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Medical and Long-Term Care with Endogenous Health and Longevity*

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Abstract. For the population over 65, long-term care (LTC) expenditure constitutes a considerable share in total health expenditures. In this paper, we distinguish between medical care, intended to improve one's state of health, and personal care required for daily routine. Personal care can be either carried out autonomously or by a third party. In the course of aging, autonomous personal care is eventually substituted by LTC. We set up a life-cycle model in which individuals are subject to physiological aging, calibrate it with data from gerontology, and analyze the interplay between medical care and LTC. We replicate health behavior and life expectancy of individuals and in particular the empirically observed patterns of medical care and LTC expenditure. We then analyze the impact of better health and rising life expectancy, triggered by rising income and improving medical technology, on the expected cost of LTC in the future. We predict an elasticity of LTC expenditure with respect to life expectancy of 1/3. In terms of present value at age 20, life-time LTC expenditure is predicted to decline with rising life expectancy.

Keywords: Health, Long-Term Care, Health Behavior, Life Expectancy

JEL: D11, D91, I12, J11

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1. Introduction

The evolution of health care expenditure has attracted much attention in the economic literature over the past decades. Rapid population aging, predominantly caused by income growth and medical progress, has risen concerns about the future cost burden for the health care system (e.g. Hall and Jones, 2007; Di Matteo, 2005; see Chernew and Newhouse, 2011, for a review). Since the largest share of health care expenditure is spent in old age, this fraction of the population plays an important role in this discussion.

When analyzing the (future) evolution of health care expenditure, it is worth noting that long-term care (LTC) expenditure constitutes a considerable share in total health care expenditure, especially in old age. LTC spending on average comes into the picture around age 65 and manifests itself as the dominating health expenditure type around age 90 (De Nardi et al., 2016). In fact, De Nardi et al. (2016) find that increasing health spending in the course of aging of the population over 80 is almost entirely driven by the increase in LTC spending. Other categories of health expenditures like outpatient and inpatient care, professional services, or pharmaceutical expenditure stagnate around age 80 and even slightly decrease at later ages. We pool these latter categories of health spending and call it medical care such that the sum of (formal) LTC and medical care expenditure constitutes total health care expenditure. Acknowledging the importance of informal LTC provided by the family, we will focus on formal LTC as provided under an employment contract either at home or an institution like nursing homes[1]. This allows us to measure the direct cost of LTC for the health care system.

Apart from the different expenditure patterns, distinguishing medical care from LTC is important because the two expenditure types also affect health behavior and outcomes in different ways. Medical care spending intends to cure and prevent health deficits which in turn improves the state of health and increases the life expectancy of the individual. LTC, on the other hand, assists the individual with activities of daily living (ADL) like cleaning or moving the body and with instrumental activities of daily living (IADL) like preparing meals. In other words, LTC assists with daily routine that is needed to survive, but it is not intended to counteract the accumulation of health deficits in the course of aging. In this paper, we aim to analyze the

[1]Specifically, we will define LTC in the data as "Nursing Care Facilities and Continuing Care Retirement Communities Spending", "Home Health Care Spending", and "Other Health Residential and Personal Care Spending".

(future) evolution of health care costs by differentiating between medical care and LTC and to quantify the channels through which rising life expectancy affects expenditure patterns of LTC.

To this end, we set up a gerontologically founded life-cycle model of human aging based on Dalgaard and Strulik (2014). Individuals choose consumption and health care optimally over the life course where health care is divided into medical and personal care. Personal care is provided autonomously by the individual and is eventually replaced by LTC once the individual has accumulated a critical number of health deficits. We then calibrate the model such that it fits health behavior, health outcomes, and life expectancy for the average U.S. American in the year 2012. The model calibration allows us to study the interplay between medical care and LTC and its implication for life expectancy. With the model at hand, we then examine the future evolution of LTC expenditure as a consequence of rising life expectancy through rising income and improving medical technology.

Studying the effects of better health and higher life expectancy on LTC expenditure is interesting for at least two reasons. First, LTC expenditure accounts for a considerable share in total health expenditure for the population over 65 and is thus quantitatively important. Second, the effect of improving health and life expectancy on LTC expenditure is a priori ambiguous as two counteracting mechanisms are at work. On the one hand, a better health enables individuals to carry out personal care autonomously until higher ages, thus demanding costly LTC at a later point in time. Therefore, the dependency level on LTC decreases for given age. This channel, taken for itself, decreases LTC expenditure. On the other hand, higher life expectancy requires LTC on average until higher ages as well, thereby c.p. increasing LTC expenditure. By projecting the future evolution of income and medical technology and their impact on individual health, we examine the quantitative importance of each channel.

If the effects through the two channels balanced each other, our results would be in line with the prominent Red Herring Hypothesis (Zweifel et al., 1999) stating that better health and higher life expectancy do not lead to higher health expenditures per se, but only shift health expenditures to higher ages. We indeed find that the bulk of expected LTC expenditures will be shifted to higher ages; however, this shift turns out to be not cost-neutral. We find that expected LTC cost will increase in the future, implying that the increase in LTC expenditure through higher life expectancy dominates the reduction in LTC expenditure through better health. Specifically, our model implies a 1/3-percentage increase in expected LTC expenditure for each percentage increase in life expectancy. This means that, compared to the predicted evolution of medical care expenditure, the increase in LTC expenditure is rather small. Interestingly, the response of LTC expenditure changes its direction when we calculate it in terms of present value at the beginning of young adulthood. Since LTC spending is generally delayed to higher ages following income and technology growth, it gets discounted more heavily. This capital market effect results in a reduction of expected LTC expenditure. Summarizing, the effect of higher income and better technology on LTC expenditure as compared to medical care spending is much more moderate since higher medical spending and the resulting better health state are dampening the effect of higher life expectancy on LTC spending.

There exists a vast literature, both theoretical and empirical, which studies the economics of LTC (see Cremer et al. (2012), Norton (2016), and Bannenberg et al. (2019) for comprehensive surveys). As Bannenberg et al. (2019) point out, however, "there is little (theoretical) understanding of the behavioral mechanisms behind the emergence of LTC needs and means over the individual's life-cycle". The survey identifies the missing inclusion of dynamics in economic models of LTC as a shortcoming of the existing literature. We aim to fill this gap by proposing a biologically founded life-cycle model of human aging in which the demand for LTC is determined by preferences, health behavior, and external factors such as income and medical technology.

There also exist a number of studies that provide projections for LTC expenditure in the future (e.g. Spillman and Lubitz, 2000; Comas-Herrera et al., 2006, Karlsson et al., 2006; EC, 2018). These studies typically use projection models to account for demographic change due to population aging and assume different (ad-hoc) scenarios for the evolution of dependency levels by age. We are the first, however, to offer a theory-based approach where the demand for LTC is endogenously determined by the health behavior of the individual. Health behavior, in turn, is affected by the economic environment which may vary in the future. This intricate relationship between medical care and LTC allows us to causally investigate the impact of income and technology on LTC. Therefore, we are not only able to quantify the impact that lower mortality and thus higher life expectancy has on LTC spending, but also to take into account the fact that the dependency on LTC endogenously declines for given age with an improving health status.

