Why Do Americans Spend So Much More on Health Care than Europeans?*

by Hui He, Kevin X.D. Huang, and Lei Ning[1]

IMF and SAIF; Vanderbilt; SUFE

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Abstract

Empirical evidence shows that both leisure and medical care are important in maintaining health and taxation may affect the allocation of these two inputs. We highlight this point using an analytical setting whose implications conform to micro and macro data. We then quantify these implications using a life-cycle overlapping-generations model where taxation and relative health care price are key determinants of the composition of the two inputs in the endogenous accumulation of health capital. We find that differences in taxation alone explain 44.7% of US-EU differences in health expenditure-GDP ratio and more than 70% of their differences in time allocation.

JEL classifications: E2; E6; H2

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1 Introduction

In the past 30 years or so, Americans have persistently spent much more on medical care than Europeans have. In one account, the average medical expenditure to GDP ratio over the period 1990-2015 is about 5.7 percentage points higher in the United States than the average across seven comparably rich European countries, including: Finland, France, Germany, Italy, Netherlands, Spain, and the United Kingdom, as shown in the first column of Table 1. Medical expenditure per capita is also much greater in the United States than in Europe. The differences in health care expenditure between the United States and Europe illustrated above are not

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attributed to the US-EU differences in expenditure on health-related research and development, or to differences in expenditure on education and training of health personnel.[1] There also do not seem to exist notable cross-country differences in the age structure of population or age-related health status, to which the reported US-EU differences in health care expenditure can be attributed (e.g., Anderson and Hussey 2000; Gerdtham and Jonsson 2000; Peterson and Burton 2007; Pearson 2009; Squires 2012). This is consistent with the finding that health care expenditures are higher in the United States than in many of the European countries not only on aggregate but also within different age groups.[2] In addition, the differences do not seem to be driven by greater supply or utilization of hospitals and doctors in the United States

[1] According to the Organization for Economic Co-operation and Development (OECD), total health care expenditure is defined as the sum of expenditures on activities that – through application of medical, paramedical, and nursing knowledge and technology – have the goals of: 1) Promoting health and preventing disease; 2) Curing illness and reducing premature mortality; 3) Caring for persons affected by chronic illness who require nursing care; 4) Caring for persons with health-related impairments, disability, and handicaps who require nursing care; 5) Assisting patients to die with dignity; 6) Providing and administering public health; and 7) Providing and administering health programmes, health insurance, and other funding arrangements. This definition does not include expenses on education and training of health personnel, research and development in health, food, hygiene and drinking water control, and environmental health. See http://stats.oecd.org/index.aspx for details.

[2] See, for example, Hagist and Kotlikoff (2009) for the European countries, and Jung and Tran (2014) for the United States. See, also, Table 2 in Anderson and Hussey (2000).

(Squires 2012).

Then why do Americans spend so much more on health care than Europeans? We highlight a channel that has not received much attention in the literature on health care costs through the lens of a life-cycle overlapping-generations (OLG) model of health investment portfolio. We emphasize two forms of health investment: (1) medical goods and services, which are the usual focus in the economics literature and policy debate, and (2) health-enhancing leisure-time activity, which has received much less attention, even though, as we show below, ample empirical evidence reveals its importance in producing and maintaining health. The thesis of this paper is that these two inputs for health production must be jointly determined and that cross-country variations in the determinants of such portfolio composition of health investment can hold a key to understanding the cross-country differences in health care expenditure.

We show that one determinant of the composition of the health investment portfolio is taxation, in particular, labor income and consumption taxes; higher rates of these would lead to using relatively more leisure time in maintaining health and in enhancing utility while spending less time on paid work. On the other hand, less medical care would be used in health investment with higher tax rates on labor income and on medical goods and services but with a lower tax rate on non-medical consumption. Whereas labor income taxes are relevant for the working-age population, consumption taxes matter for both workers and retirees. We highlight this taxation channel using an analytical setting whose implications are consistent with micro and macro data, and we quantify the importance of this channel using our life-cycle OLG macro-health model.

The crucial and relevant fact, then, is that for the same period that Europeans spend much less on health care than Americans, labor income and consumption tax rates are significantly higher in Europe than in the United States, as we document in Section 3. We find that this difference in taxation may account for 44.7% of the difference in the medical expenditure-GDP ratio between the United States and Europe.

This account of the US-EU difference in medical expenditure is accompanied by a simultaneous prediction of our model on cross-country difference in leisure time input as another component of an optimal health investment portfolio. We wish to emphasize from the outset that this portfolio view of health investment is essential for our model's success stated above. Were we to abstract time input from health production, as we will show below through a counterfactual experiment (Section 7.4), the model's performance in helping account for cross-country differences in health expenditures would deteriorate by 18.3%.

The important question, then, is whether our model's prediction on cross-country difference in time input for health production has any empirical support. Our analytical setting predicts that, for two economies that are identical in all other aspects, the one with higher labor and consumption tax rates would see more leisure time devoted to maintaining health. Since labor and consumption tax rates are higher in Europe than in the United States, this suggests that, everything else being equal, Europeans would invest more leisure time than Americans when it comes to maintaining health. As we will show in Section 3, this is indeed what is observed from micro data on health-enhancing leisure time, whether broadly or narrowly defined. According to our quantitative model, the US-EU difference in taxation may help account for 79.4% of their difference in broadly defined health-enhancing leisure time, while it explains 3.3% of the US-EU difference in narrowly defined health-enhancing leisure time.

These suggest that difference in taxation may help provide a coherent account of the US-EU differences in the composition of the health investment portfolio.

Another factor that may also affect the health investment portfolio in an important way is the price of health care goods and services relative to the general price level. As we document in Section 3, relative health care price on average is higher in the United States than in Europe. In fact, such cross-country difference in relative health care price is often thought of as contributing significantly to the higher overall health spending by Americans than by Europeans (e.g., Squires 2012, Horenstein and Santos 2019). It is thus also fitting to examine the relative health care price effect viewed through the lens of our model on health investment portfolio.

There are two countervailing effects of a higher relative price of medical care on overall health spending: (1) higher spending per unit of medical consumption, and (2) substitution away from medical care towards other goods or leisure in generating utility and toward time investment for maintaining health. As we will show below, in our quantitative simulations, the effect of (1) dominates that of (2), but is largely offset by the latter. That is, the contribution of a higher relative health care price to higher overall health expenditure is significantly weakened by the rebalancing of the health investment portfolio. Moreover, this rebalancing implies that a higher relative health care price would lead to using relatively more time input for maintaining health, which again weakens the power of the cross-country difference in relative health care price in explaining the US-EU difference in time allocation.

When we turn to the US-EU differences in taxation and in relative health care price at the same time, our model can account for 60.2% of their differences in overall medical expenditure-GDP ratio and more than 80% of their difference in general time allocation, although the model's explanatory power on narrowly defined health-enhancing leisure time remains small at 6.2%.

A caution shall be issued in drawing inferences from our quantitative results for cross-country comparisons. We begin our quantitative exercises by constructing and calibrating our baseline life-cycle OLG macro-health model to the US economy. We then replace the US tax rates or relative health care price, or both, with their European counterparts, while keeping other parameters and model features as in the baseline. Differences in the equilibrium values of the variables of interest across the baseline model and its variants so constructed are compared against cross-country differences in these variables observed from the data. The contrasts between these cross-model differences and observed cross-country differences should be interpreted in a manner that is consistent with the nature of such quantitative exercises.

For instance, were the US tax rates on labor income and consumption (of both medical and non-medical goods and services) in the baseline model replaced by their French counterparts, then our model-produced health expenditure-GDP ratio would be 2.19% lower, the fraction of time spent on paid work would be 2.23% lower, the fraction of time spent on potentially health-enhancing leisure activity would be

1.55% higher, and fraction of time devoted to narrowly defined health-enhancing leisure activity would be 0.07% higher. In our cross-country data set, the health expenditure-GDP ratio is 4.27% lower, the fraction of time spent on paid work is 7.00% lower, the fraction of time spent on potentially health-enhancing leisure activity is 4% higher, and the fraction of time devoted to narrowly defined health-enhancing leisure activity is 0.27% higher in France than in the United States. The cross-model differences account for respectively 51.3%, 31.9%, 38.8%, and 23.6% of the cross-country differences. This suggests that, were the United States to adopt the French tax code, *while keeping all of its other institutional features as they are*, we could see changes in the respective variables of interest amounting to significant portions of the observed US-France differences in these variables. It is only in this sense do we say that the US-France differences in taxation may help account for their differences in medical expenditure and allocation of time pertaining to health production. Results from our other quantitative exercises concerning cross-country comparisons should be interpreted in a similar manner.

The remaining of the paper proceeds as follows. In Section 2, we review related literature that motivate our current study. In Section 3, we describe the data sources and provide motivating empirical evidence to link taxation, health expenditures, and time allocation in a cross-country context. In Section 4, we use an analytical setting to highlight the paper's main messages and provide supporting evidence to the main mechanism derived from the analytical setting. In Section 5, we build our large-scale life-cycle OLG macro-health model and present the definition of equilibrium. In Section 6, we detail the calibration of our baseline quantitative model to the US economy. In Section 7, we conduct our quantitative exercises using this baseline model along with its variants where we report our main results in terms of their implications for cross-country comparisons, and where we also highlight the importance of modeling time allocation pertaining to health production. We provide additional sensitivity analysis in Section 8, and we offer some concluding remarks in Section 9. Some technical details and measurement descriptions are relegated to the appendices.

2 Related Literature

The point of departure of our analysis in this paper is to recast the issue of health care costs as a general equilibrium problem regarding the choice of health investment portfolio, of which the two crucial components are medical consumption and health-enhancing leisure-time activity. The idea that not only medical commodity but also leisure time are critical health inputs has been envisioned in several classic writings, such as Grossman (1972), Gronau (1977), and Ruhm (2000), which are accompanied by many supporting empirical studies. One such empirical investigations is conducted by Sickles and Yazbeck (1998). Using a structural model to control for endogeneity and reverse causality, these authors estimate a trans-log production function of health, with both leisure time and medical commodity as inputs, based on US time series data. Their finding is that both inputs make significantly positive contributions to producing and maintaining health.[3] A recent econometric study by

[3] Corroborating evidence has also been found by Kenkel (1995), Contoyannis and Jones (2004), Scholz and Seshadri (2010), and Insler (2014), among others.

He, Huang, and Hung (2013) also presents consistent empirical evidence based on multicountry data.

Empirical evidence on the significant contribution of certain leisure categories to good health can also be found in the literatures of biomedical science, public health, psychobiology, and biosociology. While most of such studies in these literatures focus on identifying separately the specific health benefits of individual leisure activities,[4] some of them also show the evidence that increases in leisure-time activities help reduce medical expenditures (e.g., Colditz 1999; Pratt *et al.* 2000; Wang and Brown 2004; Brown *et al.* 2005). The recent study by Pressman *et al.* (2009) establishes a general positive link between a wide variety of leisure activities (e.g., having hobbies, playing sports, socializing, spending time unwinding, spending time in nature, visiting friends or family, going on vacation, going to clubs or religious events) and a broad spectrum of health benefits (e.g., lower blood pressure, waist circumference, body mass index, and cortisol measurements, lower levels of stress and depression, stronger and better social networks, better feelings of satisfaction and engagement in lives, better sleep, better physical function and mood). Caldwell (2005), Russell (2009), and Payne *et al.* (2010) provide a comprehensive review of the empirical evidence on the importance of leisure in achieving and maintaining good health, and an

[4] For example, leisurely walking or cycling, exercising, vacationing, spending time in nature, engaging in social activities, having hobbies, proper sleep hygiene, and restorative activities have all been independently shown to improve physical, mental, social, or cognitive health. See He and Huang (2013) for a list of references.

intuitive account of the prevention, coping, and transcendence mechanisms through which leisure enhances physical, mental, social, and cognitive health.[5]

A large body of literature documents cross-country differences between the United States and Europe in health inputs and health output such as objective health status (e.g., disease incidence, disease prevalence, mortality rate, and life expectancy) and self-reported health (Banks *et al.* 2010), including those studies cited in the introduction. This literature is mainly empirical and serves as an important motivation of our current paper. We tackle our research questions using a structural model in a general equilibrium framework, rather than relying on reduced form regressions. This permits us to quantify the contributions of different factors in shaping the cross-country differences in medical expenditures, as well as in the allocation of time pertaining to health production, using counterfactual approaches in a structural manner. We also wish to point out from the outset that our main focus in the present paper is on understanding the US-Europe differences in health inputs, not on the output.[6]

Some recent studies suggest various cultural and institutional differences between the United States and Europe as potentially relevant for their differences in hours worked. These include US-EU differences in preferences (e.g., Blanchard 2004), in

[5] See He and Huang (2013) for a list of references. These studies do not just provide evidence on statistic correlation between leisure time and health; they also rely on experimental designs and econometric techniques to help establish causality.

[6] Our quantitative exercises in Section 7.1 predict slightly better health status for Europeans than for Americans, which appears to be consistent with empirical observations.

taxation and government transfer policy (e.g., Rogerson 2001, 2004, 2006, 2008; Prescott 2004; Davis and Henrekson 2005; Ohanian *et al.* 2008; Olovsson 2009), in union-imposed regulations and the associated social multiplier through complementarities in the consumption of leisure (e.g., Alesina *et al.* 2005), and in social norms for leisure and the associated multiplicity of equilibria (e.g., Alesina *et al.* 2005; Boeri *et al.* 2008). These studies typically abstract from health-related issues. On the other hand, there is an emerging class of economic models featuring endogenous health accumulation, which are developed to help understand the rising medical expenditure in the United States (e.g., Suen 2006; Hall and Jones 2007; Zhao 2014; Fonseca *et al.* 2021), welfare effects of health care reforms (e.g., Feng 2008; Jung and Tran 2010), implications of health risks for consumption, health expenditure, and allocation of wealth among bonds, stocks, and housing (e.g., Yogo 2016), implications of employment-based health benefits in the United States (e.g., Fang and Gavazza 2011; Huang and Huffman 2014), and the trade-off of provision of health-related social insurance on risk-sharing against dynamic disincentive ("moral hazard") effect of health investment (e.g., Cole, Kim, and Krueger 2019). These studies do not address cross-country differences in health care expenditure and they do not model time input in health production.

Finally, our work is close in spirit to the paper by Dubois *et al.* (2014) who use detailed household-level data to study cross-country differences in food purchases among the United States, France, and the United Kingdom. Their paper empirically estimates a demand system for food and nutrients and simulates counterfactual choices if households in one country faced prices and nutritional characteristics from other countries. Our paper differs from theirs in terms of topic (we study cross-country differences in medical expenditure-GDP ratio and health-enhancing leisure time) and methodology (we rely on a macroeconomic general equilibrium model and use the model to conduct simulated counterfactual exercises). They find that an interaction between economic environment (e.g., relative prices of food) and differences in preferences is needed in explaining cross-country differences in food purchases. Our quantitative results suggest that, while economic environment such as taxation can be a key factor behind cross-country differences in medical expenditures and time allocation, factors beyond economic arrangement, such as preferences, may also play a role in explaining cross-country differences in health-enhancing leisure time. Thus the nature of their main message is echoed in the present paper as well.

