$\text{cov}(\Delta \ln(\tilde{c}_t), \varepsilon_t^h) = \text{cov}(\Delta \ln(\tilde{c}_t), -\Delta \tilde{h}_{t+1}) \quad (14)$$

The covariance between log-consumption growth and the transitory income shock is:

$$\text{cov}(\Delta \ln(\tilde{c}_t), \varepsilon_t^y) = \text{cov}(\Delta \ln(\tilde{c}_t), -\Delta \ln(\tilde{y}_{t+1})) \quad (15)$$

In contrast, it is not possible to estimate the pass-through to permanent shocks without more stringent restrictions about the evolution of consumption.

Since the variances of the income and health shocks are identified from equations (7) and (8), the pass-through coefficients can be estimated as follows

$$\widehat{\phi}_c^{\varepsilon^h} = \frac{\text{cov}(\Delta \ln(\tilde{c}_{i,t}), -\Delta \tilde{h}_{i,t+1})}{\text{cov}(\Delta \tilde{h}_{i,t}, -\Delta \tilde{h}_{i,t+1})} = \phi_c^{\varepsilon^h} \quad (16)$$

$$\widehat{\phi}_c^{\varepsilon^y} = \frac{\text{cov}(\Delta \ln(\tilde{c}_{i,t}), -\Delta \ln(\tilde{y}_{i,t+1}))}{\text{cov}(\Delta \ln(\tilde{y}_{i,t}), -\Delta \ln(\tilde{y}_{i,t+1}))} = \phi_c^{\varepsilon^y} \quad (17)$$

Similarly, the pass-through of the transitory health and income shocks to medical expenditures can be estimated as follow:

$$\widehat{\phi}_m^{\varepsilon^h} = \frac{\text{cov}(\Delta \ln(m_{i,t}), -\Delta \tilde{h}_{i,t+1})}{\text{cov}(\Delta \tilde{h}_{i,t}, -\Delta \tilde{h}_{i,t+1})} = \phi_m^{\varepsilon^h} \quad (18)$$

$$\widehat{\phi}_m^{\varepsilon^y} = \frac{\text{cov}(\Delta \ln(m_{i,t}), -\Delta \ln(\tilde{y}_{i,t+1}))}{\text{cov}(\Delta \ln(\tilde{y}_{i,t}), -\Delta \ln(\tilde{y}_{i,t+1}))} = \phi_m^{\varepsilon^y} \quad (19)$$

To implement our estimators, we detrend consumption and medical expenses from some observed characteristics, as we do for health and income (see Appendix A for details), and estimate equations (16), (17), (18), and (19) with the generalized method of moments (GMM), clustering the residuals at the household level, and using a weighting matrix that is robust to heteroskedasticity.

	Income shock			Health shock		
	All	Low w.	High w.	All	Low w.	High w.
Nondurables $\phi_c^{\varepsilon^h}$	.109*** (.036)	.23** (.101)	.087** (.039)	.173** (.085)	.325*** (.12)	.094 (.112)
<i>Necessities</i>	.089** (.04)	.332*** (.109)	.046 (.042)	.082 (.089)	.321*** (.131)	-.041 (.114)
<i>Food</i>	.073 (.063)	.385** (.194)	.018 (.066)	.065 (.151)	.627*** (.266)	-.224 (.182)
<i>Utilities</i>	.091* (.054)	.292*** (.122)	.056 (.06)	.014 (.132)	-.242 (.197)	.146 (.171)
<i>Car maintenance</i>	.086* (.047)	.246* (.133)	.058 (.05)	.27** (.116)	.692*** (.199)	.053 (.143)
<i>Luxuries</i>	.105* (.063)	-.21 (.175)	.16*** (.066)	.361*** (.147)	.354* (.212)	.365* (.191)
<i>Leisure activities</i>	.191** (.092)	-.243 (.326)	.268*** (.088)	.63*** (.225)	.533 (.357)	.681*** (.284)
<i>Equipment</i>	.04 (.068)	-.332* (.174)	.105 (.074)	.269* (.155)	.043 (.222)	.385* (.199)
Medical exp. $\phi_m^{\varepsilon^h}$	.074 (.099)	.026 (.295)	.082 (.103)	-.607*** (.231)	-1.22*** (.354)	-.291 (.29)
<i>Drugs</i>	.012 (.104)	.117 (.285)	-.006 (.111)	-.607*** (.242)	-.948*** (.37)	-.431 (.308)
<i>Med. serv. &amp; supplies</i>	-.108 (.145)	-.215 (.4)	-.089 (.155)	-.048 (.358)	-.292 (.537)	.078 (.452)
Obs.	5193	1019	4174	5105	1000	4105

Standard errors in parentheses. \* at 10%, \*\* at 5%, \*\*\* at 1%

**Table 7:** Pass through estimates

## 5.2 Pass-through to expenses

How do consumption expenditures and out-of-pocket medical expenses move with temporary changes in health and income? The top part of Table 7 reports the effects of transitory income and health shocks on consumption expenditure. Starting from income shocks, the top-left side of the table shows that the pass-through coefficient of income shocks to nondurable consumption is 0.109 and is significant at the 1% confidence level: it means that a temporary increase in income is associated with a temporary increase in consumption. This compares with a 0.05 pass-through coefficient in Blundell, Pistaferri, and Preston (2008), although, in the same sample, the coefficient increases substantially when relaxing the assumption that log-consumption growth is a random walk (Commault (2020)), as we do here.



Looking at disaggregated consumption expenditure categories reveals that, among necessities, the response of expenses on car maintenance drives the pass through result, while among luxuries, expenses on leisure activities increase when the households over age 65 that constitute our sample experience a temporarily high income shock.

The break down of the response of consumption expenditure to an income shock by wealth is particularly interesting and highlights two important features of the data. First, the overall response of consumption expenditure is twice as large for the low-wealth households than for the overall population of older households. Second, the breakdown by consumption categories reveals that very different categories respond for low- and high-wealth households. Low-wealth older households respond to a positive income shock by spending more on necessities such as food, utilities, and car maintenance, while high-wealth households respond by spending more on leisure activities. A possible interpretation of these findings is that older households have trouble self-insuring their consumption, even against temporary shocks. More specifically, because low-wealth households are more constrained, we see this effect even in necessary consumption, while higher-wealth households tend to be satiated in necessities but are still imperfectly insured in their consumption of luxury goods.

Turning to the effect of an income shock on medical expenses (bottom left hand panel in Table 7), reveals that there are no statistically significant effects of an income shock on the medical expenses of older households, even when we split them by wealth.

The right-hand-side part of Table 7 reports the effects of a transitory health shock on consumption (top portion) and medical expenses (bottom portion). In our overall sample of households over age 65, non-durable consumption responds strongly to a transitory health shock: consumption increases when health increases temporarily, with a point estimate of 0.173, statistically significant at the 10% confidence level. This means that a one standard deviation transitory decrease in health, that is, a 0.141 level decrease, is associated with a  $0.173 \times 0.141 = 2\%$  decrease in expenditures on nondurables. The consumption breakdown reveals that this effects comes from increases in spending on car maintenance (0.27) and on leisure activities (0.63). This means that a one standard deviation transitory decrease in health, that is, a 0.141 level decrease, is associated with a  $0.27 \times 0.141 = 4\%$  decrease in spending on car maintenance and with a  $0.63 \times 0.141 = 9\%$  decrease in spending on leisure activities. From our discussion in section 3.2, a one-standard deviation decrease in health status can correspond for instance to a shift from reporting 'a little difficulty' to push or pull

large objects to reporting 'some difficulty' in doing so for one period. The breakdown by wealth reveals that, among the 66+ with low wealth, the pass-through of transitory shocks to consumption expenditures (0.325) is twice as large as in our overall sample of 66+, and that it is driven by increases in spending on food consumption and on car maintenance expenditure. Among the 66+ with high wealth, households experiencing a transitory health improvement spend more in leisure activities (0.681), and vice-versa for a transitory health deterioration.

