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

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Abstract

Empirical evidence suggests that both leisure time and medical care are important for maintaining health. We develop a general equilibrium macroeconomic model in which taxation is a key determinant of the composition of these two inputs in the endogenous accumulation of health capital. In our model, higher taxes lead to using relatively more leisure time and less medical care in maintaining health. We find that difference in taxation between the US and Europe can account for a large fraction of their difference in health expenditure-GDP ratio and almost all of their difference in time input for health production.

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1 Introduction

In the past forty years or so, Americans persistently spend much more on medical care than Europeans. In one account, the average medical expenditure to GDP ratio over the period 1970-2007 is about 4 percentage point higher in the US than the average across eight comparably rich European countries, including Belgium, Finland, France, Germany, Italy, Netherlands, Spain, and the UK. Medical expenditure per capita is also much greater in the US than in Europe. As we will document in Section 2, the difference illustrated above, and to be documented in detail below, is beyond the counting of the US-EU difference in expenditure on health-related research and development, and on education and training of health personnel, neither is there any notable cross-country difference in aging or life-cycle dynamics, such as age structure of the population, or age-related medical status and expenditure, to which the cross-country difference in medical expenditure-GDP ratio can be attributed.

Then why do Americans spend so much more on health care than Europeans? In this paper, we highlight a channel that has not received much attention in the literature on health care costs. To this end, we develop a macroeconomic theory of health investment portfolio in a general equilibrium context. 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 will show below, ample empirical evidence reveals its critical importance in producing and maintaining good health. The thesis of our analysis is that these two inputs for health production must be jointly determined in general equilibrium and that, in the general equilibrium setting, cross-country variations in the determinants of such portfolio composition of health investment may hold a key to understanding the cross-country differences in health care expenditure.

We show that a key determinant of the composition of health investment portfolio is taxation, in particular, labor income and consumption taxes. Higher tax rates on consumption and labor imply lower opportunity costs of leisure. The main prediction of our theory is that higher taxes would lead to using relatively more leisure time and relatively less medical commodity in producing and maintaining good health. 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 much higher in the Eurozone countries than in the US, as we will document in Section 2. We find that this amount of difference in taxation as observed from the US and European data can explain nearly fifty percent of the difference in medical expenditure-GDP ratio between the US and Europe.

Our theory's account of the US-EU difference in medical expenditure is accompanied by its prediction on the cross-country difference in leisure time as another component of an optimal health investment portfolio under different tax rates. It is important to emphasize at the outset that this portfolio view of health investment is essential for our theory's success stated above. If we abstract from the time input in health production, as we will show below through a counterfactual experiment, higher taxes in Europe than in the US would predict that Europeans would spend a greater, rather than a smaller, share of their GDP on health care than Americans.

The important question then is whether our theory's prediction on cross-country differences in the time input for health production has any empirical support. The theory predicts that, since labor and consumption tax rates are higher in Europe than in the US, Europeans would rely more on leisure than do Americans when it comes to producing and maintaining good health. As we will show in Section 2, this is exactly what we observe from the US and European data. We find that, in fact, the US-EU difference in taxation can explain more than ninety percent of the difference in time input in health production between Americans and Europeans.

We therefore argue that differences in taxation can provide a coherent account for much of the US-EU difference in the composition of health investment portfolio. Arising also endogenously in our general equilibrium model under different tax rates are cross-country differences in sick time and in paid work time, the patterns of which are also consistent with the US-European comparisons. The intuition for these results are as follows. Higher tax rates in Europe induce lower labor supply by Europeans, leaving them with more leisure time to engage in health-enhancing activities, when compared with Americans. It is then sensible for Europeans to rely more on leisure while spending less on medical goods and services than Americans when it comes to health production. Faced with lower tax rates and thus higher opportunity costs of leisure, Americans choose to work more and spend more on medical goods and services, while having less leisure time, when compared with Europeans.

We have highlighted the role of taxation in shaping the composition of health investment portfolio. As we also show in this paper, another factor that may affect health investment portfolio is the price of health care goods and services relative to the general price level. As we will document below, relative health care price on average is higher in the US than in Europe. As a matter of 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. In this paper, we also examine the relative price effect viewed through the lens of our theory on health investment portfolio.

In the general equilibrium context of the present paper, two countervailing effects arise from a higher relative price of medical commodity on overall health spending: (1) higher expenditure per unit of medical consumption, and (2) substitution away from medical commodity towards other goods or leisure in generating utility and towards time input in producing and maintaining good health. While the effect of (1) on overall health spending dominates that of (2), it is partially offset by the latter. This is to say that the contribution of a higher relative health care price to higher overall health spending is weakened by the re-balancing of health investment portfolio. More importantly, this re-balancing implies that a higher relative health care price would lead to using relatively more of the time input and relatively less quantity of medical commodity in producing and maintaining good health.

To put this into a quantitative perspective, we fit into our model the cross-country distribution in the relative prices of health care and services as observed from the US and European data, while keeping the cross-country differences in taxation muted. This helps isolate the account of the differences in relative health care prices for the US-EU difference in the composition of health investment portfolio. We find that the relative price difference can explain about 16.8% of the difference in overall health spending-GDP ratio between the US and Europe, but its prediction on time allocation is in a direction that is exactly opposite to the US-EU comparison: it predicts that Europeans would have longer paid work time and shorter leisure time when compared to Americans, whereas as we show the opposite is true in the data.

Finally, when we turn on the cross-country differences in taxation and in relative health care prices at the same time, our model can explain nearly two thirds of the difference in overall medical expenditure-GDP ratio and more than 80% of the difference in time input for health production between the US and Europe. We therefore argue that differences in taxation and in relative health care prices jointly provide a reasonable account for the US-EU difference in the composition of health investment portfolio.

This portfolio view of health investments shed important light on the question posed at the beginning of this introduction. Our analysis recognizes the necessity of both leisure time and medical commodity in producing and maintaining good health. This permits the study of how cross-country variations in taxation and in relative health care prices may give rise to different compositions of leisure time and medical consumption in health production. To assess the quantitative significance of these effects, we hold other institutional and cultural features constant across countries. We wish to emphasize that it is not our interpretation what we analyze in the present paper constitute all of the factors for generating the cross-country differences in health care expenditure, or in time allocation, but rather we view our approach as an effective way to isolate the impact of one particular channel that naturally links two apparently distinct dimensions in decision making.

The remaining of the paper is organized as follows. In Section 2, we document the empirical evidence that motivates our study and we review the related literature. In Section 3, we present our structural model, of which endogenous choice of health investment portfolio is a defining feature. The model is a variant of the neoclassical growth model with taxation, augmented to include multiple uses of time, which influence health production and are influenced by health status. In the model, better health reduces sick time and thus makes more of the time endowment available for paid work or leisure, while both leisure and medical care help enhance health status against the depreciation of health capital. Better health also directly increases utility, and so do greater health-neutral consumption and longer leisure time. Production of goods and physical capital accumulation are modeled in the standard ways, as in the standard neoclassical model. A government taxes consumption and labor to finance its spending. The model that is presented here is thus intended to capture some of the key incentives affected by taxation and relative prices on multiple uses of time, on consumption of medical and non-medical commodities, and on their interactions with endogenous health accumulation. We characterize the model's equilibrium, discuss key first order equations, and highlight the roles of taxation and relative health care price in shaping medical expenditure and time allocation. In Section 4, we describe model parametrization and report main quantitative results. We conduct a series of decomposition and sensitivity analyses in Section 5, and we provide some concluding remarks in Section 6.

2 Empirical Evidence and Related Literature

It is a much publicized fact nowadays that Americans spend considerably more on health care than Europeans. In 2007, for instance, health care expenditure accounts for 15.7% of GDP in the US, compared with 10% in Belgium, 8.2% in Finland, 11% in France, 10.4% in Germany, 8.7% in Italy, 9.7% in Netherlands, 8.4% in Spain, and 8.4% in the UK. To a large extent, such differences have existed for quite some time. The first column of Table 1 reports the average health spending to GDP ratio over the period 1970-2007 for the US and the eight comparably rich European countries. As is apparent from the table, the US spends a much larger share of its GDP on health care over this period of time, when compared with the other countries. Health care expenditure per capita is also much greater in the US than in Europe.[1]

The differences in health care expenditure between the US and Europe illustrated above are not attributed to the US-EU differences in expenditure on health-related research and development, or on education and training of health personnel.[2] There also do not seem to exist any notable cross-country differences in aging or life-cycle dynamics, such as age structure of the population or age-related health status and expenditure, 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). This is consistent with the finding that differences in health care expenditures between the US and many of the European countries are similar in size across different age groups.[3]

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 of such empirical investigations is conducted by Sickles and Yazbeck (1998). Using a structural model to control for endogeneity and reverse causality, whereby to also take into account the opportunity cost of leisure explicitly, 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. They find that both inputs make significantly positive contributions

[1] Source: OECD Health Data 2010. Data for France are available for 1970, 1975, 1980, 1985, and at annual frequency since 1990, and we have used linear interpolation to fit in missing annual data for those years between 1970 and 1990. Data for Italy are available only for years after 1988, and the number reported in Table 1 for Italy is an average for the period 1988-2007.