Our approach is particularly suitable to analyze optimal behavior towards medical care and LTC because aging is conceptualized as a process of health deficit accumulation. The health deficit model based on Dalgaard and Strulik (2014) has its foundation in gerontological research and, in particular, builds on the so-called frailty index (Mitnitski et al, 2002a,b) which measures in a straightforward way the health state of an individual. Since the frailty index can be easily (and continuously) measured, our model can be easily quantified and calibrated. The alternative paradigm, the Grossman model (1972), offers a less suitable approach since it is based on the accumulation of health capital instead of health deficits. Health capital, however, is a latent variable unknown to doctors or medical scientists which confounds any serious calibration of the model (see also Hosseini et al. (2019) for a critique). Direct evidence on the association of the frailty index with the risk of institutionalization in nursing homes is provided by Rockwood et al. (2006) and Blodgett et al. (2016). Our model is methodologically related to other studies employing the health deficit model that study the adaptation to a deteriorating state of health (Schünemann et al., 2017a), the gender gap in mortality (Schünemann et al., 2017b), optimal aging in partnerships (Schünemann et al., 2020), the anticipation of deteriorating health (Schünemann at al. 2019), the historical evolution of retirement (Dalgaard and Strulik, 2017), and and the optimal design of social welfare systems (Grossmann and Strulik, 2019).

The paper is organized as follows. Section 2 presents the basic model of medical care and LTC. In Section 3, we calibrate the model to the health behavior and health outcomes of a reference U.S. American in the year 2012. In Section 4, we analyze the impact of better health and increasing life expectancy through rising income and improving medical technology on the evolution of LTC expenditure. Section 5 concludes.

2. The Model

The individual maximizes expected life-time utility

$$V = \int_0^T e^{-\rho t} S(D(t)) U(c(t)) \mathrm{d}t \tag{1}$$

where $U(c(t))$ denotes utility from consumption and is given by $U(c(t)) = (c(t)^{1-\sigma} - 1)/(1-\sigma)$, with σ being the inverse of the intertemporal elasticity of substitution. The parameter ρ captures the time preference rate of the individual. The survival probability $S(\cdot)$ decreases in the number of health deficits $D(t)$ that the individual has accumulated up to age t. Intuitively, the individual calculates the expected utility stream by multiplying instantaneous utility at age t with the probability of living beyond that age (see Schünemann et al., 2017a). T represents the (endogenous) maximum lifespan of the individual. Our modeling of the survival probability implies that mortality directly depends on the number of accumulated health deficits, as emphasized by biologists (e.g. Arking, 2006), rather than on chronological age.

Besides an optimal consumption plan, the individual chooses optimal health care over the life cycle. With regard to health care, we distinguish between medical care and personal care. Medical care is defined as health investments which intend to cure and prevent health deficits in the course of aging, e.g. doctor visits, hospital stays or drugs. We assume that the individual is subject to physiological aging according to Dalgaard and Strulik (2014) such that health deficits accumulate over time as

$$\dot{D} = \mu(D - Ah^{\gamma} - a) \tag{2}$$

where μ denotes the inherent biological force of aging.[2] The maximum lifespan is associated with a critical deficit level $\bar{D}$ at which the individual dies with certainty. The accumulation of health deficits can be slowed down by investing in medical care h where the health technology is captured by the parameters A (scale) and γ (curvature) with $0 < \gamma < 1$. The parameter a denotes environmental influences that affect the speed of aging but are beyond the individual's control. Investments in medical care reduce the speed of deficit accumulation, improve the state of health and thus increase the survival probability for given age. Therefore, medical care serves to increase the life expectancy of the individual.

Personal care, on the other hand, is needed to survive but does not improve the state of health. It is required to accomplish activities of daily living (ADL) like cleaning or moving the body as well as instrumental activities of daily living (IADL) like preparing meals, but it is not intended to affect the deficit accumulation process and thus life expectancy of the individual. Depending on the number of health deficits, personal care can be provided autonomously by the individual ($P_a(D)$) or by a third party in which case we call it LTC (P_{LTC}). Naturally, the ability for autonomous care declines as individuals develop more health deficits and thus $P_a'(D) < 0$. We assume that a minimum of personal care P_{min} is needed in order to survive and that this minimum level is always provided, either autonomously or by LTC. Therefore,

$$P_{min} = P_a(D) + P_{LTC}. \tag{3}$$

[2]For better readability, we suppress, from now on, the fact that all variables are age (t)-dependent.

The equation implies that once $P_a(D) < P_{min}$ the individual demands LTC P_{LTC}[3]. While autonomous care can be provided at no monetary cost, LTC expenditure enters the budget constraint which reads

$$\dot{k} = \begin{cases} w + (r+m)k - c - ph - q \cdot max[0, P_{min} - P_a(D)] & \text{for } t < R \\ \tau w + (r+m)k - c - ph - q \cdot max[0, P_{min} - P_a(D)] & \text{for } t \geq R. \end{cases} \quad (4)$$

Individuals allocate labor income w and capital income $(r+m)k$ to savings, consumption c, medical care expenditure ph, and LTC expenditure qP_{LTC} where p and q denote the respective relative prices. Note that we have substituted Equation (3) for LTC demand P_{LTC}. The associated function $max[\cdot]$ ensures that LTC only enters the budget constraint once it is demanded and thus positive. Therefore, negative values for P_{LTC} are ruled out. Once individuals reach retirement age R, they receive a pension income τw, where τ denotes the replacement rate. For simplicity, we assume perfect annuity markets such that the effective interest rate is given by the sum of the rate of return on capital r and the instantaneous mortality rate $m = -\dot{S}/S$.

Summarizing, individuals maximize (1) with respect to (2), (3), (4), and the boundary conditions $D(0) = D_0$, $D(T) = \bar{D}$, $k(0) = k_0$, and $k(T) = \bar{k}$. The Hamiltonian associated with this maximization problem is given by

$$\mathcal{H} = S(D)U(c) + \lambda_D \mu(D - Ah^\gamma - a) + \lambda_k(w + (r+m)k - c - ph - q \cdot max[0, P_{min} - P_a(D)] \quad (5)$$

where λ_D and λ_k denote the shadow prices of deficits and capital, respectively. The transversality condition for the optimal control problem is given by $\mathcal{H}(T) = 0$. From the first-order conditions, we can derive the well known Euler equation for optimal consumption growth over the life cycle:

$$\frac{\dot{c}}{c} = \frac{r - \rho}{\sigma}. \quad (6)$$

Whether consumption rises or falls depends only on the relative size of the rate of return on capital r and the time preference rate ρ while the (inverse of the) intertemporal elasticity of substitution σ captures the degree of consumption smoothing. The optimal growth of medical care over time is given by