The bottom-right-hand side of the table reports the response of out-of-pocket medical spending to a transitory health shock. The pass-through of transitory changes in health to medical expenses is negative, large, at  $-0.607$ , and statistically significant at the 1% confidence level. This means that a one standard deviation transitory decrease in health, that is, a 0.141 level decrease, is associated with a 9% increase in medical expenses (and vice-versa). Breaking down the effect of a health shock on the components of medical expenses, we find that only drugs respond significantly to transitory health shocks and drive the overall response of medical expenses.

Importantly, we find the effect of a temporary change in health is heterogeneous by wealth level. The pass through coefficient is almost twice as large ( $-1.220$ ) and statistically significant at the 1% confidence level for older households with low-wealth, but is much lower  $-0.291$ ) and not statistically significant even at the 10% confidence level among the older households with high wealth. This finding is consistent with the fact that older low-wealth households, on average, spend about half in medical insurance compared with high-wealth households, even after removing the effect of demographics.<sup>10</sup> This large and significant response suggests that, despite Medicare, which all household heads receive although the spouse might not, medical expenses are not perfectly insured against health shocks. This is in contrast to the pass-through of a transitory income shock on medical expenses, which, as we have already discussed, are small and not significant.

The findings from our 'pass through' analysis of temporary changes in health and income can be summarised as:

- First, out-of-pocket medical expenses move with health shocks but not with income shocks. This suggests that out-of-pocket medical spending in medical expenses is well insured against income shocks after age 65. Perhaps unsurpris-

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<sup>10</sup>The net (residual) expense in medical insurance is on average 1.772 among older low-wealth households and 3.055 among older high-wealth households in 2015 \$.

ing given that people in this age group are covered by Medicare health insurance and have already accumulated assets for their retirement.

- Second, shocks to health and income are associated with changes in consumption.
- Third, the changes in consumption associated to health shocks tend to be larger than those associated with income shocks.
- Fourth, the fact that consumption fluctuates when income fluctuates but that medical expenses do not fluctuate with income shocks, suggests that health shocks can have a potentially important role in affecting a household's needs to consume.
- Finally, the breakdown in consumption categories shows that necessities move with health for lower wealth households, while luxury consumption moves with health for higher-wealth households.

Our findings thus show that temporary changes in income and health affect consumption in old age but do not address our main question: To what extent do consumption fluctuations later in life reflect lack of insurance against income fluctuations as opposed to fluctuations in one's needs to consume? Our next section imposes more structure to our problem to address this question.

## 6 Structural decomposition of the responses

To gain a better understanding of the drivers of consumption fluctuations in old age, we specify a fully structural model in which health affects the utility from consumption and derive its testable implications. More specifically, we assume that each household chooses its consumption and medical expenses from age 66 (which we renormalize as period 0) and until a maximum age  $T$  by solving the following maximization problem:

$$\max_{\{c_t\}_{t=0}^T} \sum_{t=0}^T \beta^t E_0 \left[ s_t(\pi_t^h) \left( \sum_{k=1}^K \delta_k(h_t) u(c_t^k) + \kappa(h_t) v(\tilde{m}_t) - \alpha(h_t) \right) \right] \quad (20)$$

subject to the following constraints

$$p_{t+1}a_{t+1} = (1 + r_t)p_t a_t + p_t y_t - p_t^m m_t(\tilde{m}_t) - \sum_{k=1}^K p_t^k c_t^k \quad \forall 0 \leq t \leq T, \quad (21)$$

$$c_t^k \geq 0 \quad \forall 0 \leq t \leq T, \quad \forall 1 \leq k \leq K, \quad (22)$$

$$a_T \geq 0, \quad (23)$$

where we assume that utility is time additive, that  $\beta$  is the discount factor, that  $s_t(\pi_t^h)$  is the cumulative survival probability of a household age  $t$  (conditional of having been alive at age 66, and a permanent health component  $\pi_t^h$ ), and that the term  $\alpha(h_t)$  captures one's utility cost of being in poor health. The expected value of future utility is taken with respect to one's health evolution (which affects both one's survival and marginal utilities from consumption) and with respect to uncertain income.

Utility within a period is a function of  $K$  consumption goods  $c^k$  and total medical expenses  $\tilde{m}_{t+s}$ , which include medical expenses paid both out-of-pocket and by private and public insurance. The utilities of different consumption goods and medical expenses depend on the household's current health status through the coefficients  $\delta_k(h_t)$  and  $\kappa(h_t)$ . We assume that the period utilities of consumption are isoelastic, with  $u(c_t) = \frac{c_t^{1-\rho}}{1-\rho}$ , and that the period utility of out-of-pocket medical expenses,  $v(\tilde{m}_t)$ , is a flexible function.

The price of consumption good  $k$  is denoted by  $p_t^k$ , the price of medical expenses by  $p_t^m$ , and the average price index by  $p_t$ , which is used to define real assets and real income. During each period, the household earns a net income  $p_t y_t$ , which is stochastic.

To account for the fact that part of medical expenses are insured, we allow for the out-of-pocket portion paid by the households to be a flexible function of total medical expenses consumed,  $m_t(\tilde{m}_t)$ .

Health and income follow the same transitory-permanent processes that we specified in equations (1) and (2).

Taking the first order conditions of the maximization problem with respect to

consumption good  $k$  we obtain the following Euler equation:

$$u'(c_t^k)\delta_k(h_t) = E_t \left[ u'(c_{t+1}^k)\delta_k(h_{t+1}) \frac{s_{t+1}(\pi_{t+1}^h)}{s_t(\pi_t^h)} \frac{p_t^k/p_t}{p_{t+1}^k/p_{t+1}} \right] \beta(1+r). \quad (24)$$

It means that a household chooses its consumption of good  $k$  so its marginal utility of consuming  $k$  at  $t$ ,  $\delta_k(h_t)u'(c_{i,t}^k)$ , equals its expected future marginal utility of consuming  $k$  at  $t+1$ ,  $E_t[\delta_k(h_{t+1})u'(c_{i,t+1}^k)]$ , weighted by their relative prices  $\frac{p_t^k}{p_{t+1}^k}$  and the strength of (deterministic) intertemporal substitution motives  $\beta(1+r)$ .

We derive each side of this Euler equation with respect to a change in the value of the transitory health shock:

$$\frac{dc_t^k}{d\varepsilon_t^h} u''(c_t^k)\delta_k(h_t) + \frac{dh_t}{d\varepsilon_t^h} \delta'_k(h_t)u'(c_t^k) = E_t \left[ \frac{da_{t+1}}{d\varepsilon_t^h} \frac{dc_{t+1}^k}{da_{t+1}} u''(c_{t+1}^k)\delta_k(h_{t+1}) \frac{s_{t+1}(\pi_{t+1}^h)}{s_t(\pi_t^h)} \frac{p_t^k/p_t}{p_{t+1}^k/p_{t+1}} \right] \beta(1+r). \quad (25)$$