3 Empirical Motivation and Empirical Analysis

We have illustrated the relevance of taxation for time allocation and health investment portfolio, i.e., the trade-off between health-enhancing leisure time and health expenditure. We here provide empirical evidence to further motivate our theoretical analysis. Since health-enhancing leisure time plays a key role in our analysis, we will pay particular attention to its measurement.

3.1 Data Sources

The data on non-medical consumption tax and labor income tax come from McDaniel (2007) and subsequent updates. McDaniel applies the methodology in Mendoza *et al.*

(1994) to calculate a variety of average tax rates over an extended period of time for a number of OECD countries, using national account statistics as a primary source. The data are downloaded from http://www.caramcdaniel.com/researchpapers. The data on medical consumption tax are taken from the World Health Organization/Health Action International (WHO/HAI).[7]

The data on working hours are taken from the OECD Labor Market Database for the period 1990-2015. We adjust working hour to focus on working-age population using the methodology outlined in Ohanian and Raffo (2012).

The indexes for the relative prices of health care goods and services for the selected countries are constructed by He, Huang, and Hung (2013),[8] based on the data from the OECD 2005 PPP Benchmark Results, which is a widely used dataset for international comparison of relative prices for health care goods and services (e.g., Pearson 2009).[9]

Our data on health expenditure are adapted from WHO and OECD.

Finally, we appeal to micro-level data from the Multinational Time Use Study

[7]Section 6.5 describes the details on the construction of medical consumption tax rate.

[8]In addition to constructing these relative price indexes, He, Huang, and Hung (2013) discuss some general issues concerning measures of data on prices and quantities (including time uses).

[9]Source of original data: http://stats.oecd.org/Index.aspx?DataSetCode=PPP2005. The data obtained here are broadly consistent with those from earlier studies, such as the individual country case studies on the price level of health care conducted by McKinsey Global Institute (1996).

(MTUS) to formally measure health-enhancing leisure time. MTUS was originally developed by Jonathan Gershuny in the mid 1980s. Since then it has grown to offer harmonized episode and context information and to encompass over 60 datasets from 25 countries, including recent data from the American Time Use Survey (ATUS) and other national-level time use projects. It now allows researchers to analyze time spent by different sorts of people in various sorts of work and leisure activities, over the last 55 years and across 30 countries.

3.2 Empirical Motivation

As discussed in the introduction, one determinant of the composition of the two health inputs is taxation and, therefore, cross-country differences in labor income and consumption tax rates may hold a key to understanding cross-country differences in medical consumption, as well as in time input for health production. The linchpin of our analysis in this paper is the fact that, for the same period that Europeans spend much less on health care than Americans, labor income and consumption tax rates are much higher in Europe than in the United States. This can be seen from the fifth to the seventh columns of Table 1, which report the average labor and consumption tax rates (for both medical and non-medical goods) over the period 1990-2015 for the eight selected countries and the mean across those seven European countries. The contrast between these US and European data on taxation and health expenditures conforms to our model prediction, as mentioned in the introduction, and to be demonstrated in detail in the current section. As we document in this section, the relationship between taxation and health-enhancing leisure time predicted from

Table 1: US and European Data: Long Run Averages

Country	$\frac{pm}{y}$[1](%)	n^2(%)	lei^3(%)	l^4(%)	$\boldsymbol{\tau}_n{}^5$(%)	$\boldsymbol{\tau}_c{}^6$(%)	$\boldsymbol{\tau}_m{}^7$(%)	p^8
Finland	8.0	29.0	68	n.a.	15.8	21.9	9.0	1.14
France	9.9	26.6	68	17.9	9.3	23.4	2.1	1.11
Germany	10.1	26.8	69	16.6	9.9	15.1	15.1	0.94
Italy	8.0	26.6	67	20.7	12.7	19.2	10.0	1.24
Netherlands	8.7	27.5	68	17.8	9.2	17.8	6.0	0.94
Spain	7.7	26.2	67	20.4	8.2	14.9	4.0	0.92
UK	7.2	29.2	66	20.4	12.7	15.6	15.6	1.05
Euro Mean	8.5	27.4	68	19.3	11.2	18.2	11.9	1.04
US	14.2	33.5	64	17.6	10.6	7.6	0	1.20

Sources: OECD Health Data, OECD Labor Market Database, WHO, and MTUS.
[1] Health expenditure to GDP ratio-OECD Health Data 2018 and WHO.
[2] Fraction of time spent on paid work-OECD Labor Market Database.
[3] Fraction of time spent on potentially health-enhancing leisure activity-OECD (2011).
[4] Fraction of time spent on narrowly defined health-enhancing leisure activity-MTUS and ATUS.
[5] Average labor income tax rate-McDaniel (2007) and the subsequent updates.
[6] Consumption tax rate-McDaniel (2007) and the subsequent updates.
[7] Medical expenditure tax rate-WHO (2011).
[8] Relative price of health care-He, Huang, and Hung (2013).

our model is also consistent with the contrast in data observables between the United States and Europe.

Empirical evidence shows that conventionally defined leisure time, as measured by the time spent away from paid work, is much shorter, whereas measured hours of paid work are much longer, in the United States than in most European countries. This fact is elaborated by Figure 1 in Jones and Klenow (2011). More formally, as can be seen from the second column of Table 1, Europeans on average spend 6.1% less of their time endowment on paid work, and thus 6.1% more of their time endowment is spent on leisure, when compared to Americans over the period 1990–2015. As a standard practice in the literature (e.g., Rogerson 2006; Ohanian *et al.* 2008; Jones and Klenow 2011), time spent on paid work is here calculated as annual hours per worker, divided by 360×16 to get a measure of paid work time as a percentage of annual discretionary time. Leisure time is then taken as the residual of paid work time following the conventional definition.

The US-EU differences in time allocation continue to hold even if we tease out unpaid work time (e.g., home production time) from the conventionally measured leisure time (i.e., the residual of paid work time). Based on national time-use surveys, which record how people allocate their time (typically using a 24-hour diary), OECD (2011) classifies time allocation by working-age population in 29 countries over the period 1998–2009 into *paid work or study*, *unpaid work*, *personal care*, *leisure*, and *other time use*, which, when averaged over the 29 countries, take up, respectively, 19%, 14%, 46%, 20%, and 1% of the total time endowment (24 hours or 1440 minutes per day), and which also show significant variations across the countries. The division between unpaid work and personal care, or leisure for that matter, is determined by the "third-person" criterion: If a third person could be hired to carry out the activity, while the benefits of the activity would still accrue to the hirer, then it is considered to be work. Under this criterion, cooking, cleaning, doing laundry, shopping, walking the dog, gardening, volunteering, and caring for children and other family and non-family members are all examples of unpaid work. In contrast, someone else cannot be paid on another's behalf to sleep, eat, drink, visit a doctor, watch a game, go to a concert, lay on the beach, jog, swim, play tennis, ride the treadmill, socialize with friends and family, attend a cultural event, read a book silently, or spend time unwinding, as the benefits of the activity would accrue to the doer, but not to the hirer. Thus, these activities are all examples of *personal care* or *leisure*, which are arguably potential time inputs for the production of health.

The third column in Table 1 reports the sum of these two categories of time use (*personal care* and *leisure*), which we shall broadly refer to as potential time input in health production, or, with some abuse of terminology, leisure time for short, as a fraction of the time endowment for the eight selected countries and the Euro mean across the seven European countries. As is apparent from the table, all of the seven European countries are much higher on this time input for health production when compared with the United States, and the Eurozone average is about 4% higher than the America. This is equivalent to saying that Europeans on average spend one hour more per day on potentially health-enhancing activities than Americans. And that one-hour difference comes from the reduction in paid work time as shown in the second column.

It is also widely known that the prices of health care goods and services relative to the general price levels are generally higher in the United States than in Europe (e.g., Anderson *et al.* 2003; Angrisano *et al.* 2007; Cutler and Ly 2011; Squires 2012; Horenstein and Santos 2019). This can be seen from the eighth column of Table 1, which reports the purchasing power parities–adjusted price indexes of health care goods and services relative to non-medical commodities for the eight selected countries in 2005. As is shown, for example, the price of health care is 20% higher than that of non-medical consumption in the United States, while in Germany the price of health care is only 94% of that of non-medical consumption. This implies that the relative price of health care is about 26% higher in the United States than in Germany. It can be inferred from the indexes reported in this column of the table that the relative price of health care in the United States is about 16% higher than the European average.

3.3 Measuring Health-Enhancing Leisure Time

We measure health-enhancing leisure time based on MTUS.[10] There are 10 countries in our MTUS sample for our empirical illustration to be presented later in Section 4.2, including Australia (AU), Austria (AT), France (FR), Germany (DE), Israel (IL), Italy (IT), Netherlands (NL), Spain (ES), the United Kingdom (UK), and the United States (US). Appendix A.1 provides details on the choice of these countries.

Consistent with our analytical setting and, more importantly, with the quantitative model to be presented, our data sample includes both currently employed workers and retirees. We construct our health-enhancing leisure time measure using 20 categories of time use. Details of the construction are described in Appendix A.1.

The fourth column in Table 1 reports time spent on this narrowly defined measure of health-enhancing leisure activities as a fraction of discretionary time for each of the eight selected countries and Eurozone average.[11] As can be seen from the table,

[10] Except for Finland, the other six European countries reported in Table 1 are covered in MTUS.

[11] The time periods covered in MTUS vary across countries. For each country, we take the average of this measure of time use over the available years covered in the sample.

except for Germans, Europeans spend more time in the narrowly defined health-enhancing leisure activities than Americans do. On average, this measure is about 2.7% greater in Europe than in the United States.

4 Qualitative Illustration

We here use a simple analytical model to illustrate the main mechanism emphasized in this paper. Through this mechanism, taxation may influence not only time allocation, but also the health investment portfolio, or, the leisure time-medical commodity choice discussed in the introduction. We also illustrate here how the model's implications are generally consistent with data observables.

4.1 An Analytical Model

The economy consists of a household, a firm, and a government. The household chooses wage-generating work time n, utility-generating consumption c and health-neutral leisure time v, time invested in enhancing health l, medical commodity m, and health stock h to maximize

$$\frac{\left[U(c)+V(v)+\Omega\frac{h^{1-\frac{1}{\varpi}}-1}{1-\frac{1}{\varpi}}\right]^{1-\xi}-1}{1-\xi},$$

while the feature that being healthier directly enhances household utility, reflected by the term $W(h)\equiv\Omega\frac{h^{1-\frac{1}{\varpi}}-1}{1-\frac{1}{\varpi}}$ in the felicity function, captures Grossman (1972)'s notion of consumption motive for health investment, subject to

$$
\begin{aligned}
(1+\tau_c)c+(1+\tau_m)pm &= (1-\tau_n)wn+T, \\
n+\upsilon+l &= 1, \\
h &= B\left[\theta m^{\frac{\varpi-1}{\varpi}}+(1-\theta)\,l^{\frac{\varpi-1}{\varpi}}\right]^{\frac{\varpi}{\varpi-1}},
\end{aligned}
$$

while the feature that both medical commodity and time are invested in enhancing health according to $g(m,l)\equiv B\left[\theta m^{\frac{\varpi-1}{\varpi}}+(1-\theta)\,l^{\frac{\varpi-1}{\varpi}}\right]^{\frac{\varpi}{\varpi-1}}$ is consistent with the empirical evidence presented by Sickles and Yazbeck (1998) and He, Huang, and Hung (2013). τ_c, τ_m, and τ_n denote tax rates on non-medical consumption, medical commodity, and labor income, respectively. w is the wage rate, p is the relative price of medical goods, and T is a lump-sum transfer from the government to the household. The functions U and V are strictly increasing, strictly concave, and twice continuously differentiable.

Assumption 1. $U'>0$, $V'>0$, $U''<0$, and $V''<0$.

The firm's problem is to maximize profit $y-wn$ based on a production function $y=An$, for some $A>0$. The government runs a balanced budget and rebates all tax revenues to the household in the form of the non-distortionary lump-sum transfer, or, $\tau_c c+\tau_m pm+\tau_n wn=T$. The goods market clearing condition requires $c+pm=y$.

Definition 1. Admissible values of the deep parameters are $A>0$, $B>0$, $\Omega>0$, $\xi>0$, $\varpi>0$, and $\theta\in(0,1)$.

Using the time constraint and the health production function to substitute out

n and h, and then combining the first order conditions with respect to c, v, l, and m for solving the household's utility maximization problem, we obtain

$$\frac{V'(v)}{U'(c)} = w\frac{1-\tau_n}{1+\tau_c}, \tag{1}$$

$$\frac{g_l(m,l)}{g_m(m,l)} = \frac{w}{p}\frac{1-\tau_n}{1+\tau_m}, \tag{2}$$

$$\frac{V'(v)}{W'(g(m,l))} = g_l(m,l). \tag{3}$$

Equations (1)-(3) describe three optimal marginal trade-off conditions: (1) prescribes an optimal consumption-leisure trade-off for generating utility, (2) governs an optimal health investment portfolio that combines medical commodity and non-market time for enhancing health, and (3) determines an optimal allocation of non-market time that can be either enjoyed leisurely to directly generate utility or invested to enhance health to deliver utility.

Combining the budget equations for the household and the government gives rise to the following economy-wide resource constraint

$$c + pm = w(1 - v - l). \tag{4}$$

Before we proceed further, it is useful to differentiate the endogenous variables from the exogenous ones explicitly.

Definition 2. Endogenous variables are c, m, n, v, l, h, y, w, and T. The tax rates and the relative health care price are all treated as exogenous with $\tau_n \in [0, 1)$, $\tau_c \geq 0$, $\tau_m \geq 0$, and $p > 0$.