[2] According to the 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; 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 detail.

[3] See, for example, Hagist and Kotlikoff (2009) for the European countries, and Jung and Tran (2010) for the US. See, also, Table 2 in Anderson and Hussey (2000).

to producing and maintaining health, while the contribution of leisure can be even more than that of medical consumption.[4] Our recent econometric estimates based on multi-country data reach a similar conclusion (e.g., He, Huang, and Hung 2013).

Empirical evidence on the significant contribution of leisure 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,[5] some of these studies also show the evidence that increases in leisure time activities help reduce medical expenditures (e.g., Colditz 1999; Pratt, Macera, and Wang 2000; Wang and Brown 2004; Brown, Wang, and Safran 2005). The recent study by Pressman, Matthews, Cohen, Martire, Scheier, Baum, and Schulz (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, Ainsworth, and Godbey (2010) provide a comprehensive review of the empirical evidence on the importance of leisure in achieving and maintaining good health, and an intuitive account of the prevention, coping, and transcendence mechanisms through which leisure enhances physical, mental, social, and cognitive health.[6]

As is explained in the introduction section, a key determinant of the composition

[4]Corroborating evidence has also been found by Kenkel (1995), Contoyannis and Jones (2004), Scholz and Seshadri (2010), and Insler (2011), among others.

[5]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, among others, Watson (1988), House, Landis, and Umberson (1988), Simon (1991), Ulrich, Simons, Losito, Fiorito, Miles, and Zelson (1991), Haskell (1994), Benca and Quintas (1997), Staats, Gatersleben, and Hartig (1997), Cohen, Doyle, Skoner, Rabin, and Gwaltney (1997), Szabo, Mesko, Caputo, and Gill (1998), Tominaga, Andow, Koyama, Numao, Kurokawa, Ojima, and Nagai (1998), Gump and Matthews (2000), Diener, Lucas, and Oishi (2002), Batty, Shipley, Marmot, and Davey (2003), Ayas, White, Al-Delaimy, Manson, Stampfer, Speizer, Patel, and Hu (2003), Ayas, White, Manson, Stampfer, Speizer, Malhotra, and Hu (2003), Ryff, Singer, and Dienberg (2004), Sacker and Cable (2005), and Warburton, Nicol, and Bredin (2006).

[6]See, also, Lazarus, Kanner, and Folkman (1980), Iso-Ahola and Weissinger (1984), Weissinger and Iso-Ahola (1984), Kleiber (1985), Tinsley and Tinsley (1986), Caldwell and Smith (1988), Iso-Ahola (1988), Hull (1990), Chalip, Thomas and Voyle (1992), and Coleman and Iso-Ahola (1993), Iwasaki and Mannell (2000), Iwasaki and Schneider (2003), and Iwasaki, Mackay, Mactavish, Ristock, and Bartlett (2006), among others.

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 then has to do with 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 US. This can be seen from the fourth to the sixth columns of Table 1, which report the average labor and consumption tax rates, along with the corresponding tax wedge, over the period 1970-2007 for the nine selected countries.[7] The tax wedge reported in the sixth column of the table, of which the precise definition will be given in the next section, is a monotonically increasing function of the labor and consumption tax rates. As such, the tax wedge is much higher in Europe than in the US, as is clear from the table. Our model then predicts that Europeans may rely less on medical commodity and more on leisure than Americans when it comes to health production. The first part of this prediction is consistent with the observation from the US and European data, as reported above, whereby the second part of the prediction also conforms to the data, as we document below.

Empirical evidence shows that conventionally defined leisure time, as is measured by the time spent away from paid work, is much shorter, whereas measured hours of paid work are much longer, in the US 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 4.3% less of their time endowment on paid work, and thus 4.3% more of their time endowment is spent on leisure, when compared to Americans.[8] As a standard practice in the literature (e.g., Rogerson 2006; Ohanian, Raffo, and Rogerson 2008; Jones and Klenow 2011), time spent on paid work is here calculated as the product of total civilian employment and annual hours per worker, divided by the size of the population aged 15-64. We then divide the measure so constructed by 365×16 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

[7] Source: McDaniel (2007). The author applies the methodology in Mendoza, Razin, and Tesar (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 average labor and consumption tax rates for Italy reported in the fourth and fifth columns of Table 1 are for the same period 1988-2007 for which the Italian health expenditure data are reported in the first column of the table. The data are downloaded from http://www.caramcdaniel.com/researchpapers.

[8] The data are taken from Ohanian, Raffo, and Rogerson (2008). They are the average for the period 1970-2004, except for Italy for which it is the average for the period 1988-2004.

unpaid work time (e.g., home production time) from the conventionally measured leisure time (i.e., the residual of paid work time). Based on the multi-country time-use surveys, which record how people allocate their time (typically using a 24-hour diary), OECD (2011) classifies time allocation by working age populations 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 19%, 14%, 46%, 20%, and 1% of the total time endowment, 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 important time inputs for the production of health.

The third column in Table 1 reports the sum of these two categories of time use, which we shall refer to as time input in health production, or, with some abuse of terminology, leisure time for short, as a fraction of the time endowment for the nine selected OECD countries. As is apparent from the table, all of the eight European countries are much higher on this time input for health production when compared with the US, and the Eurozone average is about 4% higher than the America's. This is equivalent to saying that Europeans on average spend one hour more per day on health-enhancing activities than Americans. It is worth recalling that these Eurozone countries on average spend one hour less per day on paid work than the US. Thus, it seems that Europeans shift much of this one-hour time from paid work to personal care or leisure, rather than to unpaid work, when compared with Americans.

It is also much known nowadays that the prices of health care goods and services relative to the general price levels are generally higher in the US than in Europe (e.g., Anderson, Reinhardt, Hussey, and Petrosyan 2003). This can be seen from the seventh 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 nine 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 US, 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 US 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 US is about 15% higher than the European average. These indexes are constructed by He, Huang, and Hung (2013),[9] 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).[10]

Some recent studies suggest various cultural and institutional differences between the US and Europe as potentially relevant for their differences in hours worked and/or leisure time. These include US-EU differences in preferences (e.g., Blanchard 2004), in taxation and government transfer policy (e.g., Rogerson 2001, 2004, 2006, 2008; Prescott 2004; Davis and Henrekson 2004; 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, Glaeser, and Sacerdote 2005), and in social norms for leisure and the associated multiplicity of equilibria (e.g., Alesina, et al. 2005; Burda, Hamermesh, and Weil 2008). However, none of of these studies deals with any health-related issue. On the other hand, there is an emerging class of economic models that feature endogenous health capital accumulation. These models are developed to help understand the rising medical expenditure in the US (e.g., Suen 2006; Hall and Jones 2007; Fonseca, Michaud, Gamama, and Kapteyn 2009; Zhao 2014), the welfare effects of proposed health care reforms (e.g., Feng 2008; Jung and Tran 2009), the implications of health risks for consumption, health expenditure, and the allocation of wealth among bonds, stocks, and housing (e.g., Yogo 2009), the implications of employment-based health care benefits in the US (e.g., Fang and Gavazza 2011; Huang and Huffman 2013), the relative importance of consumption and investment motives of health care demand (e.g., Halliday, He and Zhang 2014), and the joint cyclical properties of medical expenditure and health capital (e.g., He, Huang, and Hung 2014). However, none of these studies addresses the cross-country differences in health care expenditure or in time allocation.

[9] 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).

[10] 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).

3 Model and Equilibrium

Our analytical framework integrates endogenous health accumulation into a variant of the neoclassical growth model with taxation, augmented to include multiple uses of time, which influence health production and which are influenced by health status. This argumentation defines the key characteristics of our model, as suggested by the empirical evidence documented above, that is, both leisure and medical consumption are important for enhancing health status against the depreciation of health capital, which in turn affects sick time and thus the time endowment available for paid work or leisure. The linchpin of our analysis lies with taxation and relative health care prices as the key determinants of the composition of these health inputs. The model presented here is thus intended to capture key incentives affected by these determinants on multiple uses of time, on consumption of medical and non-medical commodities, and on their interactions with endogenous health accumulation, which are essential to address the topic at hand.