[3] One could also argue that personal care provides utility directly. One direct implication of this feature would be that rich individuals would demand more (or better) LTC. Since we consider a representative agent and thus do not have any source of income heterogeneity, we do not include personal care into the utility function. It could also be the case that relying on LTC provides disutility through the loss of autonomy. In order to flesh out the core mechanisms of the model, however, we keep it as simple as possible and neglect this feature as well.

$$\frac{\dot{h}}{h} = \begin{cases} \frac{(r+m)-\mu-\frac{1}{\lambda_D}S'(D)U(c)}{1-\gamma} & \text{for } P_{LTC}=0 \\ \frac{(r+m)-\mu-\frac{1}{\lambda_D}\left(\lambda_k q P_a'(D)+S'(D)\frac{\partial U(c)}{\partial c}\right)}{1-\gamma} & \text{for } P_{LTC}>0. \end{cases} \tag{7}$$

The first determinant of medical care expenditure growth is given by the relative size of the effective interest rate $r+m$ and the force of aging μ. Intuitively, if the benefit of delaying medical care $(r+m)$ is greater than the resulting harm of deficit accumulation (μ), individuals substitute present for future medical care and expenditure growth increases. The third term of Equation (7) unambiguously affects expenditure growth negatively. To see this, note that deficits are a "bad" rather than a "good" so that the associated shadow price λ_D is negative. Further, $P_a'(D) < 0$ and $S'(D) < 0$ follow by assumption. The economic explanation for this observation is twofold. First, the state of health enters life-time utility through the survival probability $S(D)$, implying that medical care not only increases expected life-time utility through a higher expected life time, but also through a higher (discounted) instantaneous utility stream through better health. This induces individuals to shift medical care to earlier life stages in order to lead an overall healthier life (the effect of $S'(D)$). The second effect sets in once individuals demand LTC. Individuals tend to substitute future for present medical care in order to counteract the rising and costly need for LTC (the effect of $P_a'(D)$). It is important to note that individuals understand that higher medical spending at younger ages delays the onset of LTC expenditure in old age. The effect of $P_a'(D)$ apparent in the lower part of Equation (7) is an additional effect which is triggered by the decreasing ability to carry out personal care autonomously which, once LTC is required, directly leads to higher cost for LTC. Finally, the curvature parameter of the health technology γ captures the degree of diminishing returns of health investments and thus affects the willingness to smooth health investments over the life cycle.

Our model is determined by the dynamic system consisting of Equations (2), (4), (6), and (7), together with the mentioned initial and final conditions as well as the transversality condition. Given that LTC depends on the amount of deficits accumulated, medical care directly affects expenditure for LTC. Higher medical spending slows down the accumulation of health deficits, which in turn delays the dependency on LTC and subsequently leads to lower LTC expenditure for any given age. Since the model cannot be solved analytically, we rely on numerical solution techniques to scrutinize the interplay between medical care and LTC.

3. Calibration

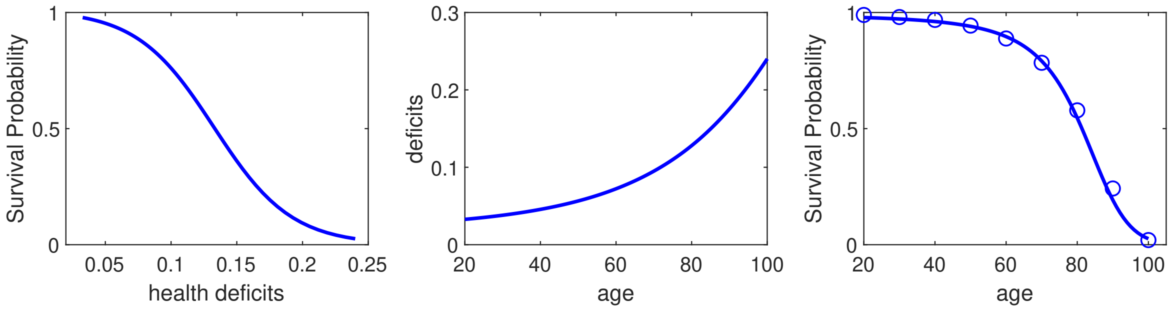
We calibrate the model to match health behavior and health outcomes for a reference U.S. American in the year 2012. We begin by explaining our calibration strategy for the survival function. As stated above, biologists emphasize that mortality does not depend directly on chronological age but only implicitly through the accumulated health deficits $D(t)$ (e.g. Arking, 2006). We conceptualize health deficits with the help of a study by Mitnitski et al. (2002a) who built a straightforward and well-established health deficit index, the so-called frailty index. In simple words, the index measures a share of deficits that an individual has accumulated from a potential set of health deficits. We take into account the biological understanding of mortality and assume that survival is directly determined by health deficits. As in Schünemann et al. (2017a) we assume that the survival probability is given by

$$S(D) = \frac{1+\omega}{1+\omega e^{\xi D}}. \tag{8}$$

Our parametrization of the survival function implies that the survival probability follows a logistic function which is one for the state of best health ($D = 0$) and approaches zero for high deficit levels (the first panel of Figure 1). Since we lack data on the association between health deficits and survival probability, we proceed as follows to calibrate the parameters of the survival function. First, we take up the study from Mitnitski et al. (2002a) who estimate a power-law association between the frailty index and age. Since the study estimates this association separately for men and women, we take as the relevant health deficit index the average of the health deficit index of men and women which is weighted according to their respective survival probabilities (the second panel in Figure 1). We then feed this relationship into Equation (8). This allows us to predict the association between age and survival probability which can be confronted with actual data from life tables (the third panel of Figure 1). The parameter values which provide the best fit to the data are given by $\omega = 0.11$ and $\xi = 34$. The dots in the last panel of Figure 1 indicate the data points from U.S. life tables for the year 2012 (NVSS, 2016), implying that the model predictions are fairly accurate.

With regard to the initial deficit level, we again rely on the frailty index by Mitnitski et al. (2002a). From their regression analysis, we can back out the average initial deficit level between men and women at age 20, the starting age of our model, which yields $D_0 = 0.0328$. We further assume that autonomous personal care declines with health deficits according to

Figure 1: Health-Dependent Survival and Survival by Age



Left Panel: Assumed survival function S(D), Middle panel: Estimated Association D(t) (Mitnitski et al., 2002a). Right panel: Predicted (line) and empirically observed (dots) association between age and survival probability (data from NVSS (2016)). Blue (solid) lines: men. Red (dashed) line: women.

$P_a(D) = E - BD$. Moreover, we set $\gamma = 0.2$ according to Schünemann et al. (2017b) and Hall and Jones (2007). From the Consumer Expenditure Survey (BLS, 2014), we calculate average wages and salaries in 2012 of single-person households younger than 65 (the retirement age R) which yields $w = 30324$. According to OECD (2013), we set the gross replacement rate to $\tau = 0.383$. As far as the interest rate is concerned, we set $r = 0.07$ according to Jorda et al. (2019). In order to confine the savings motive to consumption and health expenditure, we abstract from receiving and leaving bequests and set $k_0 = \bar{k} = 0$. Finally, we normalize the relative prices to $p = q = 1$.