We here note that the endogenous wage rate is determined by $w = A$, as resultant from the first-order condition for the firm's profit maximization problem. With this, Equations (1), (2), (3), and (4) constitute a system of four equilibrium conditions for solving four endogenous variables, c, v, l, and m, which can be viewed as implicit functions of the tax rates τ_n, τ_c, and τ_m, along with the relative health care price p and the deep parameters. Viewed from this perspective, the system is a collection of four identities about τ_n, τ_c, and τ_m. Formally, we have

$$\frac{V'(v(\tau_n,\tau_c,\tau_m))}{U'(c(\tau_n,\tau_c,\tau_m))} \equiv A\frac{1-\tau_n}{1+\tau_c}, \tag{5}$$

$$\frac{g_l(m(\tau_n,\tau_c,\tau_m),l(\tau_n,\tau_c,\tau_m))}{g_m(m(\tau_n,\tau_c,\tau_m),l(\tau_n,\tau_c,\tau_m))} \equiv \frac{A}{p}\frac{1-\tau_n}{1+\tau_m}, \tag{6}$$

$$\frac{V'(v(\tau_n,\tau_c,\tau_m))}{W'(g(m(\tau_n,\tau_c,\tau_m),l(\tau_n,\tau_c,\tau_m)))} \equiv g_l(m(\tau_n,\tau_c,\tau_m),l(\tau_n,\tau_c,\tau_m)), \tag{7}$$

$$c(\tau_n,\tau_c,\tau_m)+pm(\tau_n,\tau_c,\tau_m) \equiv A\left[1-v(\tau_n,\tau_c,\tau_m)-l(\tau_n,\tau_c,\tau_m)\right]. \tag{8}$$

Using (5)-(8), we can prove the following proposition.

Proposition 1. Under Assumption 1 there is a unique equilibrium, in which

$$\frac{\partial v}{\partial \tau_n}>0, \quad \frac{\partial l}{\partial \tau_n}>0, \quad \frac{\partial m}{\partial \tau_n}<0; \tag{9}$$

$$\frac{\partial v}{\partial \tau_c}>0, \quad \frac{\partial l}{\partial \tau_c}>0, \quad \frac{\partial m}{\partial \tau_c}>0; \tag{10}$$

$$\frac{\partial v}{\partial \tau_m}>0, \quad \frac{\partial l}{\partial \tau_m}>0, \quad \frac{\partial m}{\partial \tau_m}<0, \tag{11}$$

for all admissible values of the deep parameters presented in Definition 1.

Proof: See Appendix A.2.

Proposition 1 implies $\partial n / \partial \tau_i < 0$, for $i = n$, c, and m, given the time constraint. The result that greater labor or consumption tax results in less work and more leisure time echoes the message of Prescott (2004). We here generalize this to health enhancing leisure time and to tax on medical commodity. The message that greater labor or medical consumption tax leads to rebalancing of the health investment portfolio by using more leisure time activity and less medical commodity in maintaining health is totally new.[12] What is also new here is the message that greater tax on non-medical consumption implies across-the-board increases in all health-enhancing measures, whether medical consumption or health-enhancing leisure activities.

4.2 Empirical Correlations of Health Expenditures and Health-enhancing Leisure Time with Tax Rates

Our analytical model presented in Section 4.1 generates implications for how health expenditures and time allocation pertaining to health production correlate with the tax rates. We now show that empirical evidence in terms of simple correlations of health expenditures and health-enhancing leisure time (as well as other time use mea-

[12] Given that the relative health care price p is taken exogenously, Proposition 1 also implies that $\frac{\partial pm}{\partial \tau_n} < 0$, $\frac{\partial pm}{\partial \tau_c} > 0$, and $\frac{\partial pm}{\partial \tau_m} < 0$. In other words, higher tax rates on labor income and medical consumption and lower tax rate on non-medical consumption lead to less health expenditure.

sures) with the tax rates is generally consistent with the predictions of the analytical model as indicated by Proposition 1.

Figure 1 displays the log health expenditure per capita and the narrowly defined health-enhancing leisure time (as in Section 3.3) against each of the three individual tax rates (both averaged across the past five decades for each country so as to be consistent with the comparative static analysis nature of Proposition 1 from our analytical model) for the 10 selected countries discussed in Section 3.3.[13] As is clear, all scatter plots in the figure show correlation results consistent with the predictions of Proposition 1 from the analytical model.[14]

Taken together these scatter plots lend empirical support to the relevant role of taxation in shaping the health investment portfolio as illustrated by Proposition 1 from the analytical model. The illustrated mechanism will be built into our large-scale life-cycle OLG macro-health model, to be presented next, which will be used to quantify the extent to which the US-Europe differences in consumption and labor

[13] The health expenditure data are from OECD for the period 1970–2019. The tax data are from McDaniel (2007) and subsequent updates for the period 1970–2015. The data do not contain the labor income tax rate for Israel. Health-enhancing leisure time are taken from MTUS for all available years.

[14] Scatter plots on health-neutral leisure time ν (non-working time minus health-enhancing leisure time) against each of the three tax rates also show positive correlations, just as prescribed by Proposition 1 from the analytical model. To conserve space, these scatter plots are not presented here but are available upon request from the authors.

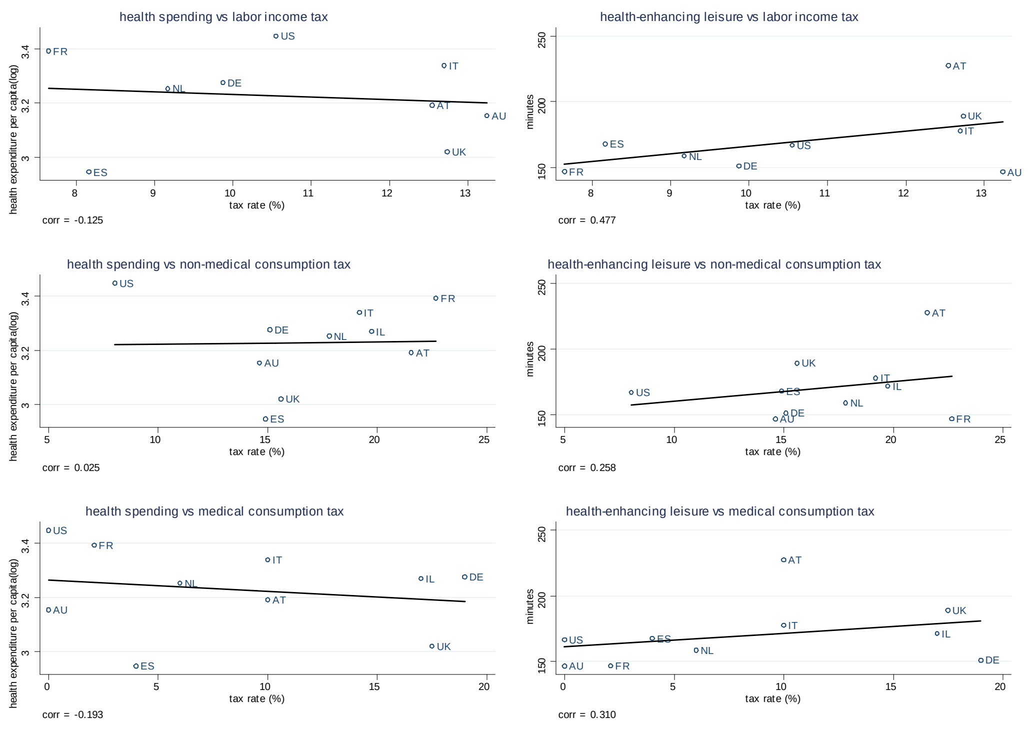

Figure 1: Health Expenditures, Health-enhancing Leisure Time, and Taxes: Cross-country Evidence

income tax rates (and in relative health care prices) may help account for their differences in health expenditures and time allocation pertaining to health production.

5 A Life-Cycle Overlapping-Generations Model

The analytical model presented above is for the purpose of illustrating qualitatively the working of the main mechanism emphasized in this paper. For quantitative assessment of the significance of the highlighted mechanism, we need to take into account important aspects of health expenditures that are abstracted away from the analytical setting; for example, the fact that health expenditures increase as an individual ages, and at a faster pace in late ages. We believe that any quantitative study on health expenditures should include age as an important dimension.

In this section, we present a large-scale life-cycle OLG model that is suitable for our quantitative exercise. The model follows the macro-health literature (e.g., Zhao 2014; Halliday *et al.* 2019) to feature endogenous health accumulation. Health directly enters into the felicity function to provide consumption value. Better health also reduces sick time to allow more time for work or leisure (Grossman 1972). Finally, health positively influences survival probability.

5.1 Model

5.1.1 Households

In each period there is a continuum of individuals with unit measure living in the economy. An individual starts working at age 1, retires at age j_R, and then lives through age J. From age 1, the expected lifetime utility of the individual is given by

$$\mathbb{E}\sum_{j=1}^{J}\beta^{j-1}\left[\prod_{k=1}^{j}\varphi_k(h_k)\right]u(c_j,v_j,h_j),$$

where β denotes the subjective discount factor, c is non-medical consumption, v is health-neutral leisure time, and h is health status or health capital. The term $\varphi_j(h_j)$ represents an age-dependent conditional probability of surviving from age $j-1$ to j with the property $\varphi_1 = 1$ and $\varphi_{J+1} = 0$.

The model features an age-dependent health depreciation rate profile $\{\delta_{h_j}\}_{j\in[1,J)}$, where health status follows the law of motion

$$h_{j+1} = (1-\delta_{h_j})h_j + g(m_j, l_j). \tag{12}$$

This configuration of age-specific health depreciation rate profile, together with proper calibration of the elasticity of substitution between consumption and health in the utility function (see Section 6.3), make the model consistent with the life-cycle patterns of health expenditures, which can increase substantially with age and be concentrated in the last years of life (e.g., Jung and Tran 2014; Halliday *et al.* 2019).

A defining feature of the model is that, as shown by the last term in equation (12), new investment in health capital is produced using both medical consumption (m) and health-enhancing leisure time (l).

When working, i.e., for $j \in [1, j_R)$, an individual faces the following sequences of age-dependent budget and time constraints:

$$(1+\tau_c)c_j + (1-\phi_p)(1+\tau_m)pm_j + (1-\tau_{n,j}-\tau_{ss}-\tau_{med})\pi + a_{j+1} \leq$$

$$(1-\tau_{n,j}-\tau_{ss}-\tau_{med})w\varepsilon_j\eta n_j + (1+r)a_j + T, \tag{13}$$

$$n_j + v_j + l_j = 1 - s(h_j). \tag{14}$$

In budget constraint (13), τ_c stands for tax rate on non-medical consumption, τ_m represents tax rate on medical consumption, τ_n is the labor income tax rate which we will define in details later, τ_{ss} is the social security tax rate, τ_{med} is the Medicare tax rate, and p is the relative price of medical consumption. ε_j denotes age-specific (deterministic) efficiency unit of labor at age j. η represents an idiosyncratic productivity shock the individual faces at each age. We assume that η follows a first-order autoregressive stochastic process. w denotes the wage rate and r denotes the rate of return on asset holdings a. Accordingly, $w\varepsilon_j\eta n_j$ is age-j labor income. T is a lump-sum transfer which comes partially from the tax revenue that government collects and partially from accidental bequests left by people who die in the period. Thus the right-hand side of (13) is the individual's total disposable income at age j. The left-hand side of (13) says that the individual needs to use the income to consume non-medical goods (c), pay for medical expenditures (pm), and save (a'). Every employed working-age individual is enrolled in the private employer-based health insurance (EHI). The individual pays the health insurance premium π, which is tax exempt, and in exchange a fraction ϕ_p of her medical expenditures are paid by the insurance company. In other words, the individual only needs to pay $1-\phi_p$ percent of total medical expenditures out of her own pocket. It should be noted that only employed workers (i.e., with $n > 0$) are entitled to the insurance program; people who are not working (i.e., with $n = 0$) are not eligible for it.[15]

Time constraint (14) says that in each period an individual is endowed with one unit of discretionary time. She spends the time working (n), enjoying health-neutral leisure activity (v), or investing in health production (l), net of sick time (s). We assume that sick time is a decreasing function of health status, i.e., $s'(h_j) < 0$.

Following Benabou (2002), Heathcote *et al.* (2017), and Holter *et al.* (2019), we model the progressive labor income tax that an individual faces as a function of her labor income:

$$\tau_{n,j} = 1 - \theta_0 \left(w\varepsilon_j \eta n_j\right)^{-\theta_1}, \tag{15}$$

where θ_0 controls the level and θ_1 captures the progressivity of the income tax code.

After retirement, i.e., for $j \in [j_R, J]$, an individual faces the following sequences of age-dependent budget and time constraints:

$$(1+\tau_c)c_j + (1-\phi_m)(1+\tau_m)pm_j + a_{j+1} \leq b + (1+r_j)a_j + T, \tag{16}$$

$$v_j + l_j = 1 - s(h_j). \tag{17}$$

[15] With the feature of EHI, an individual's decision whether or not to work would need to take into account the EHI benefit in addition to the wage rate. This helps capture an important incentive to work that is embedded in the EHI program popularized in the United States (e.g., Huang and Huffman 2014, Feng and Zhao 2018).

Here b denotes social security benefits. Following Imrohoroglu, Imrohoroglu, and Joines (1995), we model social security as a pay-as-you-go system. b is calculated as a fraction κ of some base income, which we take to be the average lifetime labor income, so that

$$b = \kappa \frac{\sum_{j=1}^{j_R-1} w\varepsilon_j \eta n_j}{j_R - 1}, \tag{18}$$

where κ is the replacement ratio. A retiree is also automatically enrolled in the Medicare system. To receive Medicare, she does not need to pay a premium. Yet, Medicare pays a fraction ϕ_m of her medical expenditures.

For asset holdings a_j, we assume that an individual holds zero assets both when first entering the labor force and when finally leaving the world. In addition, she faces a non-borrowing constraint over the lifespan,

$$a_1 = a_{J+1} = 0, \;\; a_j \geq 0, \;\; \text{for } j \in (1, J].$$

We summarize the individual's dynamic problem as a dynamic programming. For any age j, the state space at the beginning of age j is a vector (a_j, h_j, η). We let $V_j(a_j, h_j, \eta)$ denote the value function at age j, given the state vector (a_j, h_j, η). The Bellman equation is then given by

(19)

$$V_j(a_j, h_j, \eta) = \max_{c_j, m_j, a_{j+1}, h_{j+1}, n_j, v_j, l_j} \left\{ u(c_j, v_j, h_j) + \beta \mathbb{E}_{\eta'|\eta} \left[\varphi_{j+1}(h_{j+1}) V_{j+1}(a_{j+1}, h_{j+1}, \eta') \right] \right\},$$

subject to

$$(1+\tau_c)c_j + (1-\phi_p)(1+\tau_m)pm_j + (1-\tau_{n,j}-\tau_{ss}-\tau_{med})\pi + a_{j+1} \leq$$

$$(1-\tau_{n,j}-\tau_{ss}-\tau_{med})w\varepsilon_j\eta n_j + (1+r)a_j + T,\ \forall j < j_R,$$

$$(1+\tau_c)c_j + (1-\phi_m)(1+\tau_m)pm_j + a_{j+1} \leq b + (1+r_j)a_j + T,\ \forall j \geq j_R,$$

$$n_j + v_j + l_j = 1 - s(h_j),\ \forall j < j_R,$$

$$v_j + l_j = 1 - s(h_j),\ \forall j \geq j_R,$$

$$h_{j+1} = (1-\delta_{h_j})h_j + g(m_j, l_j),$$

$$\tau_{n,j} = 1 - \theta_0 \left(w\varepsilon_j\eta n_j\right)^{-\theta_1},$$

$$a_{j+1} \geq 0,\ \forall j,$$

$$a_1 = a_{J+1} = 0,\ h_1 \text{ is given.}$$

5.1.2 Production

Next, we describe the production side of the economy. At date t, a representative firm combines labor and physical capital inputs to produce the final good, according to the constant-return-to-scale technology

$$Y_t = F(K_t, N_t) = K_t^{\alpha} N_t^{1-\alpha}.$$

The physical capital stock follows the law of motion

$$K_{t+1} = (1-\delta_k)K_t + I_t.$$

The firm maximizes profit

$$\Pi_t = F(K_t, N_t) - (r_t + \delta_k)K_t - w_t N_t.$$

Profit maximization yields the following optimality conditions

$$w_t = F_N(K_t, N_t),\ r = F_K(K_t, N_t) - \delta_k.$$

5.1.3 Government

For each period, the government plays four roles in the economy. First, it collects consumption taxes on non-medical (at rate τ_c) and medical (at rate τ_m) goods and progressive labor income tax (at rate τ_n), while it returns the total tax revenue to all living individuals in a lump-sum fashion. Second, it maintains a pay-as-you-go social security system by imposing social security tax (at rate τ_{ss}). Third, it imposes Medicare tax (at rate τ_{med}) to support a self-financed Medicare system. Finally, it collects accidental bequests left by people who die in the period and returns the bequests to all living individuals in a lump-sum fashion.