3.1 Setup and Equilibrium Conditions

The economy is populated with a large number of identical households, a large number of perfectly competitive firms, and a government. A representative household has one unit time endowment in each period. The length of time in period t in which the household is sick (s_t) decreases with its stock of health capital at the beginning of the period (h_t), as specified by a twice-differentiable monotone function,

$$s_t = S(h_t), \quad S'(\cdot) < 0. \tag{1}$$

The household can devote its non-sick time in period t to either paid work (n_t) or leisure (l_t), such that,

$$n_t + l_t = 1 - s_t. \tag{2}$$

This time constraint implies that the household can't work or enjoy leisure when sick. This together with equation (1) capture Grossman's (1972) notion of investment motive for health care, in that better health reduces sick time and thus makes more of the time endowment available for paid work or leisure.

The household derives utility from consumption of health-neutral goods (c_t), leisure, and health stock in period t according to $U(c_t, l_t, h_t)$, which is a twice-differentiable concave function that increases in all of its arguments. The postulation that better health directly enhances household utility captures Grossman's (1972) notion of consumption motive for health investment.

Health investment is created using health-related consumption (m_t) and leisure time according to $H(m_t, l_t)$, which is a twice-differentiable, quasi-concave function increasing in both of its arguments. The level of health stock in period $t+1$ is an update of period-t investment in health plus undepreciated health stock from the previous period, such that,

$$h_{t+1} = (1 - \delta_h)h_t + H(m_t, l_t), \tag{3}$$

where δ_h is a health capital depreciation rate. This specification is along the lines of the models estimated by Sickles and Yazbeck (1998) and by He, Huang, and Hung (2013).[11]

The household's budget constraint in period t is given by

$$(1 + \tau_c)[c_t + p_m m_t] + k_{t+1} = (1 - \tau_n)w_t n_t + (r_t + 1 - \delta_k)k_t + \Pi_t + T_t, \tag{4}$$

where τ_c, τ_n, and p_m denote respectively the tax rate on consumption, the tax rate on labor income, and the price of health care relative to that of the health-neutral commodity,[12] w_t is the wage rate, r_t is the rate of return on the household's rental of physical capital to firms in period t (k_t), δ_k is a depreciation rate of physical capital, and Π_t and T_t are respectively the profits and lump-sum transfer from firms and the government to the household.

The objective of the household is to choose the allocation of time among different uses, consumption of non-medical and medical commodities, and health and physical capitals to maximize the expected, discounted lifetime utility,

$$\mathrm{E} \sum_{t=0}^{\infty} \beta^t U(c_t, l_t, h_t), \tag{5}$$

where E is the expectations operator and β is a subjective discount factor, subject to (1)-(4), taking the wage and capital rental rates, the tax rates and relative health care price, and the initial conditions h_0 and k_0 as given.

A representative firm has a production function that generates $F(K_t, N_t; z_t)$ units of output from K_t units of physical capital and N_t units of labor inputs, under the level of technology z_t. The production function is of constant returns to scale with

[11] Sickles and Yazbeck (1998) allow the stock of health capital at a given point in time to be affected by a distributed lag of past health stocks. Using this more general specification would not change the main results of this paper.

[12] For the topics addressed in the present paper through our long-run cross-country analysis, it is without loss of generality to consider time-invariant tax rates and relative health care price, which will be calibrated to their long-run averages in the data for each of the countries under consideration.

respect to capital and labor, and is twice-differentiable, quasi-concave, and increasing in both of these two inputs. The firm rents physical capital and hires labor services from the households to produce output. The firm's profit in period t is

$$\Pi_t = F(K_t, N_t; z_t) - r_t K_t - w_t N_t. \tag{6}$$

The objective of the firm is to choose physical capital and labor inputs to maximize the profit in each period, taking the wage and capital rental rates as given.

To close the model, we assume, without the loss of generality and insight, that the government runs a balanced budget in every period and rebates all tax revenues to the households in the form of a non-distortionary lump-sum transfer,

$$\tau_c[c_t + p_m m_t] + \tau_n w_t n_t = T_t. \tag{7}$$

While being kept as simple as possible, our baseline model presented above has all the necessary features to build the central mechanism that we aim to investigate. This mechanism has to do with how labor income and consumption taxes and the relative price of medical commodity affect the incentives in the allocation of time among different uses, and of expenditure on medical and non-medical commodities, and their interactions with health production. Our view is that, it is important to understand the effect that taxation and relative health care price can have on the composition of time and goods inputs in the endogenous accumulation of health capital, and that our model described above provides a simple macroeconomic setting for conducting such analysis.

An equilibrium for this economy consists of allocations n_t, l_t, s_t, c_t, m_t, h_{t+1}, and k_{t+1} for households, and N_t and K_t for firms, together with wage rate w_t and capital rental rate r_t, for all $t \geq 0$, that satisfy the following conditions: (i) given the wage and capital rental rates, the allocations for households solve the utility maximization problem; (ii) given the wage and capital rental rates, the allocations for firms solve the profit maximization problem; (iii) the government budget constraint is satisfied; and (iv) markets for labor, physical capital, and goods clear.

To provide a general characterization of the model's equilibrium conditions, it is useful to define, in the spirit of Prescott (2004), a tax wedge as the sum of the tax rates on labor income and on consumption in units of the consumption goods,

$$\tau = \frac{\tau_n + \tau_c}{1 + \tau_c}, \tag{8}$$

which is a monotonically increasing function of the labor and consumption tax rates.

The Euler equation for optimal intertemporal allocation of consumption of the health-neutral commodity, along with the condition for optimal accumulation in physical capital, gives rise to the following familiar condition,

$$U_c(t) = \beta \mathrm{E_t} \left[U_c(t+1)(r_{t+1} + 1 - \delta_k) \right]. \tag{9}$$

The left-hand side of this equation is the cost of giving up one unit of consumption of the health-neutral commodity, measured in terms of (marginal) utility, where the right-hand side is the present value of expected future benefit from investing the foregone consumption goods in physical capital.

The Euler equation associated with the optimal composition of leisure time and health-related commodity inputs in health production is given by,

$$MRS_{l,c}(t) + MRTS_{l,m}(t) p_m = (1-\tau) w_t, \tag{10}$$

where $MRS_{l,c}(t) \equiv U_l(t)/U_c(t)$ denotes the marginal rate of substitution of leisure l for health-neutral consumption c, which measures the amount of c that can be saved on with an additional unit of l, while maintaining the same level of utility, and $MRTS_{l,m}(t) \equiv H_l(t)/H_m(t)$ denotes the marginal rate of technical substitution of leisure l for health-related consumption m, which measures the amount of m that can be saved on with one additional unit of l, while maintaining the same level of health production. The left-hand side of this equation is thus the benefit from having additional leisure, while the right-hand side of the equation is the opportunity cost of the leisure time in terms of the foregone labor income on paid work, all measured in units of the health-neutral commodity.

The Euler equation for optimal health accumulation, when combined with the condition for optimal intratemporal allocation between health-related consumption and health-neutral consumption, gives rise to the following condition,

$$\begin{aligned} & \beta \mathrm{E_t} \left[U_h(t+1) - (1-\tau) w_{t+1} S'(h_{t+1}) U_c(t+1) + (1-\delta_h) \frac{U_c(t+1)}{H_m(t+1)} p_m \right] \\ = & \frac{U_c(t)}{H_m(t)} p_m. \end{aligned} \tag{11}$$

The right-hand side of this equation is the cost at date t of producing one additional unit of health capital for date $t+1$ through health-related consumption, measured in terms of (marginal) utility. The left-hand side of this equation is the present value of expected future benefit, measured in terms of expected future (marginal) utilities, from having one additional unit of health capital at date $t+1$. The benefit includes (i) higher utility directly derived from the additional health capital, (ii) reduced sick time due to better health status, allowing more time for paid work and thus greater labor income (which boosts consumption to increase utility), and (iii) saving on future health investment (in terms of expected future marginal utility) from undepreciated health capital. It is worth mentioning that (i) and (ii) generalize Grossman's (1972) notions of consumption and investment motives for health expenditure, and relate them to the household's incentives on labor and goods markets in the presence of labor income and consumption taxes, and that the continuation value captured by (iii) indicates that the benefit from current health investment will last for many future periods due to the incomplete depreciation of health capital.