Substituting for  $a_{t+1}$  using equation (19) at  $l = t$ , substituting for  $dx/d\varepsilon = d\ln(x)/d\varepsilon \times x$ , and rearranging, it rewrites:

$$\begin{aligned} \frac{d\ln(c_t^k)}{d\varepsilon_t^h} &= \underbrace{\left( \frac{d\ln(y_t)}{d\varepsilon_t^h} \frac{p_t y_t}{p_t} - \frac{d\ln(m_t)}{d\varepsilon_t^h} \frac{p_t^m m_t}{p_t} - \sum_{l \neq k} \frac{d\ln(c_t^l)}{d\varepsilon_t^h} \frac{p_t^l c_t^l}{p_t} \right)}_{\substack{\text{effect of the shock on real future assets} \frac{da_{t+1}/p_t}{d\varepsilon_t^h} \\ \text{effect of a change in future assets on} \\ \text{current consumption} \\ \underbrace{A_t^k} \\ \text{contribution of change in resources} \\ = 0 \text{ if the shock does not affect income nor other spending}}} & \quad (26) \\ + \underbrace{\left( \frac{dh_t}{d\varepsilon_t^h} \right)}_{\substack{\text{effect of the shock on} \\ \text{current health} = 1}} & \underbrace{\left( \delta'_k(h_t) \right)}_{\substack{\text{effect of a change} \\ \text{in current health on} \\ \text{current consumption} \\ \underbrace{B_t^k} \\ \text{contribution of change in marginal utility} \\ = 0 \text{ if } \delta_1(\cdot) \text{ is a constant}}} \end{aligned}$$

with:

$$A_t^k = \frac{E_t \left[ \frac{dc_{t+1}^k}{da_{t+1}} \frac{-u''(c_{t+1}^k)}{-u''(c_t^k)} \frac{\delta_k(h_{t+1})}{\delta_k(h_t)} \frac{s_{t+1}(\pi_{t+1}^h)}{s_t(\pi_t^h)} \frac{p_t^k}{p_{t+1}^k/p_{t+1}} \right] \beta(1+r)}{c_t^k + \frac{c_t^k p_t^k}{p_t} E_t \left[ \frac{dc_{t+1}^k}{da_{t+1}} \frac{-u''(c_{t+1}^k)}{-u''(c_t^k)} \frac{\delta_k(h_{t+1})}{\delta_k(h_t)} \frac{s_{t+1}(\pi_{t+1}^h)}{s_t(\pi_t^h)} \frac{p_t^k}{p_{t+1}^k/p_{t+1}} \right] \beta(1+r)} \quad (27)$$

$$B_t^k = \frac{\frac{\delta'_k(h_t)}{\delta_k(h_t)} \frac{u'(c_t^k)}{-u''(c_t^k)}}{c_t^k + \frac{c_t^k p_t^k}{p_t} E_t \left[ \frac{dc_{t+1}^k}{da_{t+1}} \frac{-u''(c_{t+1}^k)}{-u''(c_t^k)} \frac{\delta_k(h_{t+1})}{\delta_k(h_t)} \frac{s_{t+1}(\pi_{t+1}^h)}{s_t(\pi_t^h)} \frac{p_t^k}{p_{t+1}^k/p_{t+1}} \right] \beta(1+r)} \quad (28)$$

This decomposition shows that there are two reasons why the consumption of good  $k$  can respond to a temporary change in health in this model. First, if the change in health affects income, medical expenses—say a decrease in health raises one’s out-of-pocket medical bill for instance—, or expenses in other consumption goods, it modifies the amount of assets that can be passed on to the next period. This change in resources at the next period modifies the consumption of good  $k$  at the next period. Thus, to keep the first order condition at equilibrium, the household must react by smoothing its consumption path and adjusting its current consumption of good  $k$ . This is captured by the first term in equation (26). Indeed  $\left( \frac{dy_t}{d\varepsilon_t^h} - \sum_{l \neq k} \frac{dn(c_t^l)}{d\varepsilon_t^h} \frac{p_t^l c_t^l}{p_{t+1}} - \frac{dm_t p_t^m}{d\varepsilon_t^h} \right)$  measures the change in the amount of resources that would be passed on to the next period in the absence of any adjustment in the current consumption of good  $k$ , and  $A_t^k$ , which multiplies it, the quantity by which the current consumption of good  $k$  must adjust for the Euler equation to keep holding when future assets decrease.

Second, if  $\delta_k(h_t)$  does vary with health, a temporary change in health affects the strength of the utility derived from consuming good  $k$  at  $t$ . Current consumption must then adjust so the marginal utility of current consumption, which is temporarily modified by the health shock through the change in  $\delta_k(h_t)$ , remains equal to the expected marginal utility of future consumption, whose strength  $\delta_k(h_{t+1})$  is unaffected when the shock is temporary and  $h_{t+1}$  is unaffected. This is captured by the second term in equation (24). Indeed,  $\frac{dh_t}{d\varepsilon_t^h}$  measures the magnitude of the change in current health caused by a transitory health shock, which is equal to one from our specification of the health process, and  $B_t^k$  the amount by which the current consumption of good  $k$  must adjust to account for the change in  $\delta_k(h)$ . Note that, if the utility of consuming good  $k$  is independent of one’s health, that is, if  $\delta_k(h)$  is a constant with  $\delta'_k(h) = 0$ , then  $B_t^k$  is zero. In that case, this second channel is not active and consumption only responds to a transitory health shock to the extent that this shock affects current

income, medical expenses, or the consumption of other goods.

The same reasoning yields that the response of consumption to a transitory income shock is:

$$\frac{d\ln(c_t^k)}{d\varepsilon_t^y} = \underbrace{\left( \overbrace{\frac{d\ln(y_t)}{d\varepsilon_t^y} \frac{p_t y_t}{p_{t+1}}}_{=1} - \frac{dm_t p_t^m \ln(m_t)}{d\varepsilon_t^y p_{t+1}} - \sum_{l \neq k} \frac{d\ln(c_t^l) p_t^l c_t^l}{d\varepsilon_t^y p_{t+1}} \right)}_{\substack{\text{contribution of change in resources} \\ = 0 \text{ if the shock does not affect income nor other spending}}} A_t^k \quad (29)$$

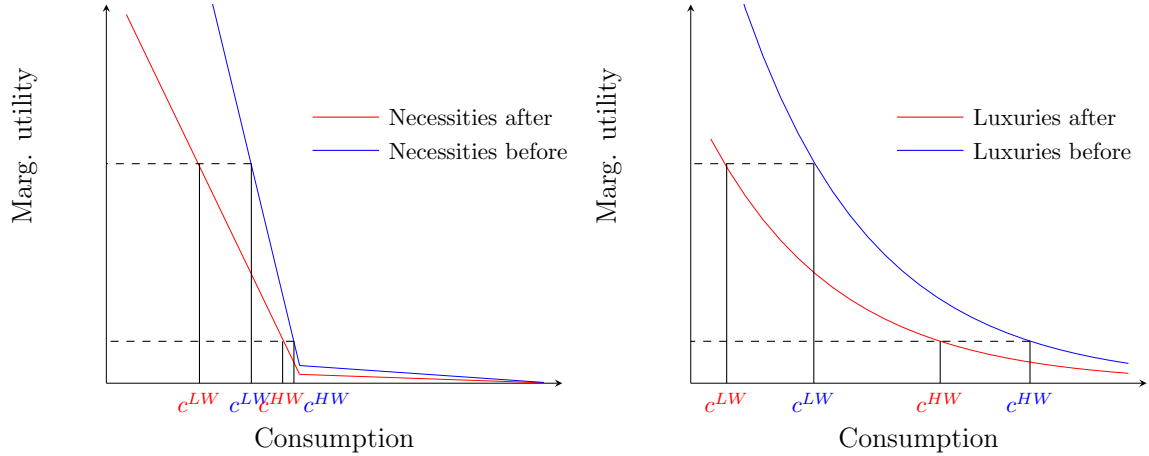
$$+ \underbrace{\frac{dh_t}{d\varepsilon_t^y} B_t^k}_{\substack{\text{contribution of change in marginal utility} \\ = 0 \text{ if } \delta_1(\cdot) \text{ is a constant}}}$$

## 6.1 Shift in utility and consumption by levels of wealth

Expression (28) shows that, in the value of  $B$ , the impact of a given shift  $\frac{\delta'(h)}{\delta(h)}$  in the weight put on consumption interacts with the functional form of utility through  $\frac{u'(c)}{-u''(c)}$ . In particular, the value of  $\frac{u'(c)}{-u''(c)}$  varies with levels of consumption, thus with underlying levels of wealth, but not in the same way for all functional forms:

- when  $u(c)$  is quadratic,  $\frac{u'(c)}{-u''(c)}$  is decreasing in  $c$
- when  $u(c)$  is exponential,  $\frac{u'(c)}{-u''(c)}$  is constant with respect to  $c$
- when  $u(c)$  is isoelastic,  $\frac{u'(c)}{-u''(c)}$  is increasing in  $c$

Consider a type of good such that the utility derived from it is piecewise linear, say because there is some form of satiation associated with this good before which the marginal utility decreases very steeply with consumption, and after which it decreases much more slowly with consumption. The households that consume low levels of this good have a high value of  $\frac{u'(c)}{-u''(c)}$ , so a given shift  $\frac{\delta'(h)}{\delta(h)}$  is associated with a high  $B$ , and their consumption responds substantially to a shift in the weight put on current consumption. On the contrary, households that consume sufficiently high levels of this good have a low value of  $\frac{u'(c)}{-u''(c)}$ , and their consumption is not very responsive to a shift in utility. Now, if for another type of good the utility is exponential or isoelastic, then  $\frac{u'(c)}{-u''(c)}$  is constant or increasing in  $c$ , and households that consume low levels of this other type of good respond similarly or even less to a shift in the weight put on current consumption than households that consume high levels of this good.