5.2 Competitive Equilibrium

We will focus on the stationary equilibrium of the model economy. For this purpose, we introduce the following equilibrium concept for the model economy.

Definition 1 *A stationary recursive equilibrium is a collection of individual value functions* $V_j(a_j, h_j, \eta)$*, individual policy rules* $C_j(a_j, h_j, \eta)$, $M_j(a_j, h_j, \eta)$, $A_j(a_j, h_j, \eta)$,

$H_j(a_j, h_j, \eta)$, $N_j(a_j, h_j, \eta)$, $\nu_j(a_j, h_j, \eta)$, $L_j(a_j, h_j, \eta)$, a measure of agent distribution $\Phi_j(a_j, h_j, \eta)$ for every age j, and a lump-sum transfer T, together with aggregate consumption C, aggregate health care commodity M, stock of health capital H, stock of physical capital K, labor input N, and wage and interest rates w and r, such that:

1. *Given constant prices $\{w, r\}$, policies $\{\kappa, \tau_n, \tau_c, \tau_m, \tau_{ss}, \tau_{med}\}$, health insurances, and lump-sum transfer T, an individual's value functions and policy rules solve her dynamic programming problem (19).*

2. *The distribution of the measure of age-j individuals $\Phi_j(a_j, h_j, \eta)$ satisfies the law of motion,*

$$\Phi_{j+1}(a', h', \eta') = \sum_{a:a'=A_j(a,h,\eta)} \sum_{h:h'=H_j(a,h,\eta)} \sum_{\eta} \Gamma(\eta, \eta')\varphi_{j+1}(H_j(a, h, \eta))\Phi_j(a, h, \eta),$$

   where $\Gamma(\eta, \eta')$ denotes the transition probability matrix.

3. *The share of age-j individuals in population $\mu_j, \forall j$, is determined by,*

$$\begin{aligned} \Psi_j &= \sum_a \sum_h \sum_\eta \Phi_j(a, h, \eta), \\ \mu_j &= \frac{\Psi_j}{\sum_{i=1}^J \Psi_i}, \end{aligned}$$

   where Ψ_j is the measure of all age-j individuals.

4. *Aggregate measures are consistent with aggregation across different age groups. Details are in Appendix A.3.*

5. *Wage and interest rates are consistent with profit maximization,*

$$w = F_N(K, N),\ r = F_K(K, N) - \delta_k.$$

6. *The lump-sum transfer* T *is determined by two parts, accidental bequests and tax rebates, so that,*

$$T = AB + TR,$$

$$\begin{aligned} AB &= \sum_j \sum_a \sum_h \sum_\eta \mu_j \Phi_j(a, h, \eta)(1 - \varphi_{j+1}(H_j(a, h, \eta)))A_j(a, h, \eta), \\ TR &= \tau_c C + \tau_m pM + w \sum_{j=1}^{j_R - 1} \sum_a \sum_h \sum_\eta \mu_j \Phi_j(a, h, \eta) \tau_{n,j} \varepsilon_j \eta N_j(a, h, \eta). \end{aligned}$$

7. *Social Security system is pay-as-you-go,*

$$\tau_{ss} = \frac{b \sum_{j=j_R}^{J} \mu_j}{wN}.$$

8. *Medicare system is self-financing,*

$$\tau_{med} = \frac{\phi_m(1 + \tau_m) \sum_{j=j_R}^{J} \sum_a \sum_h \sum_\eta \mu_j \Phi_j(a, h, \eta) pM_j(a, h, \eta)}{wN}.$$

9. *Private health insurance satisfies a zero profit condition,*

$$\pi = \frac{\phi_p(1 + \tau_m) \sum_{j=1}^{j_R - 1} \sum_{a:N_j(a,h,\eta)>0} \sum_{h:N_j(a,h,\eta)>0} \sum_{\eta:N_j(a,h,\eta)>0} \mu_j \Phi_j(a, h, \eta) pM_j(a, h, \eta)}{(1 - \tau_n - \tau_{ss} - \tau_{med}) \sum_{j=1}^{j_R - 1} \sum_{a:N_j(a,h,\eta)>0} \sum_{h:N_j(a,h,\eta)>0} \sum_{\eta:N_j(a,h,\eta)>0} \mu_j \Phi_j(a, h, \eta)}.$$

10. Goods market clears,

$$C + pM + K' - (1 - \delta_k)K = F(K, N).$$

6 Parametrization and Calibration

For our quantitative exercise, we parameterize the OLG model presented above and calibrate the parameterized model to match the long-run average of the US economy for the period 1990–2015.[16] Importantly, since this is a life-cycle model, we also aim to calibrate the parameterized model to match key aspects of life-cycle patterns in health expenditures shown in the US data, following the calibration strategy adopted in Halliday *et al.* (2019).

[16] Constrained by data availability, some moments are only available for a shorter period such as 2002 or 2003–2007. Horenstein and Santos (2019) find that the cross-country gap in medical expenditure-GDP ratio between the United States and Europe increased mostly during the period 1978–1990 and the gap has stabilized since 1990. This finding justifies our use of the period 1990–2015 for the United States in calibrating a steady-state equilibrium of the model economy. It is worth noting that the US health care system has undergone some significant changes in this period (e.g., Medicaid was expanded significantly). The analysis below is abstracted from such changes and one should be aware of this limitation.

6.1 Demographics

We assume that one model period corresponds to five years and that an individual enters into the labor force at age 20 ($j = 1$), retires at age 65, and dies at age 90. This latter assumption implies $j_R = 10$ and $J = 16$.

6.2 Preferences

The felicity function takes the following form

$$u(c_j, v_j, h_j) = \frac{[\lambda(c_j^{\rho} v_j^{1-\rho})^{\psi} + (1-\lambda)h_j^{\psi}]^{\frac{1-\sigma}{\psi}}}{1-\sigma} + \underline{c}.$$

We assume that non-medical consumption and health-neutral leisure are non-separable and we take a Cobb-Douglas specification as the benchmark. The parameter ρ determines the weight of non-medical consumption in the consumption-leisure bundle. Given the lack of consensus about the elasticity of substitution among non-medical consumption, leisure, and health, we allow for a flexible constant elasticity of substitution (CES) specification between the consumption-leisure bundle and health. The parameter λ thus measures the relative importance of the consumption-leisure bundle in the utility function. The elasticity of substitution between the consumption-leisure bundle and health is $\frac{1}{1-\psi}$. The consumption-leisure-health combination itself takes the standard constant relative risk aversion (CRRA) form with the parameter σ determining the intertemporal elasticity of substitution. Finally, the inclusion of a constant term $\underline{c} > 0$ is to guarantee that the period utility is positive so that people would prefer to live longer (e.g., Hall and Jones 2007).

Next, following Halliday *et al.* (2019), we assume that the survival probability is a logistic function that depends on health status,

$$\varphi_j(h_j) = \frac{1}{1 + \exp(\varpi_0 + \varpi_1 j + \varpi_2 j^2 + \varpi_3 h_j)}, \tag{20}$$

where we assume $\varpi_3 < 0$ so that the survival probability is an increasing function of an individual's health. Note that the survival probability is age-dependent, and that given suitable values for ϖ_1 and ϖ_2, it is decreasing with age at an increasing rate.

We calibrate the annual subjective discount factor to 0.965 so as to match the capital-output ratio of 2.5 in year 2002, which gives rise to $\beta = (0.965)^5$. We choose $\sigma = 2$ to obtain an intertemporal elasticity of substitution of 0.5, which is a value widely used in the literature. We calibrate the share of the consumption-leisure bundle in the felicity function, λ, to 0.27 to match the average consumption-labor income ratio for working age adults, which is 78.5% (data are taken from Halliday *et al.* 2019). We calibrate the share of consumption ρ to 0.51 to match the fraction of working hours in discretionary time for workers, which is 0.335 from the OECD Labor Market Database.[17] We calibrate ψ, the parameter governing the elasticity of substitution between the consumption-leisure bundle and health, to -4.7, which implies an elasticity of $\frac{1}{1-\psi} = 0.175$. This value is chosen to match the average ratio of non-medical consumption to medical expenditure for working age in 2002, which

[17] The OECD Labor Market Database shows that average American workers work 1930 hours per year for the period 1990-2015. We divide this number by 16×360 to convert it into a ratio to annual discretionary time, which is 0.335.

is 13.5 (data are taken from Consumer Expenditure Survey (CEX) and Medical Expenditure Survey (MEPS)). Compared to the elasticity of substitution between consumption and leisure (equal to 1, given the Cobb-Douglas specification), health and the consumption-leisure bundle are complements. This implies that the marginal utility of consumption increases as the health status improves, which conforms to the empirical evidence (e.g., Viscusi and Evans 1990; Finkelstein, Luttmer, and Notowidigdo 2013). Finally, following Halliday *et al.* (2019), we calibrate $\underline{c}$ to match the ratio of the change in survival probabilities to the change in medical expenditures from ages 65–69 to 55–59, which is -0.06 in the MEPS data. The resulting $\underline{c}$ is 3.5. As Hall and Jones (2007) point out, $\underline{c}$ also determines the value of a statistical life (VSL). Our baseline model generates an average VSL of 8.67 million dollars, which falls into the range of the estimates found in the recent empirical literature (e.g., Rohlfs, Sullivan, and Kniesner 2015).

For age-dependent survival probability, following Halliday *et al.* (2019), we calibrate the four parameters ϖ_0, ϖ_1, ϖ_2, and ϖ_3 to match four moment conditions involving survival probabilities in the data (US Life Table 2002): 1) Dependency ratio ($\frac{\text{number of people aged 65 and over}}{\text{number of people aged 20-64}}$), which is 39.7%. 2) Age-share weighted average death rate from age 20 to 100, which is 8.24%. 3) The ratio of survival probabilities for ages 65–69 to 20–24, which is 0.915. 4) The ratio of the change in survival probabilities from ages 65–69 to 75–79 to the change in survival probabilities from ages 55–59 to 65–69 ($\frac{\varphi_{12}-\varphi_{10}}{\varphi_{10}-\varphi_8}$ in the model), which is 2.27. This calibration obtains $\varpi_0 = -5.81, \varpi_1 = 0.285, \varpi_2 = 0.0082$, and $\varpi_3 = -0.27$.

6.3 Health Production and Sick Time

We parameterize the age-dependent health depreciation rate profile $\{\delta_{h_j}\}_{j\in[1,J)}$ using the following functional form,

$$\delta_{h_j} = \frac{\exp(d_0 + d_1 j + d_2 j^2)}{1 + \exp(d_0 + d_1 j + d_2 j^2)},$$

based on the study by Halliday *et al.* (2019).

For the health production function, given the lack of consensus on the elasticity of substitution between the two primary inputs, we assume that it takes a CES form,

$$g(m_j, l_j) = B\left[\theta m_j^{\frac{\varpi-1}{\varpi}} + (1-\theta)\, l_j^{\frac{\varpi-1}{\varpi}}\right]^{\frac{\varpi}{\varpi-1}}, \tag{21}$$

where B is a productivity measure, θ measures the relative importance of goods (medical consumption) input in health production, and ϖ measures the elasticity of substitution between goods input and health-enhancing leisure input.

Following Grossman (1972), we assume that sick time is a decreasing function of health status which takes the following form,

$$s(h_j) = Q h_j^{-\gamma}, \tag{22}$$

where Q is a scaling factor and γ measures the sensitivity of sick time to health.

The three parameters d_0, d_1, and d_2 are calibrated to match three moment conditions governing health status over the life cycle, and their resulting values are

d_0 =-4.8, $d_1 = 0.46$, and $d_2 = 0.004$.[18] The three moment conditions are: average health status from age 20 to 74, the ratio of health status for ages 20–29 to for ages 30–39, and the ratio of health status for ages 30–39 to health status for ages 40–49. The calibrated health depreciation rate increases over the life cycle.

The three parameters governing the health production function are calibrated to match three relevant moment conditions. We calibrate $B = 1.6$ to match the average medical expenditure-GDP ratio for the period 1990–2015, which is 14.2%. We calibrate $\theta = 0.133$ to match the average fraction of health-enhancing leisure time (see Appendix A.1 for the definition for details) to discretionary time in ATUS for the period 1990–2012, which is 0.176. Finally, ϖ is calibrated to be 1.3 to match the gap between the ratio of medical expenditures between the United States and Europe for working age (ages 20–64) and the same ratio between the United States and Europe for retirees (ages 65–90). In our model, the gap is expressed as $\frac{pm^{US}_{\text{working age}}}{pm^{EU}_{\text{working age}}} / \frac{pm^{US}_{\text{retirees}}}{pm^{EU}_{\text{retirees}}}$.

[18] Following Halliday *et al.* (2019), our health status measure is taken from Panel Study of Income Dynamics (PSID) and it is a self-reported categorical variable in which the respondent reports that her health is in one of five states: excellent, very good, good, fair, or poor. We then map the health variable into a binary variable in which a person is either healthy (self-rated health is either excellent, very good, or good) or unhealthy (self-rated health is either fair or poor). Health status as shown in Panel B of Figure 2 would be the portion of individuals reporting healthy.