The optimality conditions for profit maximization are standard, given by,

$$r_t = F_k(k_t, n_t; z_t), \quad w_t = F_n(k_t, n_t; z_t), \tag{12}$$

which have taken into account the market clearing conditions for physical capital, $k_t = K_t$, and for paid work time, $n_t = N_t$.

The household and government budget constraints then imply the market clearing condition for goods (i.e., the resource constraint),

$$c_t + p_m m_t + k_{t+1} - (1 - \delta_k)k_t = F(k_t, n_t; z_t). \tag{13}$$

Equations (1)-(3) and (9)-(13) characterize an equilibrium.

3.2 Highlighting the Roles of Taxation and Relative Health Care Price in Shaping Health Investment Portfolio

Equations (10) and (11) hold the key to the model's central mechanism for how taxation and relative health care price may affect the optimal composition of leisure and health-related consumption, and of the multiple uses of time, as they pertain to health production.

We shall first highlight the role of taxation. As the right-hand side of (10) shows, a higher tax wedge means a lower effective wage rate and thus a lower opportunity cost of leisure. Then, as the left-hand side of (10) shows, more leisure time l will be used (relative to health-neutral consumption c) in deriving utility and (relative to health-related consumption m) in maintaining health. The flip side of the l-c trade-off in deriving utility and its implication for labor supply in the face of taxation are the linchpin of the analysis in Prescott (2002, 2004), Ohanian et al. (2008), and Rogerson (2008). Equation (10) generalizes their theory by adding on top of the l-c trade-off in deriving utility, the l-m trade-off in maintaining health. This extension strengthens the effect of taxation on labor supply, while at the same time it provides a novel theory on how a higher tax wedge may induce the household to use relatively more leisure activity and relatively less medical commodity in health production.

This extension is further enriched by another novel feature of the model, that is, health capital affects sick time and thus time available for leisure or paid work. This can be better seen by rewriting Equation (11) as follows,

$$\frac{U_c(t)}{H_m(t)}p_m = \mathrm{E_t}\sum_{i=1}^{\infty}\beta^i(1-\delta_h)^{i-1}\left[U_h(t+i)-(1-\tau)w_{t+i}S'(h_{t+i})U_c(t+i)\right]. \quad (14)$$

As the second infinite-sum on the right-hand side of (14) illustrates, a higher tax wedge weakens the investment motive for health expenditure, as the benefit from enhanced health status, in terms of reduced sick time and thus increased time for paid work, is reduced by the lowered effective wage rate. Then, as the left-hand side of (14) indicates, the household will consume less of health-related commodity m relative to health-neutral consumption c. This effect of taxation on the c-m trade-off might be quantitatively significant, given that a permanently higher tax wedge will reduce the benefit (in terms of increased time available for paid work) from current health investment for many periods in the future.

To summarize, in the presence of a higher tax wedge, the various optimal trade-offs embedded in conditions (10) and (11) would reinforce to generate a longer leisure time, a shorter time on paid work, and a smaller share of health care expenditure in total consumption spending (and a smaller medical expenditure-GDP ratio). This is to say that, when it comes to the US-Europe comparisons in medical expenditure and time allocation, cross-country difference in taxation would tend to make the model fit all dimensions of the data.

We turn now to highlighting the role of relative health care price. As Equations (10) and (14) reveal, in some sense, a higher relative health care price may play a qualitatively similar role as a higher tax wedge in affecting the optimal composition of health investment portfolio and labor supply. A higher p_m implies that more leisure time will be used (relative to medical commodity) in maintaining health and (relative to other goods and services) in deriving utility (and less of the time endowment will be supplied to paid work), as revealed by (10), and that a smaller quantity of medical commodity will be consumed relative to other goods and services, as revealed by (14).

Hence, in the presence of a higher relative health care price, the various optimal trade-offs dictated by conditions (10) and (11) would tend to generate a longer leisure time and a shorter time on paid work, along with a greater share of overall health spending in total consumption expenditure, although the magnitude of the latter is mitigated by the effect of substitution away from medical commodity towards other goods or leisure in delivering utility and towards time input in maintaining health.

Recall that relative health care price is higher in the US than in Europe. The US-EU difference in relative health care price then predicts that Europeans would have longer paid work time and shorter leisure time than Americans, a pattern of cross-country difference in time allocation that is exactly opposite to the US-EU comparison actually observed from the data, although its prediction on the US-EU difference in overall health spending to GDP ratio can be in line with the data.

4 Parametrization and Main Quantitative Results

As illustrated by the analysis in Section 3, our model predicts that households would use relatively more leisure time and less medical commodity in health production, while working less for pay, when faced with a higher tax wedge. Then an interesting question is: To what extent can the US-EU differences in taxation account for their differences in health expenditure-GDP ratio and in time allocation? Given that this question is quantitative in nature, we need to parameterize our model to answer it.

4.1 Parametrization and Measurement

To begin, we follow Grossman (1972) to postulate the following functional form for how the stock of health capital affects sick time,

$$S(h_t) = Qh_t^{-\gamma}, \tag{15}$$

where parameter γ measures the sensitivity of sick time with respect to health stock, and Q is a scaling parameter.

Then, in light of our empirical study presented in a companion paper (e.g., He, Huang, and Hung 2013), we parameterize the health production function using a CES version of the trans-log production function of health estimated by Sickles and Yazbeck (1998),

$$H(m_t, l_t) = \begin{cases} B[\theta m_t^{\frac{\omega-1}{\omega}} + (1-\theta) l_t^{\frac{\omega-1}{\omega}}]^{\frac{\omega\xi}{\omega-1}} & \text{if } \omega \neq 1, \\ B(m_t^{\theta} l_t^{1-\theta})^{\xi} & \text{if } \omega = 1, \end{cases} \tag{16}$$

where θ and $1-\theta$ measure respectively the shares of medical commodity and leisure time inputs in health production in the long-run stationary equilibrium, ω measures the elasticity of substitution between these two inputs, ξ measures the degree of returns to scale in the health production technology, and B is a scaling parameter that measures the level of technology in health production.

Next, similarly as in Huang and Huffman (2013), we parameterize the period utility function in the following form,

$$U(c_t, l_t, h_t) = \frac{\log[\lambda c_t^{1-\eta} + (1-\lambda)h_t^{1-\eta}]}{1-\eta} + \rho \log l_t, \tag{17}$$

where λ measures the importance of health-neutral consumption relative to the stock of health capital in the household's preferences and the inverse of η is the elasticity of substitution between these two entries, and ρ measures the importance of leisure relative to the consumption-health bundle in the household's preferences.

Finally, we postulate the standard Cobb-Douglas form for the production function of goods,

$$F(K_t, N_t; z_t) = z_t K_t^{\alpha} N_t^{1-\alpha}, \tag{18}$$

where α and $1-\alpha$ measure respectively the cost shares of physical capital and labor services in the value-added productive inputs in the long-run stationary equilibrium.

In the rest of this section, we calibrate the model to the US data and compute the steady-state values of the key variables of interest (we compute the steady state by setting the technology level z_t to its unconditional mean of 1). We then recompute the model's equilibrium while replacing the labor income and consumption tax rates with those observed for each of the eight European countries, but keeping the other baseline parameter values unchanged. This will allow us to see what would happen to the US economy if it adopts the tax rates of these Eurozone countries. This will then give us a sense about the extent to which the observed difference in taxation may account for the observed difference in medical expenditure-GDP ratio, time input in health production, and time spent on paid work between the US and Europe.

To proceed, we set the share of payment to physical capital in the value-added productive factors, α, to 0.36, and the annual physical capital depreciation rate, δ_k, to 0.076. These are standard values used in the literature (e.g., Cooley and Prescott 1995; Nadiri and Prucha 1996; Chen, Imrohoroglu, and Imrohoroglu 2009).

Recent estimates suggest that the annual depreciation rate of health capital for the US working-age population is on average about 5.6 percent (e.g., Scholz and Seshadri 2010), so we set $\delta_h = 0.056$, to be consistent with these studies. In terms of selecting a value for η, we note that its inverse measures the elasticity of substitution between health stock and health-neutral consumption in the utility function, and we set $\eta = 8.7$, to be consistent with the studies by Viscusi and Evans (1990), Murphy and Topel (2006), Finkelstein, Luttmer, and Notowidigdo (2010), Scholz and Seshadri (2010), and Halliday *et al.* (2014). Given this value, health is highly complementary to health-neutral consumption: being healthy helps enhance the marginal utility of consumption. We set the parameter governing the elasticity of sick time with respect to health stock, γ, and the parameter governing the degree of returns to scale in health production, ξ, to 1, following Grossman (1972). We set $\omega = 1$, corresponding to a unitary elasticity of substitution between health care and leisure time in health production, in light of the empirical estimates by Sickles and Yazbeck (1998) and He, Huang, and Hung (2013).