**Figure 3:** Effect of a shift in the weight put on utility for a linear and an exponential utility functions and for low-wealth and high-wealth households

Figure 3 illustrates the value of  $\frac{\delta'(h)}{\delta(h)} \frac{u'(c)}{-u''(c)}$  for different types of utility functions. Indeed, it pictures the effect on consumption of a shock that divides  $\delta$  by two (possibly because of an underlying shock to  $h$ ), keeping the marginal utility of current consumption constant. Deriving each side of  $\delta u'(c) = cst$  with respect to a change in delta, the variation in consumption is  $\frac{dc}{dshock} = \frac{d\delta/dshock}{\delta} \frac{u'(c)}{-u''(c)}$ . Thus, the variation in consumption on the graphs correspond to the value of the denominator in  $B$ .

On the left hand side, the utility function that is affected by a shock to  $\delta$  is piecewise linear, with a steep decrease marginal utility with the first units of consumption up to a kink, which can be interpreted a point where households are close to satiation. For this reason, we refer to this function that the one associated with necessities. The function in blue is  $\delta^{before} u'(\cdot)$  at the initial, larger value of  $\delta$ . The function in red is  $\delta^{after} u'(\cdot)$ , in which delta is smaller and such that  $\delta^{after} = \delta^{before} / 2$ . The lower dashed line corresponds to the value of  $\delta u'(c)$  for a household with a large level of wealth (denoted with an index  $HW$ ), thus a high level of consumption, and a small level of  $\delta u'(c)$ . The level of consumption is therefore not too far from the satiation kink. Because utility is linear and the level of consumption quite high, a shift in  $\delta$  has a modest effect on consumption, which moves from the blue  $c^{HW}$  to the red  $c^{HW}$ . The higher dashed line corresponds to the value of  $\delta u'(c)$  for a household with a low level of wealth (denoted with an index  $LW$ ). Because the household has less wealth, it consumes less, and the marginal utility is higher. The graph shows that, for a low-wealth household, the effect of a shift in  $\delta$  on consumption is much stronger: the



gap between before and after the shock, that is, between the blue and red values of  $c^{LW}$  is much larger. Thus, the same shift in  $\delta$  produces a large shift in the consumption of this type of good (for instance necessities) for low wealth households, but no adjustment for high wealth households.

On the right hand side, the graph now represents the effect of shift in  $\delta$  when the utility function is exponential, which for instance could be the function that households use to value luxury goods. The shift in  $\delta$  is the same as on the right hand side. In blue the function is  $\delta^{before} u'(\cdot)$ , and in red is  $\delta^{after} u'(\cdot)$ , with  $\delta^{after} = \delta^{before} / 2$ . The lower dashed line represents the constant marginal utility of a household with a high level of wealth, thus a low value of  $\delta^{after} u'(\cdot)$ . In that case, the change in consumption caused by the shift in  $\delta$  is quite substantial: the gap between the blue and red values of  $c^{HW}$  is large. A household with low wealth reacts in a very similar way, and the change in consumption before and after the shift in  $\delta$  is identical to that of high wealth households. Thus, the initial functional form of utility determines how important is the impact of a shift in the weight put on utility is, and how this impact varies with initial levels of marginal utility (thus with initial levels of wealth).

## 6.2 Identification and implementation

Our objective is to measure the respective sizes of these two effects: the contribution of the change in resources, and the contribution of the change in marginal utility. Assuming that the elasticities to shocks,  $\phi$ , and the effects  $A$  and  $B$  are approximately homogeneous across households and periods, the average of expressions (24) and (27) across households and periods is:<sup>11</sup>

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<sup>11</sup>The pass-through coefficients are typically assumed to be constants in the early semi-structural estimation literature (Blundell, Pistaferri, and Preston (2008)). If that is the case, the fact that  $A_t^k$  and  $B_t^k$  vary across households drives two different biases, likely of opposite directions with one bias making  $E[A_t^k]$  larger than our estimate of  $A$  and the other making  $E[B_t^k]$  larger than our estimate of  $B$  (if  $B$  and  $A$  covary positively which they do across low-wealth and higher-wealth). Which bias dominates depends on the respective gaps between  $E[1/A_t^k]$  and  $1/E[A_t^k]$  and between  $E[B_t^k/A_t^k]$  and  $E[B_t^k] \times E[1/A_t^k]$ .

$$E\left[\frac{d\ln(c_t^k)}{d\varepsilon_t^h}\right] = \phi_{c^k}^{\varepsilon^h} \approx \underbrace{\left(\phi_y^{\varepsilon^h} \frac{p_t y_t}{p_{t+1}} - \phi_m^{\varepsilon^h} \frac{p_t^m m_t}{p_{t+1}} - \sum_{l \neq k} \phi_{c^l}^{\varepsilon^h} \frac{p_t^l c_t^l}{p_{t+1}}\right)}_{\substack{\text{contribution of change in resources} \\ = 0 \text{ if the shock does not} \\ \text{affect income nor other spending}}} A^k + \underbrace{B^k}_{\substack{\text{contribution of change} \\ \text{in marginal utility} \\ = 0 \text{ if } \delta_1(\cdot) \text{ is a constant}}} \quad (30)$$

$$E\left[\frac{d\ln(c_t^k)}{d\varepsilon_t^y}\right] = \phi_{c^k}^{\varepsilon^y} \approx \underbrace{\left(\frac{p_t y_t}{p_{t+1}} - \phi_m^{\varepsilon^y} \frac{p_t^m m_t}{p_{t+1}} - \sum_{l \neq k} \phi_{c^l}^{\varepsilon^y} \frac{p_t^l c_t^l}{p_{t+1}}\right)}_{\substack{\text{contribution of change in resources} \\ = 0 \text{ if the shock does not} \\ \text{affect income nor other spending}}} A^k + \underbrace{\phi_h^{\varepsilon^y} B^k}_{\substack{\text{contribution of change} \\ \text{in marginal utility} \\ = 0 \text{ if } \delta_1(\cdot) \text{ is a constant}}} \quad (31)$$

To estimate the terms in (30) and (31), we note that the same  $A^k$  and  $B^k$  appear in the two equations. Thus, we have two equations and two terms that we want to identify, as the other terms in (30)-(31) can be either observed directly or estimated from other moments. Indeed, real income (with tomorrow's average price as the reference price)  $\frac{p_t}{p_{t+1}} y_t$ , real consumption expenses  $\frac{p_t^l}{p_{t+1}} c_t^l$ , and real medical expenses  $\frac{p_t^m}{p_{t+1}} m_t$  are observed for each households. The pass-through coefficients  $\phi$  can be estimated together with  $A^k$  and  $B^k$ : the pass-through coefficients of transitory health and income shocks to each category of consumption  $l$ ,  $\phi_{c^l}^{\varepsilon^h}$  and  $\phi_{c^l}^{\varepsilon^y}$ , are identified from equations (16) and (17); the pass-through coefficients of transitory health and income shocks to medical expenses,  $\phi_m^{\varepsilon^h}$  and  $\phi_m^{\varepsilon^y}$ , are identified from equations (18) and (19); the pass-through of income to a transitory health shock,  $\phi_h^{\varepsilon^y}$ , and the pass-through of health to a transitory income shock,  $\phi_y^{\varepsilon^h}$ , are identified from:

$$\hat{\phi}_h^{\varepsilon^y} = \frac{\text{cov}(\Delta \ln(y_t), -\Delta h_{t+1})}{\text{cov}(\Delta h_t, -\Delta h_{t+1})} \quad (32)$$

$$\hat{\phi}_y^{\varepsilon^h} = \frac{\text{cov}(\Delta h_t, -\Delta \ln(y_{t+1}))}{\text{cov}(\Delta \ln(y_t), -\Delta \ln(y_{t+1}))}. \quad (33)$$

The estimation is similar to the one used to estimate the pass-through coefficients only. We use a GMM, with a weighting matrix that clusters at the household level and is robust to heteroskedasticity.