We simultaneously calibrate the seven free parameters σ, ρ, μ, A, a, B, and $P_{min} - E$ to fit the following seven data moments: i) medical care expenditure at age 30, 50, 70, 90 (MEPS, 2012), ii) LTC expenditure at age 75, 93 (CMS, 2014)[4], and iii) a life expectancy at 20 of 59.6 years (i.e. death at 79.6) (NVSS, 2016). Finally, we adjust $\bar{D}$ such that the model provides a maximum lifespan of 100 years (according to De Nardi et al., 2016).

The parameter values for the best model fit are given in Table 1a while Table 1b summarizes the parameters which were set externally.

Table 1a: Calibration Results

σ	ρ	μ	A	a	$\bar{D}$	B	$P_{min} - E$
1.22	0.06	0.33	0.00125	0.011	0.23	16200	-14800

[4]LTC services refer to any services provided by professionals to individuals who need assistance with activities of daily living (ADL) and instrumental activities of daily living (IADL). We thus identify the following categories as LTC in the data: "'Nursing Care Facilities and Continuing Care Retirement Communities Spending"', "'Home Health Care Spending"', and "'Other Health Residential and Personal Care Spending"'. Since the data on medical spending from MEPS (2012) includes home health spending, we deduct this expenditure type from medical spending to avoid double accounting.

Table 1b: Externally Set Parameters

D_0	γ	w	r	p	q	τ
0.0328	0.02	30,324	0.07	1	1	0.383

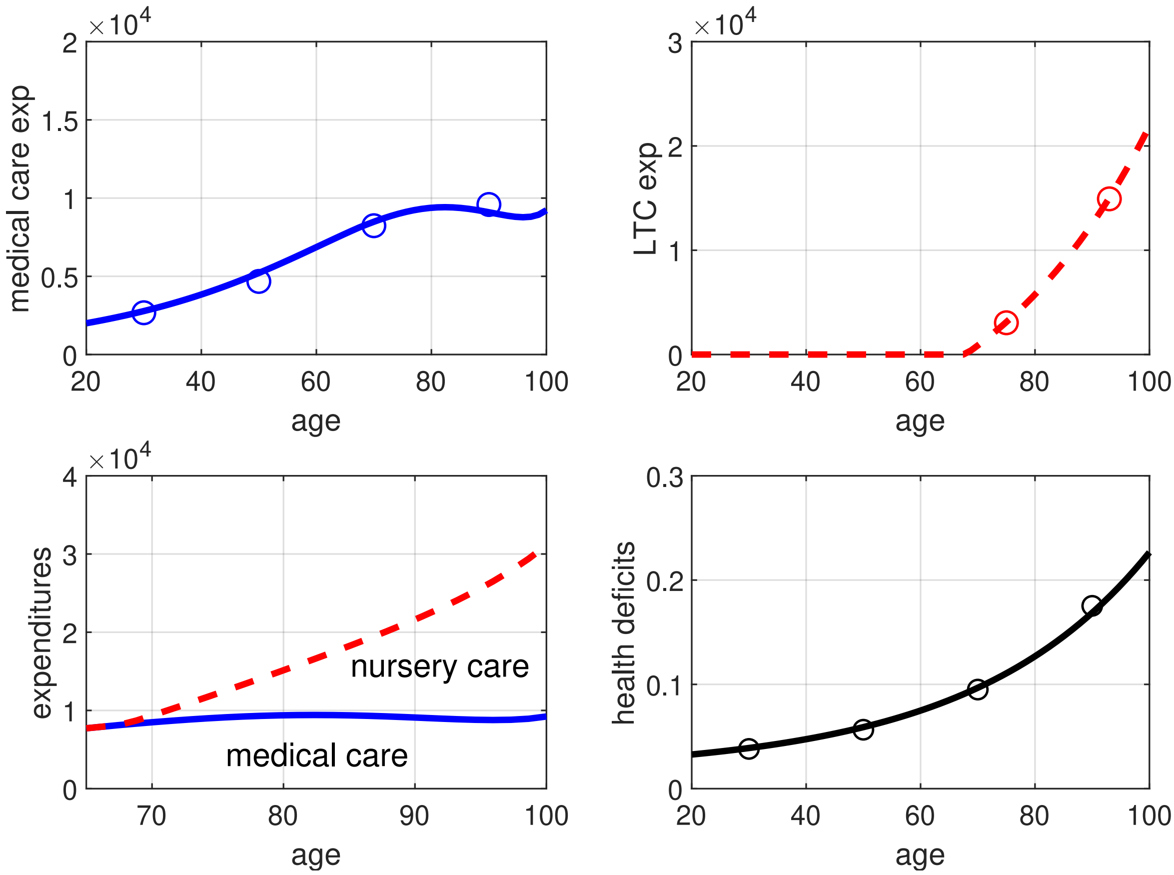
While some of the parameters are of latent nature and thus cannot be directly compared to the empirical literature, our value for σ is consistent with a study by Chetty (2006) who estimates the "'true"' values for σ to be close to unity. Our value for the force of aging μ implies that in the absence of any medical expenditure and environmental influences, the individual accumulates 3.3% new deficits from one year to another. This pooled estimate for men and women lies well in between the estimates in Mitnitski et al. (2002a) who report values of 0.31 for women and 0.43 for men. Further, our value for a fits well with the estimate in Dalgaard and Strulik (2014) of $a = 0.13$. We solve the model by numerically applying the relaxation method by Trimborn et al. (2008).

4. Results

Figure 2 shows the predicted life-cycle trajectories for the model variables of interest. The first panel shows medical care spending of the individual over the life course. The model fits the data points, as indicated by the dots, reasonably well. In particular, medical spending is increasing throughout most parts of life and flattens out around age 80. In contrast, LTC spending is virtually zero until age 70 and then rises exponentially for older ages. As the second panel illustrates, our model is also able to match LTC data in a satisfactory manner.

The third panel combines the first two panels and illustrates expenditure patterns for the population over 65, thereby replicating Figure 3 of De Nardi et al.'s (2016) study. The authors find that medical care spending for people over 80 starts to stagnate or even slightly decreases for some ages, implying that increasing health expenditure during theses ages is entirely driven by LTC expenditures. As can be seen in the third panel, our model is capable of capturing these exceptional disaggregated patterns in health spending. The fourth panel shows that, consistent with the findings of Mitnitski et al. (2002a), deficits accumulate exponentially over the life cycle. Note that although we only take the initial deficit level directly from the Mitnitski et al. study, our model matches the empirically observed health deficit index as indicated by the dots reasonably well.

Figure 2: Life-Cycle Trajectories: Benchmark Run



Dots indicate data points. Data for medical care spending are from MEPS (2010) and data on LTC spending are from CMS (2014). exp indicates expenditure.