As discussed in Section 2 and summarized in Table 1, the effective labor income and consumption tax rates are calibrated from the data constructed by McDaniel (2007). For example, for the US economy in the period 1970-2007, the average labor income and consumption tax rates are 21 percent and 8.3 percent, respectively, so we set $\tau_n = 0.21$ and $\tau_c = 0.083$ for the US accordingly. The tax rates for the other countries are calibrated in a similar fashion, except for Italy where they are for the period 1988-2007 for which the Italian health expenditure data are available. The relative price of health care to non-medical consumption, on the other hand, is taken from He, Huang, and Hung (2013), who construct the purchasing power parities-adjusted price indexes of health care goods and services relative to non-medical commodities for various OECD countries 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.

There are six remaining parameters in the model that need to be calibrated. They are the subjective discount factor, β, the parameter measuring the importance of non-medical consumption relative to the stock of health capital in the utility function, λ, the parameter measuring the importance of leisure relative to the consumption-health bundle in the utility function, ρ, the share of medical goods input in health production, θ, and the two scaling parameters, Q in (15) and B in (16), respectively. The values for these six parameters are jointly determined by matching six relevant steady-state conditions in the model with the corresponding moment conditions for the US economy for the 1970-2007 or similar periods. These moment conditions either have already been calculated in the existing literature, or can readily be derived from available data sources. These include an annual capital-output ratio of 3.32 (e.g., Cooley and Prescott 1995; Chen *et al.* 2009), a medical expenditure-output ratio of 0.114 (computed from the National Health Accounts for the period 1970-2007), a non-medical consumption-output ratio of 0.634,[13] a ratio of working hours to total discretionary time of 0.218 (e.g., Ohanian *et al.* 2008), a medical expenditure-total consumption ratio of 0.14 (computed from National Income and Product Account for the period 1970-2007), and a frequency of sick time of 0.021 (computed based on

[13] The ratio of total consumption to real GDP is about 0.748 for the post-war US economy (e.g., Cooley and Prescott 1995). Subtracting the medical expenditure-GDP ratio of 0.114 from this number, we arrive at a non-medical consumption-GDP ratio of 0.634.

the data reported by Lovell 2004).[14]

These benchmark values of parameters are summarized in Table 2.

4.2 Quantifying the Effect of Taxation

We have computed the steady-state equilibrium of the baseline model where all of the parameters take on the values prescribed in Table 2, which are calibrated to the US economy. What we will do in this section is to recompute the model's equilibrium by replacing the labor income and consumption tax rates for the US with the tax rates for each of the eight European countries reported in the fourth to the sixth columns of Table 1, while keeping all of the other parameters at their benchmark values reported in Table 2. The equilibrium values of the variables of interest in each of the eight cases can be compared with their values in the benchmark economy. These differences predicted by our model can then be contrasted with the differences observed in the data between each of the eight European countries and the US. These contrasts reveal how important a role that the differences in taxation between these European countries and the US may play in explaining their observed differences in the underlying variables of interest. The results so obtained concerning health care expenditure to GDP ratio, time spent on paid work, and time spent on health-enhancing leisure activity are reported in Table 3.[15]

The first three columns of Table 3 record respectively the differences between each of the eight European countries (as well as the Euro Mean) and the US in these three measures of their data. These numbers are derived by subtracting the last row from each of the first nine rows in the first three columns of Table 1. Thus, the three numbers on the first row in the first three columns of Table 3 tell us that, the health expenditure-GDP ratio is 4% lower, the fraction of time endowment spent on paid work is 5.2% lower, and the fraction of time endowment spent on health-enhancing leisure activity is 7% higher, in Belgium than in the US.

The middle three columns of Table 3 report respectively the variations of these three variables in our model when the labor income and consumption tax rates for the US are replaced by the tax rates in each of the eight European countries and by

[14] Based on data from the National Health Interview Survey, Lovell (2004) reports that employed adults in the US miss, on average, 4.6 days of work per year due to illness or other health-related factors. Notice that this number is very close to the one reported by Ramey and Francis (2009) based on micro-level data. This translates into 2.1% of total available working days. We view this as a proxy for the share of sick time in total discretionary time.

[15] The comparisons between the Italian and the US data reported in Table 3 are for the period 1988-2007. Accordingly, for the purpose of comparison with Italy using our model, the benchmark parameter values for the US economy are calibrated for the same period.

the average tax rates over these European countries. Thus, the three numbers on the first row in the middle three columns of Table 3 show our model's prediction that, the health expenditure-GDP ratio would be 2.34% lower, the fraction of time endowment spent on paid work would be 4.85% lower, and the fraction of time endowment spent on health-enhancing leisure activity would be 4.45% higher, under the tax rates in Belgium than under the tax rates in the US.

The contrast between the middle three columns and the first three columns of Table 3 conforms to our earlier conclusion based on analytical results. That is, our model's predicted US-Europe differences in the various variables of interest, which we recall are driven solely by their differences in taxation, 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 US than in Europe, which are exactly what we observe from the comparison of the US to the European data.

The last three columns of Table 3 give us a more quantitative feel about the extent to which the differences in taxation between the US and Europe may help explain their observed differences in those variables of interest. The numbers in these last three columns of the table are obtained by dividing the numbers in the middle three columns, which we recall are generated from our model, by the corresponding numbers in the first three columns, which we recall are recorded from the data. As we scroll down from the first row to the eighth row in these columns to go over the results for each of the eight European countries in comparison with the US, we can see that cross-country differences in taxation 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 three columns of the table, on average, the US-EU difference in labor income and consumption tax rates accounts for 47.5% of their difference in health expenditure-GDP ratio, 91% of their difference in time spent on paid work, and 93% of their difference in time spent on health-enhancing leisure activity.

4.3 Quantifying the Effect of Relative Health Care Price

A parallel exercise can be used to help isolate the effect of relative health care price. This is done in this section by recomputing the model's equilibrium while replacing the relative health care price in the US with that in each of the eight European countries reported in the seventh column of Table 1, but keeping all of the other parameters at their benchmark values reported in Table 2. The equilibrium values of the variables of interest in each of the eight cases are compared with their values in the benchmark economy. The resultant differences in health spending-GDP ratio, time spent on paid work, and time spent on health-enhancing leisure activity, which are reported in the middle three columns of Table 4, can then be contrasted with the differences in these variables observed in the data between each of the eight European countries and the US, which are presented in the first three columns of Table 4.

These numerical contrasts between our model's predictions and the data conform to our earlier conclusion from analytical scrutiny concerning the double-edged role of the US-EU difference in relative health care price in shaping their differences in those variables of interest. More specifically, while cross-country difference in relative health care price does generate cross-country difference in medical expenditure-GDP ratio in the observed direction (except for Italy), it generates cross-country difference in time allocation in a direction that is exactly opposite to what is observed in the data (except for Italy). Quantitatively, as can be seen from the last row of Table 4, on average, the US-EU difference in relative health care price accounts for 16.8% of their observed difference in medical expenditure-GDP ratio; however, this relative price difference predicts that paid work time would be 0.38% higher and time spent on health-enhancing leisure activity would be 0.3% lower in Europe than in the US, while, in actuality, Europeans spend 4.4% less of their time endowment on paid work and 4% more of their time endowment on health-enhancing leisure activity when compared with Americans.

4.4 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 both the labor income and consumption tax rates and the relative health care price for the US with those for each of the eight European countries reported in the fourth to the seventh columns of Table 1, while keeping all of the other parameters at their benchmark values reported in Table 2. The equilibrium values of the variables of interest in each of the eight cases are compared with their values in the benchmark economy. The resultant differences in health spending-GDP ratio, time spent on paid work, and time spent on health-enhancing leisure activity, which are reported in the middle three columns of Table 5, can then be contrasted with the differences in these variables observed in the data between each of the eight European countries and the US, which are presented in the first three columns of Table 5.

As is illustrated by these numerical contrasts between our model's predictions and the data, the US-EU differences in taxation and in relative health care price jointly provide a fairly successful account for their differences in all of the underlying variables of interest. As can be seen from the last row in the last three columns of Table 5, on average, the US-EU differences in taxation and in relative health care price together account for 62% of their difference in health expenditure-GDP ratio, 84.3% of their difference in time spent on paid work, and 87.5% of their difference in time spent on health-enhancing leisure activity.