And the data show a range between 1.09 and 1.31.[19,20]

For the two parameters that govern how health affects sick time, we calibrate Q and γ to match two moment conditions from the data documented in Lovell (2004). First, employed adults in the United States on average miss 4.6 days of work per year due to illness or other health-related factors. This translates into 2.1% of total available working days. We calibrate $Q = 0.01$ to match this ratio. Second, the absence rate increases with age. For workers between ages 45 and 64, it is 5.7 days per year, which is 1.5 days higher than the rate for younger workers between ages 18 and 44. Therefore, the ratio of average sick time for ages 45–64 to for ages 18–44 is 1.36. We calibrate $\gamma = 1.2$ to match this ratio.

Finally, p stands for the relative price of health care (compared to non-medical

[19] The data on the ratio of medical expenditures for working age to those for retirees in the United States are taken from the Centers for Medicare and Medicaid Services. However, because of the data limitation, we only have the ratios for Germany among European countries, depending on different categories of age groups. That's why the ratio is a range for Germans (see Robert Koch Institute (2008) "Health in Germany" report for the detail).

[20] The reason the ratio could be a good target for calibrating the key parameter ϖ is following: ϖ determines the strength of the substitution between two primary inputs in health production and hence would also affect the magnitude of the impact of taxation on medical expenditures. However, the impact of the taxation channel would obviously be much stronger for workers than for retirees. Since $\tau_{\mathrm{US}} < \tau_{\mathrm{EU}}$, keeping other things equal, we shall expect that $\frac{pm^{US}_{\text{working age}}}{pm^{EU}_{\text{working age}}} > \frac{pm^{US}_{\text{retirees}}}{pm^{EU}_{\text{retirees}}}$. The size of the difference is thus is determined by the elasticity ϖ. We thank Kai Zhao for pointing out to us this identification and calibration strategy.

consumption). We take $p = 1.20$ as documented in He, Huang, and Hung (2013), to be consistent with the fact that the price of health care goods and services is 20% higher than that of non-medical consumption in the United States.

6.4 Social Security and Health Insurance

The Social Security replacement ratio κ is set to 40%, a common value used in the literature (e.g., Kotlikoff *et al.* 1999). The Social Security tax rate τ_{ss} then is endogenously determined in equilibrium. The MEPS data show that on average American retirees have about 80% of their medical expenditures paid by health insurance, of whom the majority have Medicare. For the working age population in the United States, EHI pays the majority of medical expenditures. The coverage rate of EHI is approximately 70–80%. Therefore, we set the coverage rates for both private health insurance and Medicare equal to 80%. The Medicare tax rate τ_{med} is also endogenously determined in equilibrium.

6.5 Taxes

We set the consumption tax rate τ_c equal to the average of the US data for the period 1990–2015 (the data are taken from McDaniel 2007 and the subsequent updates). This gives rise to $\tau_c = 7.6\%$.

For the parameters governing the progressivity of labor income tax, we take the weighted average of two parameters for married with one child and with two children as in Holter *et al.* (2019) to be our benchmark, since these two cases are representative and the weighted average is the closest to the US average labor income tax rate as well. This gives rise to $\theta_0 = 0.975$, and $\theta_1 = 0.182$. For the seven European countries listed in Table 1, we follow a similar approach to calculate the weighted average of two parameters for married with one child and with two children as in Holter *et al.* (2019), and we report the numbers in the first and second columns of Table 2. Those numbers are going to be used in the quantitative exercises in Section 7. To make sense about those country-specific tax progressiveness parameters and compare them with average labor income tax rates reported in Table 1 (replicated in the third column of Table 2), we place them into the baseline model and compute the total labor income and total income tax revenue across the heterogenous agents in the model. In doing so we generate model-implied average labor income tax rate for each country under consideration, which is reported in the fourth column of Table 2. As can be seen from the table, the average labor income tax rates generated from the model are generally in line with those observed from the data. In particular, the average labor income tax rate for the United States is almost equal for the model and the data (the ninth row), and the average labor income tax rate across the seven European countries (the eighth row) is also virtually identical for the model and the data.

For our baseline model calibrated to the US economy, we set $\tau_m = 0$, i.e., medical expenditures are not subject to taxation. WHO (2011) shows that this is the case for the United States.[21] In contrast, for the seven European countries studied in this paper, WHO (2011) shows that medicines are taxed at either the same rates as non-

[21] Table 2 in WHO (2011) reports taxes for prescription medicines, which shows that medicines are exempt from taxation in 33 of the 50 US states, while only 17 US states have taxes on prescription medicines at about the same rate as general sales tax.

Table 2: Progressivity Parameters and Labor Income Tax

Country	**Tax Progressivity Parameters**[*]		**Labor Income Tax**	
	θ_0	θ_1	Data[+]	Model
Finland	0.95092401	0.27771834	0.158	0.161
France	0.98322351	0.15482028	0.093	0.093
Germany	0.99061592	0.25582959	0.099	0.121
Italy	0.9800397	0.22105076	0.127	0.121
Netherlands	1.01501429	0.25110373	0.092	0.102
Spain	0.94282109	0.13739603	0.082	0.121
UK	1.02305438	0.25403352	0.127	0.089
Euro Mean	0.98367041	0.22170746	0.112	0.114
US	0.974645327	0.18186421	0.106	0.107

[*] The tax progressivity parameters are taken from Holter et al. (2019), we construct these numbers as the weighted average of married with one child and married with two children. The weights are based on the population share of each group.

[+] The data of average labor income tax are taken from McDaniel (2007) and its updates. This is the same as in the fifth column of Table 1.

medical consumption (e.g., Germany and the United Kingdom) or lower. Because of the lack of taxation data on other categories of medical goods and services in these countries, we assume that their tax rates on medicines apply to their whole health care. The seventh column of Table 1 reports the adjusted medical consumption tax rates for all of the countries in our study.[22]

6.6 Labor Productivity

An individual's labor productivity has two components: a deterministic age-dependent efficiency component and a stochastic idiosyncratic productivity shock. We take the age-efficiency profile $\{\varepsilon_j\}_{j=1}^{j_R-1}$ from Holter *et al.* (2019), who use a third degree polynomial function to capture the hump of labor income over the life cycle. For the idiosyncratic component η, we follow Heathcote *et al.* (2010) and Huggett (1996) to assume that the log of η follows a first-order autoregressive process, with the persistence parameter $\rho_\eta = 0.96$ and the variance of the white noise $\sigma_\eta^2 = 0.018$, to be consistent with the US data. We then approximate this continuous process with a five-state, first-order discrete Markov process.

[22] For Germany and the United Kingdom, we take τ_m to be the same as their tax rates on non-medical goods as shown in the sixth column of Table 1. For the other European countries in our study, τ_m is taken to be the same as their medicine VAT tax rates as shown in Table 1 in WHO (2011).

6.7 Production

We set to 0.36 the capital income share α in the Cobb-Douglas production function. The annual capital depreciation rate is set to 0.10 so $\delta_k = 1 - (1 - 0.10)^5 = 0.41$.

Table 3 summarizes our model calibration results and Table 4 presents the matches for all of the moment conditions.

7 Quantitative Results

Given the calibrated parameter values, we solve the model numerically following the standard method (e.g., Aiyagari 1994, Imrohoroglu, Imrohoroglu, and Joines 1995).

Figure 2 reports the model's performance on several important aspects of life-cycle behavior. First, the model is able to capture rising medical expenditures over the life cycle, especially the speed-up of medical expenditures after the mid 50s (see panel A). Second, medical expenditures and health-enhancing leisure time jointly determine the evolution of health status over the life cycle in the model. As shown in panel B, the model is also able to capture declining health status over the life cycle (except for late ages). Third, as shown in panel C, the model captures almost perfectly the dynamics of survival probabilities over the life cycle, thanks to the rich age-dependent structure of survival probabilities in the model (see equation (20)). Fourth, the model is able to generate a hump shape in working hours over the life cycle matching the data well, thanks to the third-degree polynomial in the age-efficiency profile (see panel D). With this success, the model also generates a hump-shaped labor income profile, matching the data well (see panel E). Finally, the

Table 3: Parameters of the Model

Parameter	**Description**	**Value**	**Source**
	Demographics		
J	maximum life span	16	ages 95–99
j_R	mandatory retirement age	10	ages 65–69
ϖ_0	survival prob.	−5.81	calibrated
ϖ_1	survival prob.	0.285	calibrated
ϖ_2	survival prob.	0.0082	calibrated
ϖ_3	survival prob.	−0.27	calibrated
	Preferences		
β	subjective discount rate	$(0.965)^5$	calibrated
σ	Intertem. ela. sub. coefficient	2	common value
ψ	elasticity b/w cons. and health	−4.7	calibrated
ρ	share of c in c-leisure combination	0.51	calibrated
λ	share of cons-leisure com. in utility	0.27	calibrated
$\underline{c}$	constant term in utility	3.5	calibrated
	Health Accumulation		
d_0	dep. rate of health	−4.8	calibrated
d_1	dep. rate of health	0.46	calibrated
d_2	dep. rate of health	0.004	calibrated
B	productivity of health technology	1.6	calibrated
θ	goods investment share in h tech	0.133	calibrated
ϖ	elasticity of substitution	1.3	calibrated
p	relative price of health care	1.20	He *et al.* (2013)
	Sick Time		
Q	scale factor of sick time	0.01	calibrated
γ	elasticity of sick time to health	1.2	calibrated
	Labor Productivity		
$\{\varepsilon_j\}_{j=1}^{j_R-1}$	age-efficiency profile	see text	Holter *et al.* (2019)
ρ_η	persistence of productivity shock	0.96	Heathcote *et al.* (2010)
σ_η^2	variance of productivity shock	0.018	Heathcote *et al.* (2010)
	Health Insurance		
ϕ_p	coverage rate, private insurance	0.8	MEPS data
ϕ_m	coverage rate, Medicare	0.8	MEPS data
	Social Security		
κ	Social Security replacement ratio	40%	Kotlikoff *et al.* (1999)
	Taxes		
θ_0	labor income tax function	0.975	Holter *et al.* (2019)
θ_1	labor income tax function	0.182	Holter *et al.* (2019)
	Production		
α	capital income share	0.36	US data
δ_k	capital depreciation rate	0.41	US data

Table 4: Target Moments: Data vs. Model

Target (Data source)	**Data**	**Model**
Capital-output ratio (NIPA)	2.5	2.6
Non-med. consumption-labor income ratio (CEX and PSID)	78.5%	76.9%
Non-med. consumption / Med. expenditure in working age (CEX)	13.5	13.0
Fraction of average working hours (OECD)	0.335	0.331
Fraction of average health-enhancing leisure-time (ATUS)	0.176	0.154
Med. expenditure-output ratio (OECD Health)	14.2%	13.6%
Med. expenditure-labor income ratio (MEPS and PSID)	5.8%	4.6%
US-EU ratio of med. expend. (ages 20–64) / med. expend. (ages 65–90)	1.09–1.31	1.15
Fraction of average sick time (ages 20–64) (Lovell 2004)	2.1%	1.2%
Sick time (ages 45–64) / Sick time (ages 20–44) (Lovell 2004)	1.36	1.13
Average health status (ages 20–74) (PSID)	0.845	0.871
Health (ages 20–29)/health (ages 30–39) (PSID)	1.02	1.04
Health (ages 30–39)/health (ages 40–49) (PSID)	1.05	1.05
Dependency ratio (US Life Table)	39.7%	40.8%
Average death rate (ages 20–100) (US Life Table)	8.24%	8.18%
Sur. prob. (ages 65–69)/sur. prob. (ages 20–24) (Life Table)	0.915	0.917
$\triangle$sur (65–69 to 75–79)/$\triangle$sur (55–59 to 65–69) (Life Table)	2.27	2.21
$\triangle$sur (55–59 to 65–69)/$\triangle$med. exp. (55–59 to 65–69) (MEPS and Life Table)	-0.06	-0.04

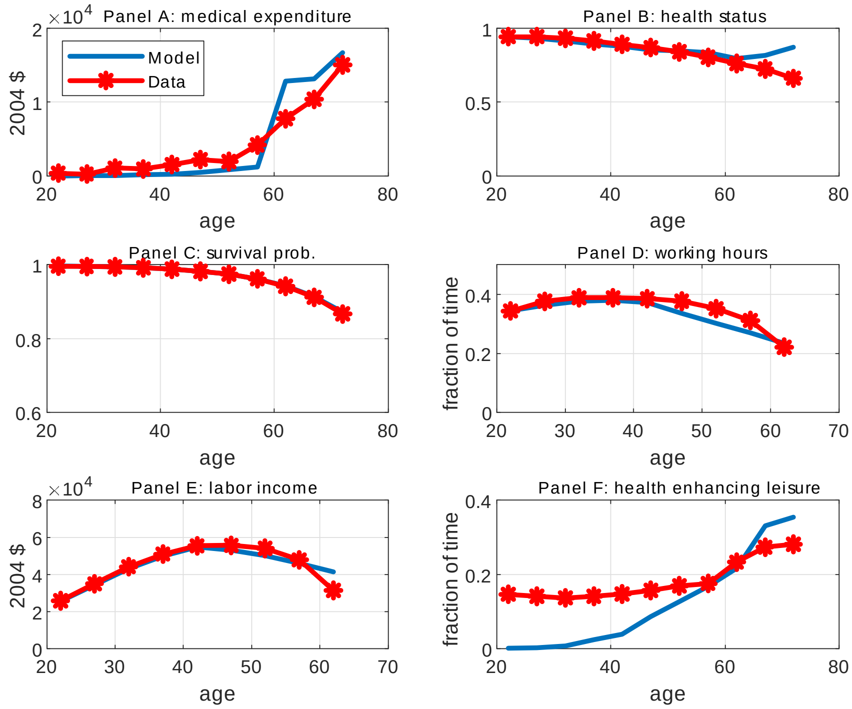

Figure 2: Life-cycle Profiles: Model vs. Data

model is able to capture the rising pattern of health-enhancing leisure time over the life cycle, especially in late ages (see panel F).

7.1 Quantifying the Effect of Taxation

To see the extent to which the observed differences in taxation may account for the observed differences in medical expenditure-GDP ratio and time allocation between the United States and Europe, we first compute the steady-state equilibrium with all parameters taking their baseline values calibrated to the US economy. Next we recompute the steady state by replacing the tax rates on labor income and consumption (both non-medical and medical) for the United States with those for each of the seven European countries and the Euro mean. For labor income tax, we follow equation (15) and take the two parameters θ_0 and θ_1 for each of the European countries as shown in Table 2. For consumption taxes on medical and non-medical goods and services, we take the rates reported in the sixth and seventh columns of Table 1, respectively. All of the other parameters are kept at their baseline values reported in Table 3. The equilibrium values of the variables of interest in each of the seven cases can be compared with their values in the baseline model. These cross-model differences computed from our simulation results can then be contrasted with the differences observed in the data between each of the seven European countries plus the Euro mean and the United States. These contrasts quantify the potential role of the observed differences in taxation between these European countries and the United States in helping account for their observed differences in the underlying variables of interest. The results so obtained from our model simulations concerning the health care expenditure-GDP ratio (pm/y), time spent on paid work (n), time spent on narrowly defined health-enhancing leisure activity (l), and time spent on potentially health-enhancing leisure activity ($v + l$), are reported in Table 5. The table also presents the data counterparts constructed from MTUS as described in Section 3 (shown in Table 1), against which the simulation results are compared.