	All	Low wealth	High wealth
<i>Nondurables</i>			
$\phi_c^{\varepsilon^h}$	.196** (.086)	.381*** (.121)	.083** (.115)
Pass-through of resources ( <i>A</i> )	.002*** (.001)	.007* (.004)	.002** (.001)
Pass-through of health through shift in utility ( <i>B</i> )	.173** (.086)	.346*** (.121)	.081 (.112)
Obs.	4975	956	4019
<i>Necessities</i>			
$\phi_c^{\varepsilon^h}$	.1 (.09)	.38*** (.13)	-.037 (.115)
Pass-through of resources ( <i>A</i> )	.002** (.001)	.01*** (.004)	.001 (.001)
Pass-through of health through shift in utility ( <i>B</i> )	.086 (.09)	.339*** (.13)	-.047 (.115)
<i>Luxuries</i>			
$\phi_c^{\varepsilon^h}$	.379*** (.148)	.389* (.223)	.374** (.189)
Pass-through of resources ( <i>A</i> )	.002 (.001)	-.01 (.008)	.003** (.001)
Pass-through of health through shift in utility ( <i>B</i> )	.358*** (.148)	.4* (.226)	.33* (.189)
Obs.	4971	954	4017

Standard errors in parentheses. \* at 10%, \*\* at 5%, \*\*\* at 1%

**Table 8:** Decomposition

### 6.3 Decomposition results

The first part of Table 8 presents the results of the decomposition of the pass-through of transitory health shocks to all nondurable consumption. The overall pass-through coefficients of transitory health shocks to nondurables are very similar to those reported in Table 7, with the slight gap coming from the difference in sample. Over the whole sample, the pass-through of a change in resources, *A*, is statistically significant. Its value of 0.002 indicates that. Given that we compute that a one unit change in the current health index is associated with a \$11,312 change in resources, on average in the sample, this channel contributes  $11.312 \times 0.002 = 0.023$  to the 0.196 response of consumption to a one unit change in the current health index. When the pass-through can be interpreted as an elasticity, it means that, through its effect

on resources alone, a one-unit decrease in current health is associated with a 2.3% decrease in the consumption of nondurables. Apart from the resource channel, current health can affect current consumption through a shift in utility, and we find that, keeping resources constant, the pass-through of changes in current health to current consumption is statistically significant and equal to 0.173. When the pass-through can be interpreted as an elasticity it means that, through its effect on the ability to derive utility from consumption, a one-unit decrease in current health is associated with a 17.3% decrease in the consumption of nondurables. Thus, the dependence of utility on health explains 88% of the pass-through of temporary health shocks to the consumption of nondurables. Among low-wealth households, consumption responds even more to temporary health shocks, with a pass-through of 0.381 and both the resource pass-through and the shift in utility pass-through are larger. Among high-wealth households, the pass-through of transitory shocks to consumption is much smaller, at 0.083. The resource pass-through is small but statistically significant. The pass-through of current health through a shift in utility is not precisely measured. From expression (28), note that extent to the shift in utility affects consumption depends on the shape of the utility function. In particular, if the ratio  $\frac{u'(c)}{-u''(c)}$  is very small, for instance because consumption is close to a satiation kink, a shift in the ability to derive consumption is not going to affect consumption too much, which will remain close to the satiation kink even after the value of consuming today has decreased.

The second and third parts of the Table presents the decomposition of the responses of necessities and luxuries. First, we examine the response of necessities. Overall in the population, we find a small and insignificant impact of temporary health shocks on the consumption of necessities. However, the pass-through of a change in resources to current consumption,  $A$ , is statistically significant at the 1%. Its level is the same as for nondurable consumption, 0.002. Because a temporary change in current health is associated with a \$11,312 change in resources, on average in the sample, the change in resources contributes 0.023 to the pass-through of temporary health shocks to the consumption of necessities, which is probably too little to make this pass-through significant. The pass-through of temporary health shocks through the shift in utility,  $B$ , is not statistically significant. The break-down by levels of wealth reveals a lot of heterogeneity. Temporary health shocks have a large and significant impact on the consumption of necessities among low-wealth. It comes

both from the effect of resources, which is five times larger than in the whole sample, and from the effect of a change in health on the utility function. Among households with high levels of wealth, both the pass-through of resources and of health through a shift in utility are small and non-significant. The latter is possibly due to the fact that high-wealth households are close to the point of satiation in their consumption of necessities.

When we turn our attention to look at the pass-through to luxuries, which is statistically significant and large, at 0.379, the opposite is true: the estimate of the pass-through of resources,  $A$ , is not statistically significant (and the point estimate remains small), while the estimate of the pass-through of health through a shift in utility,  $B$ , is large and significant at the 1% level. This means that a change in future resources plays a limited role in the response of the consumption of luxuries, while the shift in utility plays a large role. The point estimate of  $B$  is 0.358, which means that the change in health through the shape of the utility function explains 94% of the total pass-through of a transitory health shock to the consumption of luxuries. Among low-wealth households, temporary health shocks are associated with a (less precisely measured) change in the consumption of luxuries, although only the health-dependent channel is active. Among older high-wealth households, the consumption of luxuries respond significantly to temporary health shocks, and the response is driven by both resources and the effect of health on the utility function, with the estimate of  $A$  being modest but significant at the 5% level and the estimate of  $B$  being large and significant at the 10% level. This is consistent with a situation in which high-wealth households are not satiated in luxuries, so a shift in their ability to derive utility from them has a large impact on their consumption of them.

## 7 Conclusions

We show that income and health risks are pervasive in old age and that households over age 65 experience both permanent and transitory income and health shocks.

We also document that even transitory income and health shocks trigger significant consumption responses, and that, in terms of the sign of the response, a decrease in health is associated with a decrease in consumption (and vice-versa). We find important heterogeneity in these responses across consumption categories and levels of wealth. In our overall sample, a negative income shock reduces consumption across

a variety of categories of goods, while a negative health shock primarily reduces expenses on car maintenance and leisure activities. More specifically, among low-wealth households, a negative income shock mainly reduces expenses on food and utilities, while a negative health shocks generates a drop in expenses on car maintenance. Among high-wealth households, both negative income and health shocks reduce expenses on leisure activities.

We also develop a life-cycle framework to determine what drives the response of consumption to a transitory health shock. We find that, in the response of total non-durable consumption both the resource channel and the shift in utility due to health status channel are significant. However, the resource channel contributes much less, while the shift in utility explains most of the response of nondurable consumption. Considering the responses of necessities and luxuries separately, we find that on average in the population, the resource channel is only significant for necessities, that is, a change in resources significantly affects the of consumption necessities (and this is driven by low-wealth households) but not that of luxuries. Contrary to that, the shift in utility channel is only significant for luxuries, that is, a change in current health significantly affects the consumption of luxuries through the shift in the utility function that it causes (and this driven by both low-wealth and high-wealth households) but not that of necessities.

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## **Appendix A: The HRS and CAMS data and our variables**

### **Data and sample selection**

The data for our empirical analysis are drawn from the Health and Retirement Study (HRS), a longitudinal survey that is representative of the U.S. population over the age of 50 and their spouses. We combine information from the HRS core interviews and from the Consumption and Activities Mail Survey (CAMS), a supplementary study collecting data on household spending that is administered to a subset of HRS respondents. Our merged sample is biennial and covers the years 2001 to 2013.