5. The Future Cost of LTC

With the model at hand, we now predict the future cost of LTC. In particular, we are interested in the impact that better health and life expectancy have on expected per capita LTC spending. A priori, this effect is ambiguous as two counteracting mechanisms are triggered by an improving health status. On the one hand, through better health individuals start demanding LTC at later ages and thus exhibit lower dependency on LTC for given age which leads to a reduction of LTC spending. On the other hand, the resulting higher life expectancy and life span of the individual requires LTC on average until higher ages, thereby increasing expected LTC expenditures. We aim to investigate which of these effects quantitatively dominates by analyzing the impact of rising income and improving medical technology.

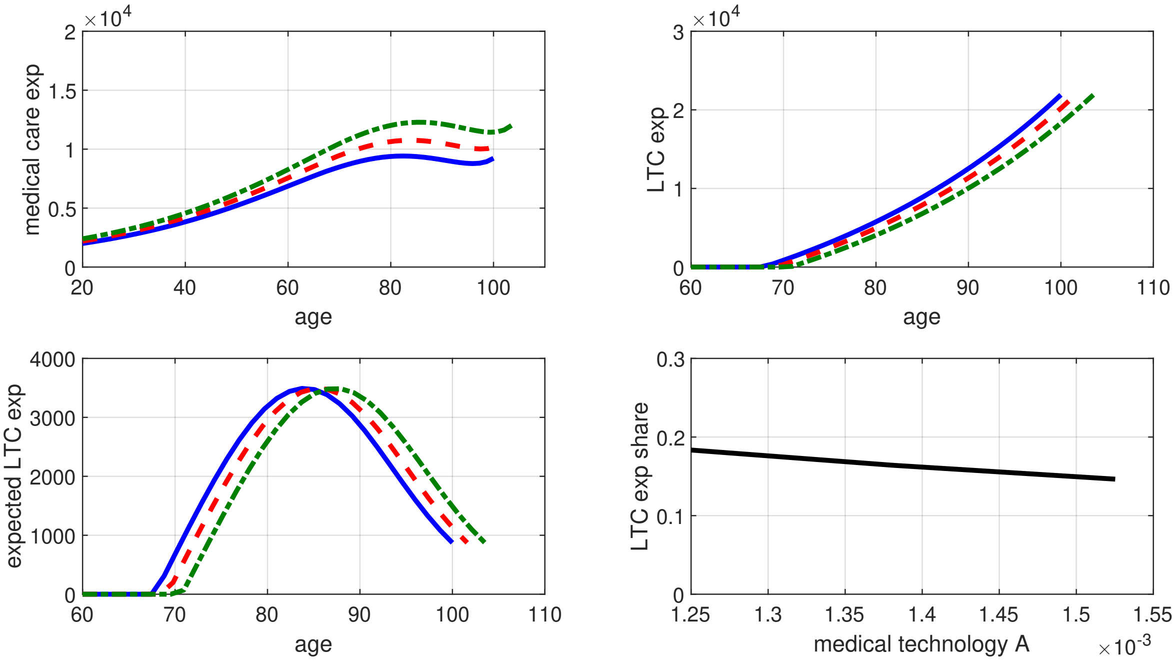
As a benchmark for the growth rate of wages (w in our model), we calculate the compound annual growth rate of average wages in the U.S. of the last 20 years from our baseline year

(2012). This procedure yields an annual growth rate of $\hat{w} = 1.21\%$ (OECD, 2019). With regard to medical technology, we fit the medical technology parameter A such that our model matches the average life expectancy at age 20 in the year 1992 of 56.9 years (VS, 1992), taking into account also the lower income level in that year. This gives a value of approximately $A = 0.00102$ which in turn implies an annual rate of medical progress of $\hat{A} = 1.00\%$. This value fits nicely with the result by Abeliansky et al. (2019) who – using the frailty index approach – estimate that white American men born between 1904 and 1966 experienced health deficit reducing medical progress at a rate of 1.30 percent per year (with a standard deviation of 0.18 percent). As a sensitivity check we will also consider lower and higher rates of income growth and technological progress in a comparative dynamic analysis.

5.1. **Improving Medical Technology.** Figure 3 shows the effect of medical technological progress on medical care expenditures (first panel), LTC expenditures (second panel), expected LTC expenditures, i.e. LTC expenditures adjusted by the survival rate (third panel), and the share of LTC expenditures in total health expenditures (fourth panel). Blue (solid) lines represent the benchmark run from Figure 2. Red (dashed) lines show results after 10 years, green (dash-dotted) lines after 20 years of technological progress of 1.00% per year. It should be noted that the individual still faces a constant health technology A in all three runs. When solving the model after 10 (20) years of technological progress, however, the individual experiences a (constant) level of A that has increased for 10 (20) years by 1.00% from the benchmark run. In other words, the individual faces a health technology of $A = 0.0125$ in the benchmark run and $A = 0.0125 * 1.01^{10}$ ($A = 0.0125 * 1.01^{20}$) when he solves the life cycle 10 (20) years after technological progress.

Due to technological advances in curing and preventing health deficits, people spend more on medical care since the marginal return to medical care increases. In other words, the higher productivity of medical treatment triggers a substitution effect towards medical care. Through the combined effect of greater efficacy and higher utilization of medical care, people accumulate deficits more slowly and are thus healthier at any given age. This enables them to carry out personal care autonomously until higher ages such that the age at which individuals first require LTC increases accordingly. As can be seen in the second panel of Figure 3, the age of first demanding LTC increases from 68.8 to 69.8 (71.0) years after 10 (20) years of technological progress. In the aftermath, LTC expenditure remains lower in the high-technology regimes because individuals stay healthier at any given age and need less support. This effect, taken for itself, reduces the cost of LTC in the future.

Figure 3: Improving Medical Technology and Health and LTC



Blue (solid) lines reiterate the benchmark run. Red (dashed) lines show results after 10 years, green (dash-dotted) lines after 20 years of medical technological progress of 1.00 % per year. exp indicates expenditure.

On the other hand, the fact that people exhibit better health through medical progress increases their life expectancy. The calibrated model predicts that life expectancy at 20 increases from 59.6 to 61.0 (62.7) years due to the experience of 10 (20) years of technological progress. This in turn increases the average age until people require LTC. This effect, taken for itself, increases expenditure for LTC.

Multiplying LTC expenditure by the survival rate yields for any given age the expected LTC expenditure. The third panel of Figure 3 shows the associated trajectories for the three different scenarios. Expected LTC expenditure exhibits an inverse u-shaped profile. The dominating effect on the rising part of the trajectories is that people demand more LTC as they age. After a certain point, this mechanism is balanced out by the fact that the survival probability declines more and more. With improving medical technology and the associated improvements in health and life expectancy, the peak of expected LTC expenditures moves to higher ages. This finding is qualitatively consistent with the seminal Red Herring Hypothesis stated by Zweifel et al.