4.5 Quantifying the Effect of Taxation over Time

Tax rates have been changing over time in both the US and European countries. For example, tax wedge τ has increased from 25.2% in 1970 to 27.9% in 2007 for the US; while for eight European countries covered in the current paper, the mean tax wedge has raised more dramatically from 41.2% in 1970 to 51.8% in 2007. Therefore, a natural question could arise: to what extent the time series variation in tax rates would account for the change in the difference of medical expenditure-GDP ratio between the US and the selected European countries?

To answer this question, we solve the model along the time dimension. To be more specific, we first calibrate the benchmark model in Section 3.1 to match the US economy in 1970, which we treat it as the initial steady state, by matching the six moment conditions mentioned in Section 4.1.[16] We also use the US tax rates in 1970. Given the calibrated parameters, we solve the model economy for each European country by only replacing the labor income and consumption tax rates to their levels in 1970 respectively. We then calculate the difference of model-generated medical expenditure-output ratio between the US and that European country in 1970. In other words, we redo the exercise in Section 4.2 just for 1970. We then assume that the final steady state will arrive in future after a certain periods. And we input the time series data of tax rates for 1970-2007 plus the prediction of the future (after 2007) tax rates into the model to solve the transition path of the model economy for each country. Finally, we truncate the transition path of the model economy to the period 1970-2007 and compare the model-generated variables with the data. And we check the difference of model-generated medical expenditure-output ratio between the US and each European country in 2007. The change of the difference between 1970 and 2007, by design, is solely due to the change in tax wedges between the US and that European country over the time period. Therefore, it is a sufficient statistic

[16]The moment conditions are set to their 1970 level accordingly. For example, medical expenditure-output ratio is 7.1%; non-medical consumption-output ratio is 67.7%; and the ratio of working hours to total discretionary time is 0.211. Due to the data availability, we still keep sick time ratio at the level of 0.021.

to answer the proposed question.

In the benchmark simulation, we assume that the economy reaches the final steady state in 50 years after the initial steady state, which is year 2020. We also assume that the tax rates follow their trend after the initial steady state, i.e., we predict the tax rates grow at their average growth rate over the time period 1971-2007 after year 2007. Since time series data of relative health care price across countries are not available, we set relative price of health care to be unity across all countries and time for simplicity.

Table 6 reports the results. For example, the table shows that keep other things equal, given the difference of tax wedge between the US and Belgium has been widened by 7.98% from 1970 to 2007, the model predicts that the gap of medical expenditure-output ratio between two countries would increase 1% from 1970 to 2007, which accounts for about 28% of the observed increase in the gap between two countries for the same time period. The same widening tax wedge gap also affects the change in the gap of labor supply between two countries. The sixth column of the table shows that the model predicts the difference of fraction of time endowment spent on paid work between the US and Belgium would be 3.3% higher than its level in 1970, which captures 76% of the observed increase in the gap from 1970 to 2007. As is illustrated by the last row in the third and sixth columns of the table, on average, the US-EU difference in labor income and consumption tax rates across time accounts for 18% of the change in their difference in health expenditure-GDP ratio and 48% of the change in their difference in time spent on paid work over the period 1970-2007.

We shall point out that many factors that could affect health care such as health insurance system and medical care technical change have undergone significant changes over the time period we study (see Suen 2006 and Zhao 2014). One would naturally infer that by not controlling those factor changes over time, our model should be less successful in matching the data over the time dimension than the simple static comparison across countries as we did in Section 4.2. Table 6 seems confirm that inference. However, even given we do not control those important changing factors, on average, the simple taxation channel is still able to explain close to 20% of the *trend* change in the gap in medical expenditure-output ratio between the US and European countries.

To test the robustness of the results, we also conduct several additional experiments to check the sensitivity of our conclusion to the timing of the final steady state and method to predict future tax rate growth. For example, we have checked the results if the final steady state reaches in 80 years instead of 50 years after the initial steady state. We have also checked the results if we assume that tax rates remain at its 2007 level after 2007 until the final steady state. Even in the worst case (with 80 year transition and constant future tax rates), the model is still able to capture at least 16% of the *trend* change in the gap in medical expenditure-output ratio and 45% of the *trend* change in the gap in labor supply between the US and European countries on average. We therefore are confident to conclude that the US-EU difference in labor income and consumption tax rates is an important factor to explain the variations in medical expenditure-output ratio both across countries and over time.

5 Additional Analyses

We conduct a series of decomposition and sensitivity analyses in this section to help gain further insight into and check the robustness of the main results obtained above. In order to conserve space, we shall here focus on taxation as the main determinant of the composition of health investment portfolio and labor supply, and the implications of the US-EU differences in tax rates for their differences in health expenditure-GDP ratio and time allocation. Hence, in all of theses additional analyses to be conducted below, results for the benchmark economy in our model will be derived keeping all of the model parameters to their benchmark values reported in Table 2, except for the discount factor, β, the share of health-neutral consumption in utility, λ, the share of leisure in utility, ρ, the share of goods input in health production, θ, and the two scaling parameters, Q and B, which may need to be re-calibrated accordingly when we vary certain features of the benchmark economy, as is to be noted whenever this is the case, so that the benchmark model remains consistent with the US economy. The model predicted cross-country differences in health expenditure-GDP ratio and time allocation due to their differences in taxation are then obtained by replacing the various tax rates in the US with those in each of the eight European countries.

5.1 Labor Supply Elasticities

Labor elasticity is a key parameter in the benchmark model which delivers the response of labor supply to tax changes and in turn it affects the composition of health investment portfolios. A natural question would then be whether the labor elasticities generated by the benchmark model can come close to the level that empirical studies have found.

Literature is still debating how big the labor supply elasticities are. Micro empirical literature often found relatively small numbers ranging from 0.1 to 1 (see Blundell, Ducan and Meghir 1998, Blundell and MaCurday 1999). Recent work by including female labor supply and human capital accumulation into the consideration usually provided a bigger number (see Imai and Keane 2004). In our benchmark model, the utility function in equation (17) implies a Frisch labor elasticity to be l/n in the steady state, which is 3.49. This number is actually in line with the estimation provided by Imai and Keane (2004), which is 3.8.

Be aware that majority of micro studies provide a much smaller number than that, we would like to conduct a robustness check on the sensitivity of our main results to the level of Frisch labor elasticity. In order to allow a flexible labor elasticity in the model, we have to change our period utility function to the following form

$$U(c_t, l_t, h_t) = \frac{\log[\lambda c_t^{1-\eta} + (1-\lambda) h_t^{1-\eta}]}{1-\eta} + \rho \frac{l_t^{1-\mu}}{1-\mu}.$$

In this form, it is easy to show that Frisch labor elasticity is determined by $(1/\mu)(l/n)$. By changing μ, we are able to make sure the model deliver different labor elasticities as desired. We first set $\mu = 3.491$ to make sure the labor elasticity in the model is 1, which is the boardline number on the high end of the spectrum for the micro studies. We then redo the exercise in Section 4.2. By conducting this experiment, we find that, on average, the US-Europe difference in labor income and consumption tax rate accounts for 33.6% of their difference in health spending-GDP ratio, 71.2% of their difference in time spent on paid work, and 72.5% of their difference in time spent on health-enhancing leisure activity. We then further decrease labor elasticity to be 0.5 by setting $\mu = 6.98$, which is in the range of micro studies and it seems like a widely accepted value in the literature. The model predicts that the simple taxation channel, on average, is still able to explain 23% of their difference in health spending-GDP ratio, 53% of their difference in time spent on paid work, and 54% of their difference in time spent on health-enhancing leisure activity.

We do observe the explanation power of the model decreases as we bring the labor elasticity closer to the range of micro studies. However, even given the widely accepted value of labor elasticity in macro studies, US-EU difference in tax rates still plays an important role in explaining the gap in health expenditure-GDP ratio and time allocation across countries.

5.2 Endogenous Survival Probability

An distinguished feature of health capital is that it improves survival prospects (Hall and Jones 2007, Zhao 2014, Halliday, He and Zhang 2014). By following Grossman (1972), the benchmark model captures the two important motives for health investment. However, it ignores the "survival motive." How would the results change if we extend the model to include it?

To answer this question, we extend the model to include an endogenous conditional survival probability that is determined by health capital as follows

$$\psi_t = \Psi(h_t)$$

where ψ_t represents the conditional survival probability from time t to $t+1$. We assume $\Psi'(h_t) > 0$, i.e., higher health capital improves survival prospects. The life time utility function thus changes to

$$\mathrm{E}\sum_{t=0}^{\infty}\beta^t\left[\prod_{k=0}^{t}\Psi(h_{k-1})\right](U(c_t,l_t,h_t)+b).$$

The constant term b in the function is crucial here to guarantee that the period utility is always positive so that it worths extending life expectancy (Hall and Jones 2007).