Table 9 presents the sample selection. We combine information from the core interviews (that is, in the HRS) and from CAMS that refer to the same household and calendar year and obtain a sample of 24,981 household-year observations. We then remove households whose head is above age 90 or below 50, and observations with missing demographic or health information. After these screens, we are left with 23,171 household-year observations. Of these, about 30% of observations have at least one missing item in consumption. For these, we impute consumption items as described later in this Appendix. After imputing consumption items, we remove outliers. To do so, we first, we drop observations with non-durable consumption or household income less than 100\$ (in 2015 prices) and then drop the top and bottom 1% of the change in log consumption, income, and medical expenditures. After this cleaning, there were 28 observations with log income growth larger than 6, and we drop those too. We are left with 21,994 observations, 600 of which do not report health information and we thus drop them. Finally, we select households whose head is 65 or above. Our final sample contains 13,059 observations. After taking first differences and dropping those observations whose future health or income change is not observed, we are left with 5,095 observations that used in the estimation of the pass-through coefficients.

### **The CAMS questionnaire**

The CAMS questionnaire was sent to 5,000 families in 2001. The same households received the questionnaire in all the subsequent waves. Additional subsamples were added in 2005 and in 2011, to cover also the newly introduced cohorts (the Early Baby Boomers entered the HRS in 2004, and the Mid Baby Boomers in 2011).

<b>Sample Selection</b>	<b>Selected out</b>	<b>Selected in</b>
Answering to CAMS & HRS		24,981
Interview in subsequent year	1,014	23,967
Head's age less than 50 or more than 90	695	23,272
Missing demographic variables	101	23,171
Income, consumption or medical expense outliers	1,177	21,994
Missing health	600	21,344
Head's age less than 65	8,285	13,059
First differencing data		9,133
Future health and income changes not observed	4,038	5,095

**Table 9:** Sample Selection, after merging to HRS main data

We merge information from CAMS and HRS when they refer to the same household and to the same calendar year. This amounts to merge each CAMS wave to the subsequent HRS wave, as in the HRS income refers to the previous calendar year. While in CAMS interviews are always conducted in September/October, in the HRS a fraction of households are interviewed in the year following the regular interview year. Considering households interviewed in both CAMS and HRS, in most years only about half percent of interviews were conducted in the following year (wave 10 being an exception, with a higher fraction of late interviews). We drop all those households with a late interview as their incomes cannot be matched to consumption in CAMS. After matching income and consumption referring to the same year we have a sample of 24,981 observations, and after dropping individuals aged less than 50 or more than 90, we are left with 23,272 observations.

Table 10 lists which consumption items are included in our analysis.

Year	2001	2003	2005-2013	Consumption	Med exp.
Utilities	Yes	Yes	Yes	Included	
Housekeeping Supplies	Combined	Yes	Yes	Combined	
Yard Supplies		Yes	Yes		
Housekeeping Services	n.a.	Yes	Yes	Included	
Gardening/Yard Services	n.a.	Yes	Yes	Included	
Clothing	Yes	Yes	Yes	Included	
Personal care	n.a.	Yes	Yes	Included	
Vacations - tickets	Yes	Yes	Yes	Included	
Hobbies	Combined	Yes	Yes	Combined	
Sports Equipment		Yes	Yes		
Contributions - gifts	Yes	Yes	Yes	Included	
Food/Drink Grocery	Yes	Yes	Yes	Included	
Dining Out	Yes	Yes	Yes	Included	
Health Insurance	Yes	Yes	Yes		Not included
Drugs	Yes	Yes	Yes		Included
Health Services	Yes	Yes	Yes		Included
Medical Supplies	Yes	Yes	Yes		Included
Auto Insurance	Yes	Yes	Yes	Included	
Vehicle Services	Yes	Yes	Yes	Included	
Gasoline	Yes	Yes	Yes	Included	

**Table 10:** Nondurable categories of consumption and medical expenditures in CAMS. Not available (n.a.) items are imputed.

Table 11 shows that about 70% of the consumption questionnaires were fully completed, while 14% have 1 missing item, 5% have 2 missing items and 9% have 4 or more missing items. When considering the missing patterns over time for the same household, depending on items, 80-85% of missing values are missing for just one 1 year, while 90-95% are missing for one or two years for the same household. Hence, it is very unusual that the same household has many missing values over the years on the same item.

Number of missing items	year							Total
	2001	2003	2005	2007	2009	2011	2013	
0	66.9	68.3	67.6	70.8	70.9	70.8	71.2	69.5
1	14.6	14.9	14.8	12.9	15.5	14.2	12.1	14.1
2	5.4	5.1	4.6	4.5	4.4	4.6	4.1	4.7
3	2.6	2.7	3.1	2.3	2.7	2.6	2.0	2.6
4+	10.5	9.0	9.9	9.4	6.5	7.8	10.6	9.2
<b>Total</b>	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

**Table 11:** Percentage of households by number of missing items by year.

## Imputation procedure

We impute each consumption item in the following way. We impute the mean as the prediction from a fixed-effect regression. Then, we add an error term to that prediction, to tackle the attenuation in the variance of the distribution of the imputed values (David et al., 1986, French and Jones, 2011).

To compute the fixed-effect regressions, we pool all years to estimate, for each item  $m$ ,  $Item^m = z\beta^m + f^m + \epsilon^m$ , and compute  $\widehat{Item}_{it}^m = z_{it}\hat{\beta}^m + \hat{f}_i^m$ , for each household  $i$  and year  $t$ . We then use the estimated fixed effect to compute the prediction for the same household in a different time period  $s$ :  $\widehat{Item}_{is}^m = z_{is}\hat{\beta}^m + \hat{f}_i^m$ . If a household appears with a non-missing item only once, and no  $\hat{f}_i^m$  can be estimated, we impute the missing items with a similar, year by year, OLS regression.

The explanatory variables used in the regressions are: a set of dummies for age of head, set of dummies for age of wife (if present), dummies for health self-reported status, self-reported health interacted with education of the head, region of residence, region of residence interacted with education, education of the head interacted with marital status (married, partnered, never married, separated, divorced), total household income (real), social security of the spouse (real), pension of the spouse (real), total household wealth (real), total household income interacted education of the head, total wealth interacted with education of the head and with year, price index for non-durable expenditure, price index for the commodity to which the regression refers.

Then, to reduce the attenuation bias induced by the imputation procedure, we proceed as follow. For each household  $i$  for which  $Item^m$  is observed, we calculate

the predicted value  $\widehat{Item}_{it}^m = z_{it}\hat{\beta}^m + \hat{f}_i^m$ , and the residual  $\hat{e}_{it} = Item_{it}^m - \widehat{Item}_{it}^m$ . Then, we sort the predicted value  $\widehat{Item}_{it}^m$  into deciles and keep track of all values of  $\hat{e}_{it}$  within each decile. Next, for every individual  $j$  with missing  $Item^m$  we impute  $\widehat{Item}_{jt}^m = z_{jt}\hat{\beta} + \hat{f}^m$ . Then we impute  $\hat{e}_{jt}$  for household with missing item  $m$  by finding a random individual  $i$  in the non-missing sample with a value of  $\widehat{Item}_{it}^m$  in the same decile as  $\widehat{Item}_{jt}^m$ , and set  $\hat{e}_{jt} = \hat{e}_{it}$ . The imputed value of  $Item_{jt}^m$  is  $\widehat{Item}_{jt}^m + \hat{e}_{jt}$ .

We impute each item separately, and then construct non durable expenditure as the sum of the items with imputed values replacing missing values. The model predicts a small number of negative expenditure amounts, that we set to zero.

## Variables Definition

**Non-durable consumption** includes 21 items: electricity, water, heating, phone and house supplies, house and garden supplies and services, food, dining out, clothing, vacations, tickets, hobbies, sport equipment, contributions and gifts, personal care, auto insurance, vehicle services, and gasoline. The items personal care, housekeeping services and gardening services were not collected in 2001 and are imputed for that year. Expenditures on each item are deflated by the corresponding item-specific price index of the Bureau of Labor Statistics (BLS).