(1999). The authors argue that increasing life expectancy is neutral for health care costs as age per se does not affect health expenditure once time to death is controlled for. Instead, the bulk of health expenditure is simply shifted to higher age groups in the population as mortality decreases. We see a similar picture when we look at the impact of technological advancement on expected LTC expenditures. As individuals become healthier, the peak of expenditures moves from approximately 84 years to around 86 (88) years after 10 (20) years of medical progress. In contrast to the Red Herring Hypothesis, however, we find that this shift of expenditures is not entirely neutral for expected LTC expenditures. The first column of the upper part of Table 2 shows the net effect for total expected LTC expenditures, i.e. the sum of the expected LTC expenditures over the life cycle. All numbers represent percentage deviations from the benchmark run. Our model predicts a 0.80% (1.87%) increase after 10 (20) years of technological progress. In other words, our projections suggest that the effect of higher life expectancy on LTC expenditures mildly dominates the effect of later demand for LTC.

Table 2: Evolution of Expenditures: Improving Medical Technology

case	exp LTC (PV)	exp medical (PV)	exp total (PV)	share LTC (PV)	life expectancy
$\hat{A} = 0.01$					
10 years	0.80 (-11.2)	15.4 (10.8)	12.7 (10.7)	-10.6 (-19.8)	2.38
20 years	1.87 (-21.2)	33.4 (22.0)	27.6 (22.0)	-20.2 (-35.4)	5.23
$0.5 * \hat{A}$					
10 years	0.38 (-5.57)	7.40 (5.33)	6.11 (5.31)	-5.40 (-10.3)	1.14
20 years	0.80 (-11.2)	15.4 (10.8)	12.7 (10.8)	-10.6 (-19.8)	2.39
$2 * \hat{A}$					
10 years	1.86 (-21.1)	33.2 (22.0)	27.5 (21.8)	-20.0 (-35.2)	5.20
20 years	4.32 (-45.1)	82.0 (46.2)	67.8 (46.0)	-37.8 (-62.4)	12.9

All values as percentage deviation from the benchmark run in the year 2012. exp LTC, exp medical, and exp total refer to expected LTC expenditure, expected medical care expenditure, and expected total health expenditure, respectively. share LTC refers to the share of LTC expenditure in total health expenditure. PV refers to present value.

The second column shows that the relative change in expected medical care expenditure is of considerably greater magnitude, indicating an increase of 15.4% or 33.4% depending on the time horizon. This implies a change in total health expenditure of 12.7% or 27.6%. As a result, the share of LTC expenditure in total health expenditure decreases by 10.6% or 20.2% as can be seen in the fourth column and in the fourth panel of Figure 3. The last column shows that life expectancy increases by 2.38% or 5.23% through medical progress, implying that the increase in life expectancy is of higher magnitude than the relative increase in expected LTC expenditure. This finding is consistent with our argument that the effect of higher life expectancy on expected LTC expenditure is partly compensated by the effect of better health and thus later demand for LTC. Interestingly, the ratio between the relative increase in LTC expenditure and life expectancy stays considerably constant over time. Both after 10 and 20 years of medical progress, a 1% increase in life expectancy is associated with a 1/3% increase in expected LTC expenditure.

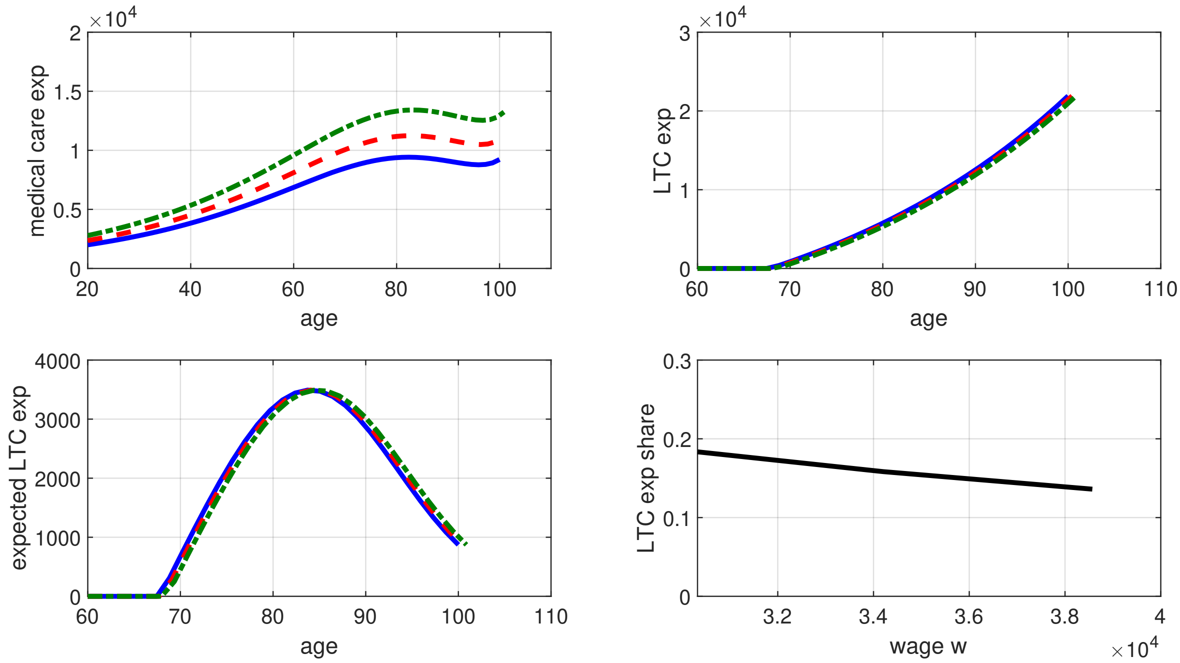
This picture changes, however, when considering the present value of expected LTC cost. The values in parentheses show the respective relative change in costs when expenditures are discounted by the effective interest rate $(r + m)$ to the beginning of the individual's life cycle. As the table shows, the present value of expected LTC expenditure decreases by 11.2% (21.2%) after 10 (20) years of technological progress. The reason for this results can be readily seen in the third panel of Figure 3. As expected LTC expenditures are shifted to higher ages, their present value declines. This capital market effect leads to a reduction in expected costs. Specifically, a one-percent increase in life expectancy is approximately associated with a 4-5% decrease in the present value of expected LTC expenditure. When looking at column 2, the table implies that calculating the present value also reduces the increase in expected medical expenditure to 10.8% or 22.0% . The same explanation as in the case of LTC expenditure also applies here. The first panel of Figure 3 shows that medical expenditure increases relatively more for higher ages through technological progress, implying that the bulk of the increase in medical care is discounted more heavily. As a consequence, the predicted increase in total health expenditure declines to 10.7% or 22.0%.

In order to illustrate the impact of different rates of medical progress, we conduct a comparative analysis with regard to the growth rate $\hat{A}$. Specifically, in Table 2 we show the results for both halving and doubling the rate of medical progress. As can be seen in the table, the effects described above increase in the rate of technological progress. In particular, moving from the lowest to the highest rate considered here, the relative increase in expected LTC expenditure rises from 0.38% (0.80%) to 1.86% (4.32%), while the relative change in life expectancy increases from 1.14% (2.39%) to 5.20% (12.9%) after 10 (20) years of technological progress. Again, the ratio between the relative increase in expected LTC expenditure and life expectancy remains remarkably constant at 1/3 in any case considered. As far as the present value of LTC expenditure is concerned, we find throughout that a 1% increase in life expectancy is associated with a 4-5% decrease in spending.