Including endogenous survival probability into the model does not change the intratemporal condition in equation (10). However, it does alter the two intertemporal conditions governing the accumulation of both health and physical capital in the following way

$$U_c(t) = \beta \mathrm{E_t}\Psi(h_{t+1})\left[U_c(t+1)(r_{t+1}+1-\delta_k)\right]$$

$$\beta\mathrm{E_t}\Psi(h_{t+1})\left[U_h(t+1)+\frac{\Psi'(h_{t+1})}{\Psi(h_{t+1})}U_{t+1}-(1-\tau)w_{t+1}S'(h_{t+1})U_c(t+1)+(1-\delta_h)\frac{U_c(t+1)}{H_m(t+1)}p_m\right] \quad (19)$$
$$= \frac{U_c(t)}{H_m(t)}p_m.$$

Comparing equation (19) to (11), one can see that the present value of expected future benefit from having one additional unit of health capital at date $t+1$ has a new term $(\Psi'(h_{t+1})/\Psi(h_{t+1}))U_{t+1}$, where $U_{t+1} \equiv U(c_{t+1}, l_{t+1}, h_{t+1}) + b$. This term represents an additional utility gain for extending life expectancy due to having one additional unit of health capital. Of course now the whole present value of expected future benefit–the left-hand side of the equation–is subject to the conditional survival probability from time t to $t+1$.

We parameterize the survival probability function Ψ following Zhao (2014)

$$\Psi(h_t) = 1 - \frac{1}{e^{\kappa h_{t+1}}}.$$

Comparing to the benchmark model, we have two additional parameters needs to be calibrated: κ and b. In the steady state of the model, $1/e^{\kappa h_{t+1}}$ represents steady state death rate. Therefore we calibrate k to match the long-run average death rate in the US for period 1970-2007, which is 0.87%. As Hall and Jones (2007) points out, the constant term b in the period utility function has a direct implication on matching so-called "value of statistical life" (VSL). We thus follow their strategy to calibrate b to match the mean VSL for working-age Americans in 2000, which is around 3.5 million (in 2000 dollars).[17][18] We also recalibrate the six parameters mentioned in Section 4.1 with this modified model.

By conducting this experiment, we find that, on average, the US-Europe difference in labor income and consumption tax rate accounts for 95% of their difference in health spending-GDP ratio, 95% of their difference in time spent on paid work, and 96% of their difference in time spent on health-enhancing leisure activity. Those numbers come very close to our benchmark results. We thus conclude that enriching the model by including endogenous survival probability does not change the key message of the paper at all.

5.3 Separating the Effects of Consumption from Labor Taxes

We have already established that the US-EU difference in the tax wedge is the main determinant of their differences in health spending-GDP ratio and in time allocation. Recall that the tax wedge is a function of consumption and labor income tax rates. It is therefore of natural interest to decompose the effect of the US-EU difference in labor income tax from the effect of their difference in consumption tax on their differences in the various variables of interest.

To identify the effect of labor income tax, we recompute the model's equilibrium by replacing the labor income tax rate for the US with that for each of the eight European countries, while keeping all of the other parameters (including consumption tax rate) to their benchmark values. The equilibrium values of those variables of interest in each of the eight cases are compared with their values in the benchmark economy. These differences predicted by our model can then be contrasted with the differences observed in the data between each of the eight European countries and the US. These contrasts reveal the importance of the differences in labor income tax rate between these European countries and the US in accounting for their differences in

[17] The number is calculated based on Table 1 in Hall and Jones (2007). Viscusi and Aldy (2003) report that US Food and Nutrition Service (USDA) and Environmental Protection Agency (EPA) also use 3.5-3.9 million (in 2000 dollars) as their benchmark VSL. We also check that b is big enough to guarantee the flow utility is always positive under all circumstances in our simulation.

[18] We follow the literature (Hall and Jones 2007, Zhao 2014) to measure VSL as the marginal cost of saving a life. In the model, it is measured by taking inverse of the marginal effect of health care expenditure on survival probability $p_m/(\partial\Psi(h)/\partial m) = p_m/((\partial\Psi/\partial h') \times (\partial h'/\partial m))$.

the relevant variables. By conducting this experiment, we find that, on average, the US-Europe difference in labor income tax rate accounts for 35.3% of their difference in health spending-GDP ratio, 68% of their difference in time spent on paid work, and 70% of their difference in time spent on health-enhancing leisure activity.

A parallel exercise allows us to identify the effect of consumption tax, through recomputing the model's equilibrium by replacing the consumption tax rate for the US with that for each of the eight European countries, while keeping all of the other parameters (including labor income tax rate) to their benchmark values. Through this exercise, we find that, on average, the US-Europe difference in consumption tax rate accounts for 13.37% of their difference in health expenditure-GDP ratio, 25.5% of their difference in time spent on paid work, and 26.5% of their difference in time spent on health-enhancing leisure activity.[19]

These two analyses together suggest that the US-EU differences in labor income tax rate play a much more important role than their differences in consumption tax rate in shaping their differences in the underlying variables of interest.

5.4 The Effect of Capital Income Tax

Our analysis so far has been abstracted from capital income tax. In actuality, capital income tax is quite common in the OECD countries. As a matter of fact, in contrast to the cases with consumption and labor income taxes, capital income tax rate is generally higher in the US than in Europe, as is documented by McDaniel (2007). For the eight European countries under consideration, for instance, the average capital income tax rate for the period 1970-2007 is 22.3% (Belgium), 22.8% (Finland), 15.5% (France), 16.0% (Germany), 20.2% (Italy, which is for the period 1988-2007), 17.8% (Netherlands), 13.2% (Spain), and 29.7% (UK), compared to 28.5% in the US.

A natural question then is: How much effect can the US-EU difference in capital income tax rate have on their difference in health investment portfolio or in labor supply? The answer is, "not much".

This may not be surprising, given that the presence of capital income tax does not

[19] One important feature of US health care system is the government heavily subsidizes medical expenditures. Therefore even though the relative price of health care in the US is higher than that in European countries, with the heavy subsidy to medical care, the *effective* price might not be. To test the effect of this institutional feature on our benchmark results, we conduct an experiment to set $\tau_c = 0$ for medical expenditure m in the US, while for European countries we keep the assumption medical expenditure is subject to the same tax rate as other non-medical consumption τ_c. Our results show that in this case, the simple taxation channel can explain about 54% of the gap in medical expenditure-output ratio and captures entirely gap in time allocation between the US and European countries.

directly affect the two equations, (10) and (11), that govern the optimal composition of health investment portfolio and time allocation. Although a higher capital income tax rate tends to make investment in health capital more attractive than in physical capital, when it comes to the US-Europe comparison, the degree of their difference in capital income tax rate does not make much material difference in the composition of health investment portfolio or time allocation.

To put this into a quantitative perspective, we re-configure the benchmark model, taking into account the capital income tax rate in the US economy. This requires to re-calibrate the six parameters, namely, the discount factor, β, the share of health-neutral consumption in utility, λ, the share of leisure in utility, ρ, the share of goods input in health production, θ, and the two scaling parameters, Q and B, so that the benchmark model remains consistent with the US economy. The model predicted cross-country differences in health expenditure-GDP ratio and time allocation due to their differences in consumption, labor and capital income tax rates are obtained by replacing these tax rates in the US with those in each of the eight European countries. The results are almost identical to those obtained when only cross-country differences in consumption and labor income tax rates are taken into account, while taxation on capital income is abstracted from: On average, the US-EU differences in consumption, labor and capital income tax rates account for 48.4% of their difference in health expenditure-GDP ratio, 86.6% of their difference in time spent on paid work, and 89.3% of their difference in time spent on health-enhancing leisure activity. These explanatory powers are close to those, namely, 47.5%, 91%, and 93%, when only the US-EU differences in consumption and labor income tax rates are taken into account.

Summarizing the results in this and the previous subsections, we conclude that the US-EU differences in labor income tax rate are the most important determinant of their differences in health spending-GDP ratio and in time allocation. Whereas their differences in consumption tax rate also play some important role, the role played by their differences in capital income tax rate is negligible, when it comes to understanding the US-EU differences in the underlying variables of interest.