**Food** is the sum of expenditure on food and beverages, including alcoholic, and dining and/or drinking out, including take out food.

**Leisure activities** is the sum of expenditure on trips and vacations; tickets to movies, sporting events, and performing arts; sports, including gym, exercise equipment such as bicycles, skis, boats, etc.; hobbies and leisure equipment, such as photography, stamps, reading materials, camping, etc.

**Equipment** is the sum of expenditure on housekeeping supplies, cleaning and laundry products; housekeeping, dry cleaning and laundry services, hiring costs for housekeeping or home cleaning, and amount spent at dry cleaners and laundries; gardening and yard supplies and services; clothing and apparel, including footwear, outerwear, and products such as watches or jewelry; personal care products and services.

**Utilities** is the sum of expenditure on electricity; water; heating fuel for the home; telephone, cable, internet.

**Car, gasoline and other** is the sum of expenditure on vehicle insurance; vehicle

maintenance; gasoline; contributions to religious, educational, charitable, or political organizations; cash or gifts to family and friends outside the household.

**Medical expenses** includes 3 items: drugs, health services, and medical supplies. We construct this variable from the raw CAMS data set. Expenditures on each item are deflated by the item-specific index provided by the BLS.

**Drugs** is expenditure on prescription and nonprescription medications: out-of-pocket cost, not including what's covered by insurance.

**Medical services and supplies** is the sum of expenditure on health care services (out-of-pocket cost of hospital care, doctor services, lab tests, eye, dental, and nursing home care) and medical supplies (out-of-pocket cost, not including what's covered by insurance).

**Household Income** Income is observed in the core part of the HRS. Our baseline measure of income includes earnings, that is wages, salaries, and bonuses; capital income, which includes business or farm income, self-employment, rents, dividend and interest income, and other asset income; pensions, that is income from employer pension or annuity; benefits, including social security retirement income, income from transfer programs and workers' compensations; and other income, which includes alimony, other income, lump sums from insurance, pension, and inheritance, referring to both the head and the spouse if present. All income variables refer to calendar year prior to the HRS main interview. Income is deflated using the price index for total consumption provided by BLS.

**Income Tax** is taken from the RAND files, which use the NBER TAXSIM to impute the income tax.

**Assets** Net worth is also observed in the HRS. We define it as the sum of all assets—primary residence, secondary residence, real estate other than primary and secondary residence, vehicles, businesses, Individual Retirement Account (IRA) and Keogh accounts, stocks, mutual funds, and investment trusts, checking, savings, or money market accounts, Certificate of Deposit (CD), government savings bonds, and T-bills, bonds and bond funds, and all other savings—minus all debts—all mortgages/land contracts on primary and secondary residence, other home loans, other debt—of the head and spouse (if present) of the household. This variable is taken from the RAND version of the HRS and refers to the time of the interview. Assets are deflated using the price index for total consumption provided by BLS. For couples, assets are divided by the square root of 2 to take into account family size.



**Demographic variables** All demographic and health variables refer to the time of the interview.

## **Health index**

To construct an index for health, we instrument self-reported health with objective measures, including difficulties in activities of daily living (ADLs), mental health, and illnesses reported by a doctor, following Blundell, Britton, Costa Dias, French (2016). In particular, our health index is the predicted value from a regression of self-reported health status on age dummies, year dummies, education dummies, initial health and labor market status, and objective measures such as difficulties in activities of daily living (ADL) or other activities, illnesses reported by a doctor, and an indicator for mental health (the complete list is in Table 12).

Mental health is measured by an index constructed by RAND using a score on the Center for Epidemiologic Studies Depression (CESD) scale. The CESD score is the sum of six negative indicators minus two positive indicators. The negative indicators measure whether the interviewed declared to have experienced over the week prior to the interview the following feelings, all or most of the time: depression, everything is an effort, sleep is restless, felt alone, felt sad, and could not get going. The positive indicators measure whether the interviewed felt happy and enjoyed life, all or most of the time. As the CESD score is missing for about 4% observations, we impute it by running a fixed effect regression of CESD score on a polynomial in age, marital status, income, labor force status, difficulties in ADLs and in other activities. The regressions are run separately for men and single and married women. In this way, we are able to recover about half missing values.

To get a household health index for couples, we average the two instrumented self-reported health indices computed for husbands and wives separately.

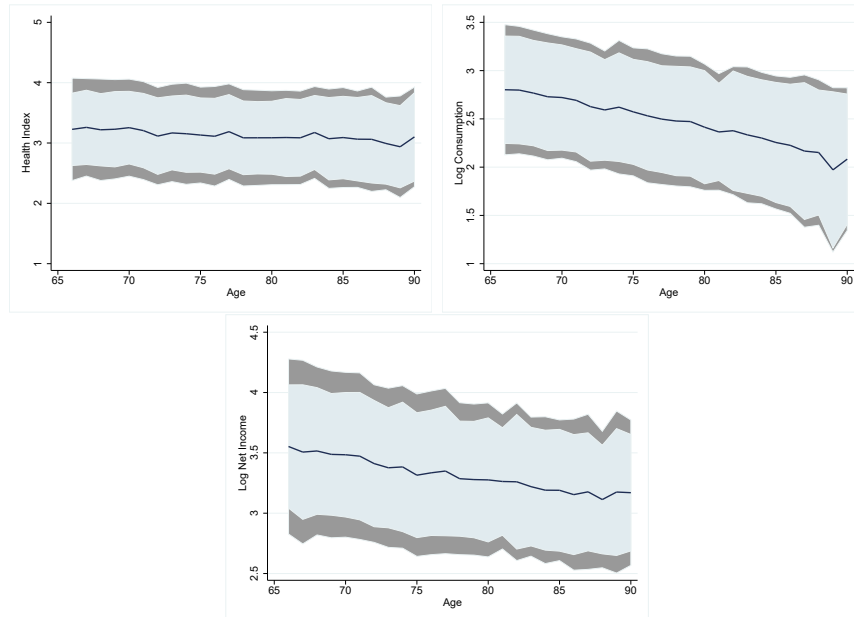
## **Detrending from the effect of demographics**

In our analysis, we consider the net values of health, income, medical expenses, and consumption, that is, after the effect of observed characteristics is removed. To this end, we run ordinary least square (OLS) regressions of the level of the health index and the logarithm of income, the medical expenses items, and the consumption items on dummies for year, year of birth, education, race, employment status, whether

<b>Health variables</b>	
Difficulties in ADLs	walking across room getting dressed bathing or showering eating getting in-out of bed using the toilet
Difficulties in other activities	walking several blocks walking one block sitting for two hours getting up from a chair climbing several ft of stairs climbing one flight of stairs stooping, kneeling, crouching lifting or carrying 10 lbs picking up a dime extending arms pushing or pulling large objects
Mental health	CES-D score for depression
Doctor reported	cancer diabetes high blood pressure arthritis psychiatric problems lung disease heart problems stroke

**Table 12:** Objective health variables used in the analysis. All variables are 0/1 (No/Yes), except for CES-D which is from 0 to 8.

there are income recipients other than the head and the spouse in the household, region, marital status, and number of household residents. We also add interactions terms (education and year, race and year, education and employment status) and we interact all variables with a binary variable picking up the age group (less than 65 and above 65). We run the regressions separately for couples, single men, and single women, allowing the effect of the observed characteristics to vary across these categories. The top left graph of Figure 4 shows the health index by age, while the top right one and bottom one display the age pattern of the logarithm of consumption and net income, respectively. The shaded areas represent plus or minus one standard deviation of the total (grey+blue) and unexplained (blue) component of the variable.



**Figure 4:** (Good) Health index by age (top left graph), logarithm of consumption (top right graph), and logarithm of net income by age (bottom graph). Shaded areas represent plus or minus one standard deviation of the total (grey+blue) and unexplained (blue) component of the variable.