5.2. **Rising Income.** Figure 4 shows results for a similar experiment in which we analyze the effect of income growth of 1.21% after 10 and 20 years. Again, the individual still faces a constant wage rate w in all three runs. When solving the model after 10 (20) of income growth, however, the individual experiences a (constant) level of w that has increased for 10 (20) years by 1.21% from the benchmark run. Therefore, the individual faces a wage rate of $w = 30,324$ in the benchmark run and $w = 30,324 * 1.01^{10}$ ($w = 30,324 * 1.01^{20}$) when he solves the life cycle 10 (20) years following income growth.

The effects are qualitatively similar to those from advancing medical technology, though somewhat lower in magnitude. As a result to higher income, individuals spend more on medical care. Medical care also rises relative to consumption. The reason is that life-time utility is concave in per-period consumption but linear in longevity. When income increases, individuals spend a lower share on per-period consumption because decreasing marginal utility sets in more quickly while they spend a higher share on medical care.

Figure 4: Rising Income



Blue (solid) lines reiterate the benchmark run. Red (dashed) lines show results after 10 years, green (dash-dotted) lines after 20 years of wage growth of 1.21 % per year. exp indicates expenditure.

As stated already for the case of technological progress, better health induces individuals to start demanding LTC at higher ages while the resulting higher life expectancy makes them more likely to demand LTC until higher ages. The first column in the upper part of Table 4 shows the net effect on expected LTC expenditures. According to our model predictions, expected LTC spending increases by 0.21% (0.43%) after 10 (20) years of income growth relative to the benchmark run. Since expected medical care expenditures increase to a much higher degree (19.7% or 43.2%), expected total health expenditure increase by 16.1% or 35.4%. As a result, the share of LTC expenditure in total health expenditure declines. Although the increase in medical expenditure is more pronounced under income growth than under technological progress, the impact on life expectancy is more modest (0.63% or 1.29%). The reason is that although in both regimes people spend more on medical care, under medical progress medical care becomes additionally more efficient.

As we have already seen before, discounting the different expenditure types reduces the relative change in expected medical care and LTC spending and, in the case of expected LTC expenditures, leads to a reduction in costs. We also report results for halving and doubling

Table 3: Evolution of Expenditures: Rising Income

case	exp LTC (PV)	exp medical (PV)	exp total (PV)	share LTC (PV)	life expectancy
$\hat{w} = 0.0121$					
10 years	0.21 (-3.08)	19.7 (18.4)	16.1 (18.4)	-13.7 (-18.1)	0.63
20 years	0.43 (-6.27)	43.2 (40.2)	35.4 (40.1)	-25.8 (-33.1)	1.29
$0.5 * \hat{w}$					
10 years	0.11 (-1.53)	9.43 (8.86)	7.72 (8.84)	-7.06 (-9.53)	0.31
20 years	0.21 (-3.09)	19.7 (18.5)	16.2 (18.5)	-13.7 (-18.2)	0.63
$2 * \hat{w}$					
10 years	0.43 (-6.23)	42.9 (39.9)	35.1 (39.8)	-25.7 (-25.7)	1.28
20 years	0.91 (-12.2)	104 (94.6)	84.7 (94.4)	-45.4 (-54.9)	2.67

All values as percentage deviation from the benchmark run in the year 2012. exp LTC, exp medical, and exp total refer to expected LTC expenditure, expected medical care expenditure, and expected total health expenditure, respectively. share LTC refers to the share of LTC expenditure in total health expenditure. PV refers to present value.

the rate of income growth. As Table 3 illustrates, the effects increase in the rate of income growth. Comparing the lowest to the highest rate, the relative change in expected LTC expenditure increases from 0.11% (0.21%) to 0.43% (0.91%) after 10 (20) years of income growth. In all specifications, the ratio between the relative increase in expected LTC expenditure and life expectancy remains constant at 1/3 as already observed in the case of medical progress, while in present value terms the ratio stays between -4% and -5%.

5.3. **Improving Medical Technology and Rising Income.** In order to wrap up the results, we also show the benchmark implications of the model for medical progress combined with income growth. The results are shown in Table 4.

Table 4: Evolution of Expenditures: Improving Medical Technology and Rising Income

case	exp LTC (PV)	exp medical (PV)	exp total (PV)	share LTC (PV)	life expectancy
$\hat{A} = 0.01, \hat{w} = 0.0121$					
10 years	1.09 (-13.8)	37.7 (30.6)	31.0 (30.5)	-22.8 (-34.0)	3.12
20 years	2.51 (-27.4)	91.3 (69.7)	75.0 (69.5)	-41.4 (-57.2)	7.07

All values as percentage deviation from the benchmark run in the year 2012. exp LTC, exp medical, and exp total refer to expected LTC expenditure, expected medical care expenditure, and expected total health expenditure, respectively. share LTC refers to the share of LTC expenditure in total health expenditure. PV refers to present value.

Combining medical progress and income growth does not change the main results of the experiment. A 1% increase in life expectancy is still associated with a 1/3% increase in expected LTC expenditures and a 4-5% decline in the present value of expected LTC expenditures. Compared to the change in medical care, the change in LTC is rather modest (or even in the opposite direction), since better health of the individual and thus lower dependency on LTC for given age counteracts the cost-increasing effect of rising life expectancy.

6. Conclusion

In this paper, we proposed a gerontologically founded life-cycle model of human aging in which we studied the interplay between medical care and LTC over the life-cycle. We calibrated the model to a reference American in the year 2012 and analyzed the impact of better health and increasing life expectancy, triggered by rising income and medical technological advancements, on expected LTC expenditure. Projecting the future evolution of income and technology, we found that each percentage increase in life expectancy is associated with 1/3 percentage point increase in expected LTC spending. Compared to the increase in medical care spending, however, the increase in LTC spending is expected to be moderate since, for given age, the level of dependency on LTC reduces with better health. This effect partially offsets the cost-increasing effect of higher life expectancy. Discounting expected LTC spending to the beginning of the individual's life cycle showed that the present value of expected LTC expenditure can be expected to decline in the future as LTC expenditures tend to be shifted to higher ages with improving health status.

Our model of medical care and LTC can be extended in various directions. One natural extension could analyze the demand for LTC when personal care is partially provided by the family. Given that women on average outlive their male partners, the provision of informal care by spouses may have interesting effects on the gender-specific demand for LTC.

References

Abeliansky, A., Erel, D., and Strulik, H. (2019). Aging in the USA. cege Discussion Paper 384, University of Goettingen.

Arking, R. (2006). *The Biology of Aging: Observations and Principles*, Oxford University Press, Oxford.