The first four columns of Table 5 record respectively the differences between each of the seven European countries (as well as the Euro mean) and the United States in these four measures of their data. These numbers are derived by subtracting the last row from each of the first eight rows in the first four columns of Table 1. Thus,

Table 5: EU-US Differences in Health Spending-GDP Ratio and Time Allocation: Data vs. Model, Taxation Channel Only

Country	**Data (%)**				**Model (%)**				**Explanation power (%)**			
	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+
Finland	6.14	4.52	-4.0	n.a.	3.41	8.32	-5.87	n.a.	55.5	184.2	146.9	n.a.
France	4.27	7.00	-4.0	-0.27	2.19	2.23	-1.55	-0.07	51.3	31.9	38.8	23.6
Germany	4.07	6.72	-5.0	1.01	3.19	5.50	-3.89	-0.07	78.3	81.9	77.9	-6.4
Italy	6.20	6.94	-3.0	-3.09	4.84	5.53	-3.86	-0.17	78.1	79.7	128.5	5.3
Netherlands	5.49	5.98	-4.0	-0.20	3.75	3.86	-2.68	-0.04	68.3	64.7	67.0	18.7
Spain	6.5	7.32	-3.0	-2.81	1.24	1.63	-1.13	-0.09	19.1	22.3	37.7	3.2
UK	7.03	4.34	-2.0	-2.80	3.07	4.57	-3.26	-0.16	43.7	105.1	162.9	5.4
Euro Mean	5.64	6.12	-4.0	-1.71	2.52	4.46	-3.18	-0.06	44.7	73.0	79.4	3.3

[*] The fraction of time spent on potentially health-enhancing leisure activity $(v + l)$.

[+] Narrowly defined health-enhancing leisure time.

the four numbers on the second row in the first four columns of Table 5 tell us that, the health expenditure-GDP ratio is 4.27% lower, the fraction of time spent on paid work is 7.00% lower, and the fraction of time spent on potentially health-enhancing leisure activity is 4% higher, while the fraction of time spent on narrowly defined health-enhancing leisure activity is 0.27% higher in France than in the United States.

The middle four columns of Table 5 report respectively the variations of these four variables in our model when the labor income and consumption tax rates for the United States are replaced by the tax rates in each of the seven European countries and by the average tax rates over these European countries. Thus, the four numbers in the second row in the middle four columns of Table 5 show our model's prediction that, the health expenditure-GDP ratio would be 2.19% lower, the fraction of time spent on paid work would be 2.23% lower, and the fraction of time spent on potentially health-enhancing leisure activity would be 1.55% higher while the fraction of time spent on narrowly defined health-enhancing leisure activity would be 0.07% higher, were the US tax rates used in the baseline model replaced by their French counterparts.

The contrast between the middle four columns and the first four columns of Table 5 conforms to our earlier conclusion based on analytical results. That is, our model predicted that US-Europe differences in the various variables of interest, which are driven solely by their differences in taxation in current simulations, are broadly consistent with their differences in these variables observed in the data. Generally speaking, the lower tax rates faced by Americans than by Europeans lead our model to predict a higher health-care expenditure to GDP ratio, more time spent on paid work, and less time spent on health-enhancing leisure activity in the United States than in Europe, which are exactly what we observe from the comparison of the US and European data.

The last four columns of Table 5 give us a more quantitative feel about the extent to which the observed differences in taxation between the United States and Europe may help explain their observed differences in those variables of interest. The numbers in these last four columns of the table are obtained by dividing the numbers in the middle four columns, which we recall are generated from our model, by the corresponding numbers in the first four columns, which we recall are recorded from the data. As we scroll down from the first row to the seventh row in these columns to go over the results for each of the seven European countries, in comparison to the United States, we can see that the observed cross-country differences in taxation may help provide a rather coherent account for the observed cross-country differences in the underlying variables of interest – sometimes to a great degree, and other times more modestly. As is illustrated by the last row in the last four columns of the table, on average, the US-EU differences in labor income and consumption tax rates may help account for 44.7% of their differences in health expenditure-GDP ratio,[23] 73.0% of their differences in time spent on paid work,[24] 79.4% of their differences in time

[23] It is worth noting that if we further assume that European countries have more generous public health insurance than the employer-based health insurance and Medicare in the United States (e.g., if their co-pay rate is assumed to be even lower than 20%), the explanatory power of the model on cross-country differences in the pm/y ratio could be lower than 44.7%.

[24] In the model, cross-country difference in taxation explains a majority of cross-country difference

spent on potentially health-enhancing leisure activity, and 3.3% of their differences in time spent on narrowly defined health-enhancing leisure time.[25]

7.2 Quantifying the Effect of Relative Health Care Price

A parallel exercise is conducted to help isolate the effect of relative health care price. This is done by recomputing the steady-state equilibrium while replacing the relative health care price in the United States used in the baseline model with that in each of the seven European countries reported in the eighth column of Table 1, while keeping all of the other parameters at their baseline values reported in Table

in working time. This result replicates the success of Prescott (2004). Finland is an outlier, in the sense that the model significantly overstates the power of cross-country difference in taxation in explaining the difference in labor supply between Finland and the United States. This is not surprising, as Rogerson (2007) points out that Scandinavian countries are the outliers of Precott's tax-labor supply story. This is so because Scandinavian countries face much higher tax rates than the United States and continental Europe, yet their working hours are much closer to the working hours in the United States than to those in continental Europe.

[25] The explanatory power of the taxation channel on cross-country differences in narrowly defined health-enhancing leisure time is much less significant when compared with its explanatory powers on cross-country differences in working hours and in potentially health-enhancing leisure time. We interpret this as indicating both the importance of differentiating more carefully different types of health-enhancing leisure activities in actuality, and the potential importance of factors that may go beyond economic arrangement like taxation, such as cultural (e.g., social norms) and preference factors, in shaping a nation's leisure time activities (e.g., Boeri *et al.* 2008).

3. The equilibrium values of the variables of interest in each of the seven cases are compared with their values in the baseline model. The resultant differences in health spending-GDP ratio, time spent on paid work, time spent on potentially health-enhancing leisure activity, and time devoted to narrowly defined health-enhancing leisure activity, which are reported in the middle four columns of Table 6, can then be contrasted with the differences in these variables observed in the data between each of the seven European countries and the United States, which are presented in the first four columns of Table 6.

These contrasts between model simulations and data observables conform to our earlier discussion concerning the double-edged role of relative health care price in shaping the health investment portfolio. Our current numerical simulations show that the observed US-EU difference in relative health care price may help explain only 2.8% of their observed difference in health expenditure-GDP ratio. This implies that while the effect of relative health care price on the cost per unit of medical consumption dominates its effect on the composition of health inputs, the former is almost entirely canceled out by the latter. On the other side, the relative health care price difference generates a negligible cross-model difference in narrowly defined health-enhancing leisure time: our data observables show that Europeans actually spend 1.71% more of that time measure than Americans, while our model can only explain 0.5% of this difference.[26] The effects of US-EU difference in relative health

[26] In addition to the aforementioned portfolio rebalancing effect arising from factor substitution in health production, the relative health care price difference could also bring with it an income effect that goes with, while the substitution effect goes against, the data on the US-EU difference in narrowly defined health-enhancing leisure time. Our numerical simulations show that this sub-

care price on cross-country difference in the other measures of time use are also very limited: the observed US-EU difference in relative health care price leads our model to predict that paid work time would be 0.20% lower and time spent on potentially health-enhancing leisure activity would be 0.17% higher in Europe than in the United States, contributing only marginally to explaining the US-EU differences in these measures of time allocation.

The above results are summarized in the last row of Table 6.

It is worth noting that the construction of the price index for health care often does not take into account changes in the quality of health care services. Lawver (2012) shows that after adjusting for health care quality changes, the price of medical goods and services in the United States rose by only 26 percent over the period 1996–2007, less than half of the Bureau of Labor Statistics estimate of 54 percent. With higher TFP growth of the health care sector in the United States than in Europe, taking into account US-EU differences in health care quality changes, the effect of the relative health care price channel could be moderated down even further from its already minor role presented here compared to that of taxation.

7.3 Joint Effects of Taxation and Relative Health Care Price

We assess in this section the joint effects of taxation and relative health care price. To do so, we recompute the model's equilibrium by replacing the labor income tax

stitution effect is quantitatively dominated by the income effect so the net effect goes along with the data. But the two effects almost cancel out each other.

Table 6: EU-US Differences in Health Spending-GDP Ratio and Time Allocation: Data vs. Model, Price Channel Only

Country	Data (%)				Model (%)				Explanation power (%)			
	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^{*}	Δl^{+}	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^{*}	Δl^{+}	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^{*}	Δl^{+}
Finland	6.14	4.52	-4.0	n.a.	0.35	0.20	-0.16	n.a.	5.7	4.5	4.0	n.a.
France	4.27	7.00	-4.0	-0.27	0.24	0.19	-0.16	-0.01	5.5	2.7	3.9	30.3
Germany	4.07	6.72	-5.0	1.01	0.09	0.20	-0.17	0.02	2.2	3.0	3.3	13.4
Italy	6.20	6.94	-3.0	-3.09	-0.36	-0.26	0.21	-0.02	-5.7	-3.7	-7.0	4.3
Netherlands	5.49	5.98	-4.0	-0.20	0.12	0.26	-0.21	0.02	2.2	4.3	5.3	-51.1
Spain	6.5	7.32	-3.0	-2.81	0.29	0.06	-0.06	0.03	4.5	0.8	2.1	-7.0
UK	7.03	4.34	-2.0	-2.80	0.16	0.22	-0.18	-0.01	2.3	5.0	8.8	1.2
Euro Mean	5.64	6.12	-4.0	-1.71	0.16	0.20	-0.17	0.00	2.8	3.3	4.2	0.5

* The fraction of time spent on potentially health-enhancing leisure activity $(v + l)$.

\+ Narrowly defined health-enhancing leisure time.

rate, the tax rates for non-medical and medical consumption, and the relative health care price for the United States with those for each of the seven European countries reported in the fifth to eighth columns of Table 1, and θ_0 and θ_1 reported in the first and second columns of Table 2, while keeping all of the other parameters at their baseline values reported in Table 3. The equilibrium values of the variables of interest in each of the seven cases are compared with their values in the baseline economy. The resultant differences in health spending-GDP ratio, time spent on paid work, time spent on potentially health-enhancing leisure activity, and time devoted to narrowly defined health-enhancing leisure activity, which are reported in the middle four columns of Table 7, can then be contrasted with the differences in these variables observed from the data between each of the seven European countries and the United States, which are presented in the first four columns of Table 7.

As is illustrated by these contrasts between our model's predictions and the data, the US-Europe differences in taxation and in relative health care price jointly may provide a fairly successful account of their differences in the underlying variables of interest (except for time spent on narrowly defined health-enhancing leisure activity). As can be seen from the last row in the last four columns of Table 7, on average, the US-EU differences in taxation and in relative health care price together may help account for 60.2% of their difference in health care expenditure-GDP ratio, 82.8% of their difference in time spent on paid work, 89.5% of their difference in time spent on potentially health-enhancing leisure activity, and 6.2% of their difference in narrowly defined health-enhancing leisure time. This is to say that, the observed US-EU differences in taxation and relative health care price can jointly help explain

Table 7: EU-US Differences in Health Spending-GDP Ratio and Time Allocation: Data vs. Model, Taxation and Price Channels Jointly

Country	**Data (%)**				**Model (%)**				**Explanation power (%)**			
	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+
Finland	6.14	4.52	-4.0	n.a.	3.69	8.93	-6.33	n.a.	60.0	197.8	158.2	n.a.
France	4.27	7.00	-4.0	-0.27	2.78	2.29	-1.61	-0.02	64.9	32.7	40.3	37.0
Germany	4.07	6.72	-5.0	1.01	3.24	6.07	-4.35	0.02	79.6	90.4	86.9	9.1
Italy	6.20	6.94	-3.0	-3.09	3.10	5.10	-3.62	-0.02	49.9	73.6	120.7	2.8
Netherlands	5.49	5.98	-4.0	-0.20	4.09	5.02	-3.51	0.03	74.4	84.0	87.8	-87.6
Spain	6.5	7.32	-3.0	-2.81	1.32	1.91	-1.35	0.02	20.3	26.1	45.1	-4.6
UK	7.03	4.34	-2.0	-2.80	3.30	5.04	-3.62	-0.03	46.9	116.0	181.1	5.4
Euro Mean	5.64	6.12	-4.0	-1.71	3.40	5.07	-3.58	-0.02	60.2	82.8	89.5	6.2

* The fraction of time spent on potentially health-enhancing leisure activity $(v + l)$.

+ Narrowly defined health-enhancing leisure time.

the majority of the US-EU differences in health expenditure-GDP ratio and time allocation, except for the last measure of time use, of which only a minority of the US-EU difference is explained.

7.4 Perils of Abstracting Leisure from Health Production

We conclude this section by showing why we consider health-enhancing leisure time as an important input in the health production function as shown in equation (12). The fact that not only medical care but leisure can be important for maintaining health, which is incorporated in the baseline model in a way that is consistent with empirical evidence, is a key feature of the model for its success in explaining cross-country differences in medical expenditures. The empirical evidence discussed in Section 3 and the analytical illustration presented in Section 4 both show, and the subsequent numerical simulations of the large-scale life-cycle OLG model also confirm, that a key mechanism by which variation in taxation can affect the medical expenditure-GDP ratio is through the impact of taxation on the composition of the health investment portfolio and the allocation of time. If we were to abstract the time input away from health production, this mechanism would be weakened.

A counterfactual experiment helps put this into a more quantitative perspective. The mis-specified model as described above is configured by setting the share of time input in health production to zero, that is, by setting $\theta = 1$, accompanied with proper recalibration to ensure internal consistency with the baseline model and the data. The mis-specified model configured this way is then used to re-conduct the exercise described in Section 7.1. The results are reported in Table 8. In this mis-specified model, the US-EU difference in taxation would account for 36.5% of their difference in medical expenditure-GDP ratio, as opposed to 44.7% in the baseline model, a significant drop by 8.2%. This is to say that abstracting the time input away from health production by itself would lead to almost 18.3% decline in the explanatory power of the model in our key variable of interest.[27] In addition, the mis-specified model also overstates the explanatory power of US-EU difference in taxation on their difference in time spent on paid work: it exceeds 100%, which is another unpleasant consequence of abstracting leisure from health production.