## Appendix B: Income and health dynamics

To better evaluate our assumptions about the evolution of income and health, Table 13 reports the autocovariances of log-income growth and health growth, and shows that both income and health are well represented by an MA(0) transitory income component and a random walk permanent component. More specifically, this table shows that the covariance between log-income growth at  $t$  and  $t + 1$  is

	$\Delta \ln(y_t)$	$\Delta \ln(y_{t+1})$	$\Delta \ln(y_{t+2})$
$cov(\Delta \ln(y_t), \cdot)$	.215*** (.007)	-.088*** (.005)	.008 (.005)
Obs.	5105	5105	3180
	$\Delta h_t$	$\Delta h_{t+1}$	$\Delta h_{t+2}$
$cov(\Delta h_t, \cdot)$	.064*** (.002)	-.02*** (.001)	.003 (.002)
Obs.	5105	5105	3127

Standard errors in parentheses. \* at 10%, \*\* at 5%, \*\*\* at 1%

**Table 13:** Autocovariance of log-income growth and health growth

statistically significant at the 1% confidence level, while it is no significant between  $t$  and  $t + 2$ . This is consistent with transitory income being an MA(0) process and thus being i.i.d. In fact, if it were an MA( $k$ ) process with  $k > 0$ , then the covariance between log-income growth at  $t$  and  $t + 2$  would be significant. In addition, if the permanent component of log-income were an AR(1) with a coefficient different from one, rather than a random walk, the covariance between log-income growth at  $t$  and all future periods would be significant, and we fail finding evidence that it is.

## Appendix C: Structural decomposition

### Derivation

The intermediate steps to move from equation (25) to equation (26) in section 6 are as follows. Equation (25) is:

$$\frac{dc_t^k}{d\varepsilon_t^h} u''(c_t^k) \delta_k(h_t) + \frac{dh_t}{d\varepsilon_t^h} \delta'_k(h_t) u'(c_t^k) = E_t \left[ \frac{da_{t+1}}{d\varepsilon_t^h} \frac{dc_{t+1}^k}{da_{t+1}} u''(c_{t+1}^k) \delta_k(h_{t+1}) \frac{s_{t+1}(\pi_{t+1}^h)}{s_t(\pi_t^h)} \frac{p_t^k/p_t}{p_{t+1}^k/p_{t+1}} \right] \beta(1+r). \quad (25)$$

We divide each side by  $u''(c_t^k) \delta_k(h_t)$ :

$$\frac{dc_t^k}{d\varepsilon_t^h} - \frac{dh_t}{d\varepsilon_t^h} \frac{\delta'_k(h_t)}{\delta_k(h_t)} \frac{u'(c_t^k)}{-u''(c_t^k)} = E_t \left[ \frac{da_{t+1}}{d\varepsilon_t^h} \frac{dc_{t+1}^k}{da_{t+1}} - \frac{u''(c_{t+1}^k)}{-u''(c_t^k)} \frac{\delta_k(h_{t+1})}{\delta_k(h_t)} \frac{s_{t+1}(\pi_{t+1}^h)}{s_t(\pi_t^h)} \frac{p_t^k/p_t}{p_{t+1}^k/p_{t+1}} \right] \beta(1+r).$$

We take  $\frac{da_{t+1}/p_t}{d\varepsilon^h}$  out of the expectation operator (since it is known at  $t$ ), and substitute it with  $\frac{dy_t p_t/p_t}{d\varepsilon^h} - \frac{dm_t p_t^m/p_t}{d\varepsilon^h} - \frac{dc_t^k p_t^k/p_t}{d\varepsilon^h} - \sum_{l \neq k} \frac{dc_t^l p_t^l/p_t}{d\varepsilon^h}$  on the right hand-side using the budget constraint (21) at period  $t$ :

$$\begin{aligned} \frac{dc_t^k}{d\varepsilon_t^h} - \frac{dh_t}{d\varepsilon_t^h} \frac{\delta'_k(h_t)}{\delta_k(h_t)} \frac{u'(c_t^k)}{-u''(c_t^k)} &= \left( \frac{dy_t p_t/p_t}{d\varepsilon^h} - \frac{dm_t p_t^m/p_t}{d\varepsilon^h} - \frac{dc_t^k p_t^k/p_t}{d\varepsilon^h} - \sum_{l \neq k} \frac{dc_t^l p_t^l/p_t}{d\varepsilon^h} \right) \\ &\times E_t \left[ \underbrace{\frac{dc_{t+1}^k}{da_{t+1}} - \frac{u''(c_{t+1}^k)}{-u''(c_t^k)} \frac{\delta_k(h_{t+1})}{\delta_k(h_t)} \frac{s_{t+1}(\pi_{t+1}^h)}{s_t(\pi_t^h)} \frac{p_t^k}{p_{t+1}^k/p_{t+1}}}_{E_t^k} \right] \beta(1+r). \end{aligned}$$

We shift the term  $\frac{dc_t^k p_t^k/p_t}{d\varepsilon^h} E_t^k$  from the right-hand side to the left-hand side:

$$\frac{dc_t^k}{d\varepsilon_t^h} \left( 1 + \frac{p_t^k}{p_t} E_t^k \right) - \frac{dh_t}{d\varepsilon_t^h} \frac{\delta'_k(h_t)}{\delta_k(h_t)} \frac{u'(c_t^k)}{-u''(c_t^k)} = \left( \frac{dy_t p_t/p_t}{d\varepsilon^h} - \frac{dm_t p_t^m/p_t}{d\varepsilon^h} - \sum_{l \neq k} \frac{dc_t^l p_t^l/p_t}{d\varepsilon^h} \right) E_t^k.$$

Now, we move from level changes to log changes, and substitute using  $\frac{dc_t^k}{d\varepsilon_t^h} = \frac{d \ln(c_t^k)}{d\varepsilon_t^h} c_t^k$ ,  $\frac{dy_t p_t/p_t}{d\varepsilon^h} = \frac{d \ln(y_t) p_t/p_t}{d\varepsilon^h} y_t$ ,  $\frac{dm_t p_t^m/p_t}{d\varepsilon^h} = \frac{d \ln(m_t) p_t^m/p_t}{d\varepsilon^h} m_t$ , and  $\frac{dc_t^l}{d\varepsilon_t^h} = \frac{d \ln(c_t^l)}{d\varepsilon_t^h} c_t^l$  for all  $l \neq k$ :

$$\frac{d \ln(c_t^k)}{d\varepsilon_t^h} \left( c_t^k + \frac{c_t^k p_t^k}{p_t} E_t^k \right) - \frac{dh_t}{d\varepsilon_t^h} \frac{\delta'_k(h_t)}{\delta_k(h_t)} \frac{u'(c_t^k)}{-u''(c_t^k)} = \left( \frac{d \ln(y_t)}{d\varepsilon^h} \frac{y_t p_t}{p_t} - \frac{d \ln(m_t)}{d\varepsilon^h} \frac{m_t p_t^m}{p_t} - \sum_{l \neq k} \frac{d \ln(c_t^l)}{d\varepsilon^h} \frac{c_t^l p_t^l}{p_t} \right) E_t^k.$$

Rearranging, this writes:

$$\frac{d\ln(c_t^k)}{d\varepsilon_t^h} = \left( \frac{d\ln(y_t)}{d\varepsilon^h} \frac{y_t p_t}{p_t} - \frac{d\ln(m_t)}{d\varepsilon^h} \frac{m_t p_t^m}{p_t} - \sum_{l \neq k} \frac{d\ln(c_t^l)}{d\varepsilon^h} \frac{c_t^l p_t^l}{p_t} \right) \underbrace{\frac{E_t^k}{c_t^k + \frac{c_t^k p_t^k}{p_t} E_t^k}}_{A_t^k} + \frac{dh_t}{d\varepsilon_t^h} \underbrace{\frac{\frac{\delta'_k(h_t)}{\delta_k(h_t)} \frac{u'(c_t^k)}{-u''(c_t^k)}}{c_t^k + \frac{c_t^k p_t^k}{p_t} E_t^k}}_{B_t^k}.$$