Bannenberg, N., Karlsson, M., Schmitz, H. (2019). The Economics of Long-Term Care, *Oxford Research Encyclopedia of Economics and Finance*

Blodgett, J. M., Theou, O., Howlett, S. E., Wu, F. C., and Rockwood, K. (2016). A frailty index based on laboratory deficits in community-dwelling men predicted their risk of adverse health outcomes. *Age and Ageing* 45(4), 463-468.

BLS (2014). Consumer Expenditure Survey. U.S. Bureau of Labor Statistics, September 2014.

Chetty, R. (2006). A new method of estimating risk aversion. *American Economic Review* 96, 1821-1834.

Chernew, M. E. and Newhouse, J. P. (2011). Chapter One - Health Care Spending Growth. *Handbook of Health Economics* 2, 1-43.

CMS (2014), Center for Medicare and Medicaid Services. Age and Gender Estimates in the National Health Expenditure Accounts(`https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/Age-and-Gender.html`)

Comas-Herrera, A., Wittenberg, R., Costa-Font, J., and Gori, C. (2006). Future long-term care expenditure in Germany, Spain, Italy and the United Kingdom, *Ageing and Society* 26(2), 285-302.

Cremer, H., Pestieau, P., and Ponthière, G. (2012). The economics of Long-Term-Care: A survey. *Nordic Economic Policy Review* 2, 107-148.

Dalgaard, C-J. and Strulik, H. (2014). Optimal aging and death: Understanding the Preston Curve, *Journal of the European Economic Association* 12, 672-701.

Dalgaard, C-J. and Strulik, H. (2017). The genesis of the golden age: Accounting for the rise in health and leisure. *Review of Economic Dynamics* 24, 132-151.

De Nardi, M., French, E., Jones, J.B., and McCauley, J. (2016). Medical spending of the US elderly. *Fiscal Studies*, 37(3-4), 717-747.

Di Matteo, L. (2005). The macro determinants of health expenditure in the United States and Canada: assessing the impact of income, age distribution and time. *Health Policy*, 71(1), 23-42.

EC (2018). The 2018 Ageing Report by the European Commission: Economic and Budgetary Projections for the EU Member States (2016-2070) . *Institutional Paper 079.*

Grossmann, V. and Strulik, H. (2019). Optimal Social Insurance and Health Inequality. *German Economic Review*, forthcoming.

Hall, R.E. and Jones, C.I. (2007). The value of life and the rise in health spending. *Quarterly Journal of Economics* 122, 39–72.

Hosseini, R., Kopecky, K. A., and Zhao, K. (2019). The Evolution of Health over the Life Cycle. Federal Reserve Bank of Atlanta, Working Paper Series, Working Paper 2019-12.

Jorda, O., Knoll, K., Kuvshinov, D., Schularick, M., and Taylor, A.M. (2019). The rate of return on everything, 1870–2015. *Quarterly Journal of Economics* 134(3), 1225-1298.

Karlsson, M., Mayhew L. and Plumb, R. and Rickayzen, B. (2006). Future costs for long-term care: Cost projections for long-term care for older people in the United Kingdom. *Health Policy* 75(2), 187-213.

MEPS (2012), U.S. Department of Health & Human Services. Center for Financing, Access and Cost Trends, Agency for Healthcare Research and Quality: Medical Expenditure Panel Survey, 2012 (`https://meps.ahrq.gov/mepsweb/data_stats/quick_tables_results.jsp?component=1&subcomponent=0&year=-1&tableSeries=1&searchText=&searchMethod=1&Action=Search`)

Mitnitski, A.B., Mogilner, A.J., MacKnight, C., and Rockwood, K. (2002a). The accumulation of deficits with age and possible invariants of aging. *Scientific World* 2, 1816-1822.

Mitnitski, A.B., Mogilner, A.J., MacKnight, C., and Rockwood, K. (2002b). The mortality rate as a function of accumulated deficits in a frailty index. *Mechanisms of ageing and development* 123, 1457-1460.

Norton, E.C. (2016). Health and long-term care. *Handbook of the Economics of Population Aging* 1B, 951-989.

NVSS (2016). US department of health and human services, national vital statistics system. National Vital Statistics Report 65(8).

OECD (2013), Gross Pension Replacement Rates. *Pensions at a Glance 2013: OECD and G20 Indicators*, OECD Publishing, Paris.

OECD (2019), Average wages (indicator). doi: 10.1787/cc3e1387-en (Accessed on 15 July 2019)

Rockwood, K., Mitnitski, A., Song, X., Steen, B., and Skoog, I. (2006). Long-term risks of death and institutionalization of elderly people in relation to deficit accumulation at age 70. *Journal of the American Geriatrics Society* 54(6), 975-979.

Schünemann, J., Strulik, H., Trimborn, T. (2017a). Going from bad to worse: Adaptation to poor health, health spending, longevity, and the value of life. *Journal of Economic Behavior and Organization*, 140, 130-146.

Schünemann, J., Strulik, H., Trimborn, T. (2017b). The gender gap in mortality: How much is explained by behavior?. *Journal of Health Economics*, 54, 79-90.

Schünemann, J., Strulik, H., Trimborn, T. (2020). The marriage gap: Optimal aging and death in partnerships. *Review of Economic Dynamics*, forthcoming.

Schünemann, J., Strulik, H., Trimborn, T. (2019). Anticipation of deteriorating health and information avoidance. Center for European, Governance and Economic Development Research Discussion Papers 365, University of Goettingen, Department of Economics.

Spillman, B. C. and Lubitz, J. (2000). The Effect of Longevity on Spending for Acute and Long-Term Care. *The New England Journal of Medicine* 342 (19), 1409-1415.

Stabile, M., Laporte, A., and Coyte, P.C. (2006). Household responses to public home care programs. *Journal of Health Economics* 25 (4), 674-701.

Trimborn, T., Koch, K.-J. and Steger, T.M. (2008). Multidimensional transitional dynamics: A simple numerical procedure. *Macroeconomic Dynamics* 12, 301–319.

VS (1992). US department of Health and Human Services, Public Health Service. Vital Statistics of the United States: Life Tables Volume II, Section 6.

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Abstract
For the population over 65, long-term care (LTC) expenditure constitutes a considerable share in total health expenditures. In this paper, we distinguish between medical care, intended to improve one›s state of health, and personal care required for daily routine. Personal care can be either carried out autonomously or by a third party. In the course of aging, autonomous personal care is eventually substituted by LTC. We set up a life-cycle model in which individuals are subject to physiological aging, calibrate it with data from gerontology, and analyze the interplay between medical care and LTC. We replicate health behavior and life expectancy of individuals and in particular the empirically observed patterns of medical care and LTC expenditure. We then analyze the impact of better health and rising life expectancy, triggered by rising income and improving medical technology, on the expected cost of LTC in the future. We predict an elasticity of LTC expenditure with respect to life expectancy of 1/3. In terms of present value at age 20, life-time LTC expenditure is predicted to decline with rising life expectancy.

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