[27] The 8.2% reduction in the explanatory power of the mis-specified model from that of the baseline model is due to the loss of the portfolio rebalancing channel in health investment. The retained 36.5% explanatory power comes from two remaining effects of taxation that are present even in the mis-specified model. First, the health-neutral leisure versus work time choice, inasmuch as it is affected by taxation, remains relevant for the working-age people, which in turn affects their demand for medical goods and services. Second, and probably more importantly, the direct effect of non-medical and medical consumption taxes on the demand for medical consumption continues to be relevant for both workers and retirees. Through the working of these two remaining channels, the remaining 36.5% explanatory power of the mis-specified model comes from the fact that labor income and medical consumption tax rates are lower in the United States than in Europe. As a result, both workers and retirees in Europe would tend to consume less medical goods and services than their American counterparts, just as is observed from the data. While the non-medical consumption tax rate is also lower in the United States than in Europe, its effect is quantitatively dominated by the effects of labor income and medical consumption taxes.

Table 8: EU-US Differences in Health Spending-GDP Ratio and Time Allocation: Data vs. Model without Health-enhancing Leisure Time

Country	**Data** (%)		**Model** (%)		**Explanation power** (%)	
	$\Delta\left(\frac{pm}{y}\right)$	Δn	$\Delta\left(\frac{pm}{y}\right)$	Δn	$\Delta\left(\frac{pm}{y}\right)$	Δn
Finland	6.14	4.52	2.95	11.06	48.0	244.9
France	4.27	7.00	1.70	2.35	39.7	33.6
Germany	4.07	6.72	2.31	8.15	56.7	121.4
Italy	6.20	6.94	2.01	6.20	32.4	89.4
Netherlands	5.49	5.98	1.68	5.41	30.6	90.6
Spain	6.5	7.32	0.79	1.35	12.1	18.4
UK	7.03	4.34	2.10	6.82	29.9	157.1
Euro Mean	5.64	6.12	2.06	6.35	36.5	103.9

8 Sensitivity Analyses

In this section, we conduct sensitivity analyses to investigate how robust our quantitative results are to alternative specifications of important features of our model. Since the health production function and private health insurance are two fundamental building blocks of the model, we focus on examining the robustness of our quantitative results to alternative coverages of private health insurance and alternative values of key elasticity of inputs in the health production function. To help conserve space, we confine our presentation in this section to sensitivity checks on the robustness of quantitative significance of the taxation channel only, while any potential cross-country difference in relative health care price is muted. In each of the sensitivity and counterfactual analyses, proper recalibration is conducted to ensure internal consistency across all model specifications and with the data.

8.1 Health Insurance Coverage

We conduct an exercise to test the robustness of our quantitative results with respect to health insurance coverage. In the baseline model, the private health insurance coverage rate for workers is set equal to 0.8. Were we to set the coverage rate to a higher level, the power of our model in explaining the US-EU difference in medical expenditure-GDP ratio would be even higher. To see how much worse our model's performance can go when this rate is set lower, we consider here a lower coverage rate. Since a coverage rate of 0.6 may be arguably viewed as a lower bound for the actual coverage rate in the real world, we consider this level of coverage rate for our robustness check. Table 9 reports the results under the health insurance coverage rate $\phi_p = 0.6$. As can be seen from the table, even with this "lower-bound" coverage rate of health insurance, the US-Europe difference in taxation may still help explain 41.2% of the US-EU difference in medical expenditure-GDP ratio.

8.2 Health Production Function

The second robustness check is on the sensitivity of our quantitative results to the elasticity of substitution between medical goods and services and health-enhancing leisure time in health production, ϖ, which is set to 1.3 in the baseline calibration that is consistent with the empirical estimates by He, Huang, and Hung (2013). We here examine two alternative values of ϖ, 1 and 0.9, both lower than the baseline value. Clearly, the case with $\varpi = 1$ corresponds to a Cobb-Douglas health production function, which is a special case of the general CES form of health production function postulated in the baseline model.

Table 10 and Table 11 summarize respectively our simulation results for the cases with $\varpi = 1$ and $\varpi = 0.9$. Recall that a key mechanism in our setting is the rebalancing of the health investment portfolio due to variations in the tax code, which hinges on substitution between goods and time inputs in health production. The lower the value of ϖ is, the weaker this mechanism is. Thus it is natural to see that the explanatory power of the taxation channel on the US-EU difference in medical expenditure-GDP ratio is smaller (i.e., 32.9% and 31.0%) the lower this elasticity of substitution is (i.e., $\varpi = 1$ and 0.9). That said, in all of the cases, the model may still help account for a significant fraction of the US-EU difference in the

Table 9: EU-US Differences in Health Spending-GDP Ratio and Time Allocation: Data vs. Model with Health Insurance Coverage=0.6

Country	**Data (%)**				**Model (%)**				**Explanation power (%)**			
	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+
Finland	6.14	4.52	-4.0	n.a.	3.27	8.43	-6.03	n.a.	53.3	186.6	150.7	n.a.
France	4.27	7.00	-4.0	-0.27	0.91	2.30	-1.67	0.18	21.3	32.9	41.9	-65.0
Germany	4.07	6.72	-5.0	1.01	3.10	5.90	-4.26	0.00	76.1	87.8	85.2	0.0
Italy	6.20	6.94	-3.0	-3.09	2.21	4.88	-3.52	0.09	35.6	70.3	117.3	-2.8
Netherlands	5.49	5.98	-4.0	-0.20	2.10	4.42	-3.18	0.29	38.2	73.9	79.5	-134.0
Spain	6.5	7.32	-3.0	-2.81	0.40	1.09	-0.80	-0.03	6.2	14.9	26.6	1.1
UK	7.03	4.34	-2.0	-2.80	3.06	4.94	-3.58	-0.14	43.5	113.8	179.1	4.7
Euro Mean	5.64	6.12	-4.0	-1.71	2.32	4.53	-3.24	-0.03	41.2	74.1	80.9	1.4

* The fraction of time spent on potentially health-enhancing leisure activity $(v + l)$.
+ Narrowly defined health-enhancing leisure time.

health expenditure-GDP ratio attributive to their difference in taxation.

9 Concluding Remarks

We have documented two sets of empirical observations over the past many years. First, the United States has spent a larger fraction of its GDP on health care and devoted more time to paid work and less time to health-enhancing leisure time activities, when compared to most comparably rich European countries. Second, labor income and consumption tax rates are considerably lower, while relative health care price is generally higher, in the United States than in these Eurozone countries. We have shown that these two sets of facts may be related to each other, and a key to such link may have to do with another empirically relevant fact, which is also documented in this paper, that is, both leisure and medical care are important for maintaining health.

We use both an analytical setting and a large-scale quantitative life-cycle OLG model to help link these sets of facts in a general equilibrium framework. Our results show that the US-EU differences in taxation may help explain 44.7% of their differences in health expenditure-GDP ratio and more than 70% of their differences in time allocation.

The fact that leisure and medical care are both important in maintaining health can be pertinent to other issues of interest. For instance, He, Huang, and Hung (2016) find that this portfolio view of health investment is important for understanding the joint cyclical behaviors of medical expenditure and health capital in modern

Table 10: EU-US Differences in Health Spending-GDP Ratio and Time Allocation: Data vs. Model with Cobb-Douglas Health Production Function

Country	**Data (%)**				**Model (%)**				**Explanation power (%)**			
	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+
Finland	6.14	4.52	-4.0	n.a.	1.32	8.98	-6.33	n.a.	21.4	198.8	158.3	n.a.
France	4.27	7.00	-4.0	-0.27	1.38	3.73	-2.40	-0.03	32.4	53.2	60.0	10.9
Germany	4.07	6.72	-5.0	1.01	2.07	6.19	-4.37	-0.30	50.8	92.2	87.3	-29.1
Italy	6.20	6.94	-3.0	-3.09	1.64	5.56	-3.94	-0.13	26.5	80.2	131.4	4.2
Netherlands	5.49	5.98	-4.0	-0.20	1.29	4.91	-3.44	-0.05	23.5	82.2	86.0	25.5
Spain	6.5	7.32	-3.0	-2.81	1.01	2.05	-1.47	0.06	15.5	28.0	48.9	-2.0
UK	7.03	4.34	-2.0	-2.80	2.26	5.12	-3.61	-0.23	32.1	117.9	180.4	7.8
Euro Mean	5.64	6.12	-4.0	-1.71	1.86	5.51	-3.90	-0.16	32.9	90.0	97.5	9.1

* The fraction of time spent on potentially health-enhancing leisure activity $(v+l)$.

+ Narrowly defined health-enhancing leisure time.

Table 11: EU-US Differences in Health Spending-GDP Ratio and Time Allocation: Data vs. Model with Elasticity of Substitution=0.9 in Health Production Function

Country	**Data (%)**				**Model (%)**				**Explanation power (%)**			
	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+	$\Delta\left(\frac{pm}{y}\right)$	Δn	Δlei^*	Δl^+
Finland	6.14	4.52	-4.0	n.a.	0.66	6.65	-3.99	n.a.	10.7	147.2	99.9	n.a.
France	4.27	7.00	-4.0	-0.27	0.95	2.40	-1.77	0.13	22.2	34.3	44.3	-46.7
Germany	4.07	6.72	-5.0	1.01	1.80	5.14	-3.61	0.22	44.3	76.6	72.1	21.1
Italy	6.20	6.94	-3.0	-3.09	1.50	4.59	-3.31	0.15	24.1	66.2	110.5	-4.6
Netherlands	5.49	5.98	-4.0	-0.20	1.18	3.67	-2.58	0.26	21.5	61.4	64.6	-123.6
Spain	6.5	7.32	-3.0	-2.81	0.54	1.30	-0.98	-0.02	8.3	17.7	32.7	0.6
UK	7.03	4.34	-2.0	-2.80	2.05	4.33	-3.14	-0.06	29.1	99.8	157.2	2.2
Euro Mean	5.64	6.12	-4.0	-1.71	1.75	4.35	-3.15	-0.01	31.0	71.1	78.6	0.6

* The fraction of time spent on potentially health-enhancing leisure activity $(v + l)$.

+ Narrowly defined health-enhancing leisure time.

industrialized economies. In light of these findings, further investigation of a broad set of macro-health issues for which this empirically motivated feature of the health investment portfolio may be relevant should be elevated to the top of our research agenda.

Appendix

A.1 Categorizing Health-enhancing Leisure Time in MTUS

In this appendix, we explain how we categorize health-enhancing leisure time from MTUS. We first note that there are three sub data sets in MTUS, namely, MTUS-adult-aggregate, MTUS-adult-episode, and MTUS-simple. "MTUS-adult-aggregate" contains 11 countries including Australia, Austria, France, Germany, Israel, Italy, Netherlands, Spain, the United Kingdom, South Africa, and the United States. "MTUS-simple" contains data from 16 countries including Australia, Austria, Canada, Denmark, France, Germany, Israel, Italy, Netherlands, Norway, Korea, Slovenia, Spain, the United Kingdom, South Africa, and the United States. There are five more countries in "MTUS-simple" than in "MTUS-adult-aggregate." They are Canada, Denmark, Norway, Korea, and Slovenia.

"MTUS-adult-aggregate" and "MTUS-simple" contain information on time use. "MTUS-adult-aggregate" contains the underlying time use data and "MTUS-simple" contains some further constructed variables. Since we need detailed information on time use in order to construct health-enhancing leisure time, we use the data set "MTUS-adult-aggregate" for our empirical analyses in Section 3 and Section 4.2. For our empirical analyses therein, we exclude South Africa since it is not a European country and its health care system is drastically distinct from the European system in nature. This leaves 10 countries in "MTUS-adult-aggregate" for our empirical analyses conducted in Section 3 and Section 4.2.

The existing empirical literature does not give a clear-cut definition on health-enhancing leisure time. For example, Duernecker and Herrendorf (2018) use MTUS to study the effects of labor income taxes and labor productivity on households' time reallocation, but they only construct general leisure time, not health-enhancing leisure time in particular. Podor and Halliday (2012) employ ATUS to analyze the relationship between health status and time allocation over the life cycle. Their focus is on the different time allocation patterns across health status rather than on which time use category may improve health. Motivated by the literatures of biomedical science, public health, psychobiology, and biosociology summarized in Section 2, we hand pick 20 categories of time use that are evidently health-enhancing. In doing so, we consider not only the potential health-enhancing effects, but also the life-cycle properties of those time use categories (e.g., Podor and Halliday 2012). Table 12 presents these categories of time use.

In an earlier version of this paper (He, Huang and Ning 2019), we constructed two nested measures of health-enhancing leisure time. The first, "clearly defined" health-enhancing leisure time, was labeled "leisure time 1" (see Table 13). This includes time spent on sports, exercises, gardening, and go-out. The second and a broader measure, "not so sure" health-enhancing leisure time, was labeled "leisure time 2," which is constructed by adding on top of leisure time 1 additional uses

Table 12: The Categories: Narrowly Defined Health-enhancing Leisure Time

Activity codes		**Description**
#	**core file variable**	
17	Educatn (5)	leisure course or other education or training
34	Religion (15)	worship and religious activity
35	Goout (23)	general out-of-home leisure
36	Goout (23)	attend sporting event
37	Goout (23)	cinema, theatre, opera, concert
42	Sportex (19)	general sport or exercise
43	Sportex (19)	Walking
44	Sportex (19)	Cycling
45	Goout (23)	other out-of-doors recreation
46	Garden (10)	gardening/forage (pick mushrooms), hunt/fish
47	Petcare (11)	walk dogs
50	Leisure (24)	games (social or solitary), other in-home social
51	Leisure (24)	general indoor leisure
52	Leisure (24)	artistic or musical activity
54	Leisure (24)	knit, crafts or hobbies
55	Leisure (24)	relax, think, do nothing
56	Read (21)	Read
57	TVradio (20)	listen to music, ipod, CD, audio book
58	TVradio (20)	listen to radio
59	TVradio (20)	watch TV, DVD, including web streamed content

Note: Categories are taken from Table 3.1: Harmonised activity codes (69 and 25 category typologies) in Fisher, K., and J. Gershuny (2016): "Multinational time use study: User's guide and documentation pertaining to data release 7."

Table 13: The Categories: Health-enhancing Leisure Time 1

Activity codes		Description
#	core file variable	
34	Religion (15)	worship and religious activity
35	Goout (23)	general out-of-home leisure
36	Goout (23)	attend sporting event
37	Goout (23)	cinema, theatre, opera, concert
40	Goout (23)	party, reception, social event, gambling
42	Sportex (19)	general sport or exercise
43	Sportex (19)	Walking
44	Sportex (19)	Cycling
45	Goout (23)	other out-of-doors recreation
46	Garden (10)	gardening/forage (pick mushrooms), hunt/fish
47	Petcare (11)	walk dogs
48	Leisure (24)	receive or visit friends
49	Leisure (24)	conversation (in person, phone)
50	Leisure (24)	games (social or solitary), other in-home social
51	Leisure (24)	general indoor leisure
52	Leisure (24)	artistic or musical activity
55	Leisure (24)	relax, think, do nothing
57	TVradio (20)	listen to music, ipod, CD, audio book
62	Travel (18)	no activity, recorded travel mode or change of location

Note: Categories are taken from from Table 3.1: Harmonised activity codes (69 and 25 category typologies) in Fisher, K., and J. Gershuny (2016): "Multinational time use study: User's guide and documentation pertaining to data release 7."

of time listed in Table 14, which may arguably be health-enhancing or not. This includes time spent on playing computer games and travels. Our baseline measure of health-enhancing leisure time adopted in the main text (Section 3.3) falls in between leisure time 1 and leisure time 2. As a robustness check, Figure 3 plots leisure time 1 and leisure time 2 against each of the tax rates. As is clear, all of these scatter plots also show evidence consistent with the prediction from the analytical model.

Table 14: The Additional Categories: Health-enhancing Leisure Time 2

Activity codes		**Description**
#	**core file variable**	
17	Educatn (5)	leisure course or other education or training
25	Shopserv (9)	consume personal care services
30	Ikidcare (14)	read to, talk or play with child
39	Goout (23)	restaurant, cafe bar, pub
41	Goout (23)	imputed time away from home
53	Leisure (24)	written correspondence
54	Leisure (24)	knit, crafts or hobbies
56	Read (21)	Read
58	TVradio (20)	listen to radio
59	TVradio (20)	watch TV, DVD, including web streamed content
60	Compint (22)	play computer games
65	Travel (18)	travel for voluntary/civic/religious activity
66	Travel (18)	child/adult care-related travel

Note: Categories are taken from from Table 3.1: Harmonised activity codes (69 and 25 category typologies) in Fisher, K., and J. Gershuny (2016): "Multinational time use study: User's guide and documentation pertaining to data release 7."

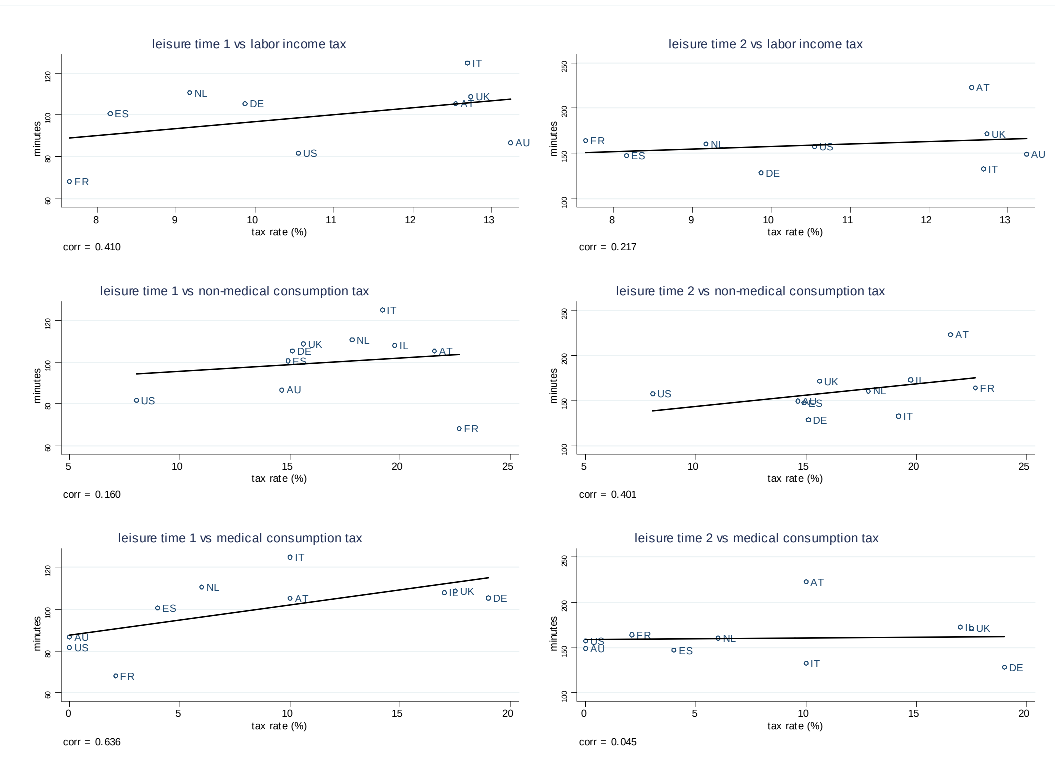

Figure 3: Taxes and Health-enhancing Leisure Times 1 and 2: Cross-country Evidence

A.2 Proof of Proposition 1

This appendix provides some details concerning the proof of Proposition 1.

Applying Implicit Function Theorem to totally differentiate equations (5), (6), (7), and (8) in the text with respect to τ_n, τ_c, and τ_m, respectively, we obtain

$$(23)\qquad \begin{bmatrix} -\frac{U''}{U'} & \frac{V''}{V'} & 0 & 0 \\ 0 & 0 & \frac{g_{ll}}{g_l} - \frac{g_{ml}}{g_m} & \frac{g_{lm}}{g_l} - \frac{g_{mm}}{g_m} \\ 0 & -\frac{V''}{V'} & \frac{W''}{W'}g_l + \frac{g_{ll}}{g_l} & \frac{W''}{W'}g_m + \frac{g_{lm}}{g_l} \\ 1 & A & A & p \end{bmatrix} \begin{bmatrix} \frac{\partial c}{\partial \tau_n} \\ \frac{\partial v}{\partial \tau_n} \\ \frac{\partial l}{\partial \tau_n} \\ \frac{\partial m}{\partial \tau_n} \end{bmatrix} = \begin{bmatrix} \frac{-1}{1-\tau_n} \\ \frac{-1}{1-\tau_n} \\ 0 \\ 0 \end{bmatrix},$$

$$(24)\qquad \begin{bmatrix} -\frac{U''}{U'} & \frac{V''}{V'} & 0 & 0 \\ 0 & 0 & \frac{g_{ll}}{g_l} - \frac{g_{ml}}{g_m} & \frac{g_{lm}}{g_l} - \frac{g_{mm}}{g_m} \\ 0 & -\frac{V''}{V'} & \frac{W''}{W'}g_l + \frac{g_{ll}}{g_l} & \frac{W''}{W'}g_m + \frac{g_{lm}}{g_l} \\ 1 & A & A & p \end{bmatrix} \begin{bmatrix} \frac{\partial c}{\partial \tau_c} \\ \frac{\partial v}{\partial \tau_c} \\ \frac{\partial l}{\partial \tau_c} \\ \frac{\partial m}{\partial \tau_c} \end{bmatrix} = \begin{bmatrix} \frac{-1}{1+\tau_c} \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

$$(25)\qquad \begin{bmatrix} -\frac{U''}{U'} & \frac{V''}{V'} & 0 & 0 \\ 0 & 0 & \frac{g_{ll}}{g_l} - \frac{g_{ml}}{g_m} & \frac{g_{lm}}{g_l} - \frac{g_{mm}}{g_m} \\ 0 & -\frac{V''}{V'} & \frac{W''}{W'}g_l + \frac{g_{ll}}{g_l} & \frac{W''}{W'}g_m + \frac{g_{lm}}{g_l} \\ 1 & A & A & p \end{bmatrix} \begin{bmatrix} \frac{\partial c}{\partial \tau_m} \\ \frac{\partial v}{\partial \tau_m} \\ \frac{\partial l}{\partial \tau_m} \\ \frac{\partial m}{\partial \tau_m} \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{-1}{1+\tau_m} \\ 0 \\ 0 \end{bmatrix}.$$

Our primary interest here is to derive analytically the implications of our model on how taxation may influence the allocation of time and health investment portfolio.

In other words, we are interested in examining how exogenous variations in τ_n, τ_c, or τ_m may affect the three endogenous variables v, l, and m. To pursue this interest, we can use the last line in (23), (24), and (25) to substitute out $\partial c/\partial \tau_n$, $\partial c/\partial \tau_c$, and $\partial c/\partial \tau_m$ from (23), (24), and (25), respectively, to obtain

$$(26) \qquad \begin{bmatrix} \frac{V''}{V'} + A\frac{U''}{U'} & A\frac{U''}{U'} & p\frac{U''}{U'} \\ 0 & m & -l \\ \varpi l \frac{V''}{V'} & 1 & 0 \end{bmatrix} \begin{bmatrix} \frac{\partial v}{\partial \tau_n} \\ \frac{\partial l}{\partial \tau_n} \\ \frac{\partial m}{\partial \tau_n} \end{bmatrix} = \begin{bmatrix} \frac{-1}{1-\tau_n} \\ \frac{\varpi lm}{1-\tau_n} \\ 0 \end{bmatrix},$$

$$(27) \qquad \begin{bmatrix} \frac{V''}{V'} + A\frac{U''}{U'} & A\frac{U''}{U'} & p\frac{U''}{U'} \\ 0 & m & -l \\ \varpi l \frac{V''}{V'} & 1 & 0 \end{bmatrix} \begin{bmatrix} \frac{\partial v}{\partial \tau_c} \\ \frac{\partial l}{\partial \tau_c} \\ \frac{\partial m}{\partial \tau_c} \end{bmatrix} = \begin{bmatrix} \frac{-1}{1+\tau_c} \\ 0 \\ 0 \end{bmatrix},$$

$$(28) \qquad \begin{bmatrix} \frac{V''}{V'} + A\frac{U''}{U'} & A\frac{U''}{U'} & p\frac{U''}{U'} \\ 0 & m & -l \\ \varpi l \frac{V''}{V'} & 1 & 0 \end{bmatrix} \begin{bmatrix} \frac{\partial v}{\partial \tau_m} \\ \frac{\partial l}{\partial \tau_m} \\ \frac{\partial m}{\partial \tau_m} \end{bmatrix} = \begin{bmatrix} 0 \\ \frac{\varpi lm}{1+\tau_m} \\ 0 \end{bmatrix},$$

where we have invoked the functional forms for W and g in simplifying expressions.

Applying the Cramer's rule, we can solve (26), (27), and (28) to obtain

$$\frac{\partial v}{\partial \tau_n} = \frac{D_v(\tau_n)}{D} > 0, \quad \frac{\partial l}{\partial \tau_n} = \frac{D_l(\tau_n)}{D} > 0, \quad \frac{\partial m}{\partial \tau_n} = \frac{D_m(\tau_n)}{D} < 0,$$

$$\frac{\partial v}{\partial \tau_c} = \frac{D_v(\tau_c)}{D} > 0, \quad \frac{\partial l}{\partial \tau_c} = \frac{D_l(\tau_c)}{D} > 0, \quad \frac{\partial m}{\partial \tau_c} = \frac{D_m(\tau_c)}{D} > 0,$$

$$\frac{\partial v}{\partial \tau_m} = \frac{D_v(\tau_m)}{D} > 0, \quad \frac{\partial l}{\partial \tau_m} = \frac{D_l(\tau_m)}{D} > 0, \quad \frac{\partial m}{\partial \tau_m} = \frac{D_m(\tau_m)}{D} < 0,$$

where

$$D \equiv l \left[\frac{V''}{V'} + A\frac{U''}{U'} - \varpi(Al + pm)\frac{V''}{V'}\frac{U''}{U'} \right] < 0,$$

$$D_v(\tau_n) \equiv \frac{l}{1-\tau_n}\left(-1 + \varpi pm \frac{U''}{U'} \right) < 0,$$

$$D_l(\tau_n) \equiv \frac{\varpi l^2}{1-\tau_n}\frac{V''}{V'}\left(1 - \varpi pm \frac{U''}{U'} \right) < 0,$$

$$D_m(\tau_n) \equiv \frac{A\varpi lm}{1-\tau_n}\frac{U''}{U'}\left(-1 + \varpi l \frac{V''}{V'} \right) > 0,$$

$$D_v(\tau_c) \equiv \frac{-l}{1+\tau_c} < 0,$$

$$D_l(\tau_c) \equiv \frac{\varpi l^2}{1+\tau_c}\frac{V''}{V'} < 0,$$

$$D_m(\tau_c) \equiv \frac{\varpi lm}{1+\tau_c}\frac{V''}{V'} < 0,$$

$$D_v(\tau_m) \equiv \frac{\varpi plm}{1+\tau_m}\frac{U''}{U'} < 0,$$

$$D_l(\tau_m) \equiv -\frac{(\varpi l)^2 pm}{1+\tau_m}\frac{V''}{V'}\frac{U''}{U'} < 0,$$

$$D_m(\tau_m) \equiv \frac{\varpi lm}{1+\tau_m}\left[-\frac{V''}{V'} - A\frac{U''}{U'} + A\varpi l \frac{V''}{V'}\frac{U''}{U'} \right] > 0.$$

It is easy to verify that the above inequalities hold under Assumption 1 about the monotonicity and curvature properties of U and V, and for all admissible values of the deep parameters presented in Definition 1. Q.E.D.

A.3 Aggregation Conditions in the Definition of Competitive Equilibrium

This appendix details some aggregation conditions concerning the definition of competitive equilibrium presented in Section 5.2 as follows:

$$
\begin{aligned}
C &= \sum_{j=1}^{J} \sum_{a} \sum_{h} \sum_{\eta} \mu_j \Phi_j(a,h,\eta) C_j(a_j,h_j,\eta), \\
M &= \sum_{j=1}^{J} \sum_{a} \sum_{h} \sum_{\eta} \mu_j \Phi_j(a,h,\eta) M_j(a_j,h_j,\eta), \\
K &= \sum_{j=1}^{J} \sum_{a} \sum_{h} \sum_{\eta} \mu_j \Phi_j(a,h,\eta) A_j(a_j,h_j,\eta), \\
H &= \sum_{j=1}^{J} \sum_{a} \sum_{h} \sum_{\eta} \mu_j \Phi_j(a,h,\eta) H_j(a_j,h_j,\eta), \\
N &= \sum_{j=1}^{j_R-1} \sum_{a} \sum_{h} \sum_{\eta} \mu_j \Phi_j(a,h,\eta) \varepsilon_j \eta N_j(a,h,\eta), \\
\nu &= \sum_{j=1}^{J} \sum_{a} \sum_{h} \sum_{\eta} \mu_j \Phi_j(a,h,\eta) \nu_j(a,h,\eta), \\
L &= \sum_{j=1}^{J} \sum_{a} \sum_{h} \sum_{\eta} \mu_j \Phi_j(a,h,\eta) L_j(a,h,\eta).
\end{aligned}
$$

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