5.5 Non-Separability of Leisure in Preferences

In the literature, it is not unusual to consider a period utility function under which leisure is non-separable from consumption. A specification of period utility function alternative to the form in (17) is, similarly as in Scholz and Seshadri (2010),

$$U(c_t, l_t, h_t) = \frac{\log[\lambda(c_t^{\rho} l_t^{1-\rho})^{1-\eta} + (1-\lambda)h_t^{1-\eta}]}{1-\eta}. \tag{20}$$

The benchmark values of the six model parameters, β, λ, ρ, θ, Q, and B, under this alternative specification of the period utility function are jointly determined, once again by matching the six relevant steady-state conditions in the model with the corresponding moment conditions for the US economy for the 1970-2007 or similar periods, as described in Section 4.1, while all of the other parameters are maintained at their values reported in Table 2. Given the value of η equal to 8.7, the period utility function as specified in (20) also implies that, health is complementary to not only consumption, but leisure. This is to say that, being healthy helps enjoy both consumption and leisure. This seems to be consistent with both causal observations and existing studies (e.g., Murphy and Topel 2006; Scholz and Seshadri 2010).

It is thus fitting to undertake some exploration to see what the results will be when the period utility function is specified by (20). This is done by repeating the exercise in Section 4.2 under this alternative specification of utility function and the correspondingly calibrated values of parameters. The results so obtained are similar to those with the original form of utility function in that cross-country difference in taxation continues to help the model fit all dimensions of the data: On average, the US-EU differences in consumption and labor income tax rates account for 55.7% of their difference in health spending-GDP ratio, 77% of their difference in paid work time, and 85% of their difference in time spent on health-enhancing leisure activity.

Even from a quantitative perspective, these explanatory powers are comparable to those reported in Section 4.2 when the period utility function is specified by (17), which are, respectively, 47.5%, 91%, and 93%. It is true that cross-country difference in taxation may explain more of their difference in medical expenditure-GDP ratio and less of their difference in time allocation, if the period utility function in (17) is replaced by that in (20).[20] But, as illustrated by the above comparisons, the changes in our model's explanatory power are fairly modest, and our general conclusions hold to quantitatively similar extents, when the specification of the period utility function is varied, from one form into the other.

[20] To understand the intuition for this, recall that higher taxes result in less medical expenditure, more time spent on leisure and less time spent on paid work, and that this is the case with either specification of the period utility function. If health and leisure are complementary to each other, as is the case with the period utility function (20), leisure helps enhance the marginal utility of health, and vice versa; thus, everything else equal, a given level of marginal utility of health (leisure) can be achieved with relatively less medical expenditure and less leisure time (and more paid work time), when compared to the case with the period utility function (17).

5.6 Explaining Health Care Expenditure to GDP Ratio for Working Age Population

Our model works most properly for a typical working age person, who naturally faces the time allocation and health investment portfolio choice problems described in the model. The difference in health care expenditure-GDP ratio between US and European data, against which our model's prediction is compared above, is, however, measured on the basis of total population. Yet, as highlighted in the Introduction, and explained with more detail in Section 2, cross-country difference (between the US and many of the European nations) in the health expenditure measure seems fairly similar across different age groups, as revealed by available empirical studies, although the health expenditure measure may differ significantly across different age groups within each country (e.g., with some steep increase for the elderly, especially towards the end of their life).[21] This implies that our model shall indeed account for the US-EU difference in health expenditure-GDP ratio for their working age populations. Nevertheless, it would be reassuring to verify this directly from available data on the working-age-population's health expenditure-GDP ratio.

For this purpose, we appeal to Anderson and Hussey (2000). Table 2 in their paper reports, for eight countries, the fraction of national health expenditure that goes to the elderly (people aged 65 and older), as well as the fraction of GDP that is spent on health care for the elderly. Four of the eight countries in their sample, namely, the US, France, Germany, and the UK, are also in ours. Based on this information, we construct the working-age-population's health expenditure-GDP ratio for each of these four countries. The numbers are 8.6% for the US (for the year of 1995), 6.2% for France (for the year of 1993), 6.9% for Germany (for the year of 1994), and 3.9% for the UK (for the year of 1993).

To see to what extent these numbers can be explained by our theory, we calibrate our baseline model to the US economy in 1995, and then repeat the exercise described in Section 4.2 by replacing the US tax rates in 1995 with those in the other three countries in those corresponding years.[22] We find that the difference in the tax wedge explains 58% of the difference in health spending-GDP ratio, 69% of the difference in paid work time, and virtually the entire difference in time spent on health-enhancing leisure activity, all for the working age population, between the US and the other three European countries. Thus, an even greater fraction of the US-EU difference in

[21] See, for example, Anderson and Hussey (2000), Gerdtham and Jonsson (2000), Peterson and Burton (2007), Pearson (2009), Hagist and Kotlikoff (2009), and Jung and Tran (2010).

[22] Labor income and consumption tax rates were, respectively, 22.2% and 8% in the US in 1995; 43% and 23.7% in France in 1993; 44.3% and 15.8% in Germany in 1994; and 27.1% and 16.4% in the UK in 1993.

health expenditure-GDP ratio can be explained by the difference in their tax rates when attention is restricted to the working age population.

5.7 Other Sensitivity Analysis

In this section, we test the robustness of the benchmark results to the two key parameters in health production technology.

5.7.1 Returns to Scale of Health Production Function

In the health production technology formalized in equation (16), ξ measures the degree of returns to scale in the health production function. In our benchmark case, we set $\xi = 1$ following Grossman (1972). However, Ehrlich and Chuma (1990) argue that this constant-returns-to-scale technology assumption introduces a type of indeterminacy problem with respect to optimal health investment decision. They fix that problem by assuming decreasing returns to scale for health production technology. In their illustration, they use $\xi = 0.5$.

We test the robustness of our benchmark results to the choice of $\xi = 0.5$. We again recalibrate the whole economy. Our results show that, on average, the US-EU differences in consumption and labor income tax rates account for 54% of their difference in health spending-GDP ratio, 83% of their difference in paid work time, and 86% of their difference in health-enhancing leisure time.

5.7.2 Elasticity of Substitution between Health Care and Leisure time

In the health production technology formalized in equation (16), ω measures the elasticity of substitution between these two inputs. He, Huang and Hung (2014) use a cross-country short panel data to empirically estimate this key parameter based on a general equilibrium framework quite close to the one in this paper. They find the elasticity based on the estimation falls into a range from 0.74 to 1.05. We use 1 in our benchmark simulation. The main mechanism of the model hinges on the strength of the substitution between goods and time input in health production. One would guess that the effect of taxation on health investment portfolio would be weakened if this elasticity is smaller.

To test the robustness of our results to the choice of ϖ, we pick ω to match the lowest estimate of the elasticity in the range proposed by He, Huang and Hung (2014). They also point out that this number is problematic due to a potential multi-collinearity issue. It could potentially downward bias the true estimation. However, even given this worst scenario, under $1/(1-\varpi) = 0.75$, the model still predicts that on average the US-EU differences in consumption and labor income tax rates alone account for 22% of their difference in health spending-GDP ratio, 101% of their difference in paid work time, and 101% of their difference in health-enhancing leisure time.

5.8 Health-Enhancing Leisure Time Narrowly Defined

In the general equilibrium model presented above, leisure time is defined as non-sick time spent away from paid work, which not only directly generates utility, but is in its entirety health enhancing. In actuality, however, part of this broadly defined leisure time, such as time spent on "couch potato", may not be health enhancing. Yet, as explained in Section 2, available empirical evidence reveals that the US-EU difference in the broadly defined leisure time is about the same as their difference in the health-enhancing leisure time (e.g., time spent in exercising, socializing, relaxing, etc.), narrowly defined to be the sum of the two categories of time use, *personal care* and *leisure*, in the OECD's multi-country time-use survey. This suggests that the mechanism described in this paper shall indeed account for the US-EU difference in the health-enhancing leisure time. Nevertheless, it would be reassuring to verify this in an extended model that formally divides the broadly defined leisure time into health-enhancing leisure time and health-neutral leisure time.

We now present such a model and its prediction. Denote by v health-enhancing leisure time and l health-neutral leisure time. All the other variables are denoted by the same notations as in the benchmark model. The time constraint becomes

$$n_t + v_t + l_t = 1 - s_t.$$

Since it is ν but not l that enters into health production function, we have

$$h_{t+1} = (1 - \delta_h)h_t + B(m_t^{\theta} v_t^{1-\theta})^{\xi}.$$

On the other side, both l and v enter into utility function, such that[23]

$$U(c_t, v_t, l_t, h_t) = \frac{\log[\lambda c_t^{1-\eta} + (1-\lambda)h_t^{1-\eta}]}{1-\eta} + \rho \log l_t + \phi \log v_t.$$

[23]The two types of leisure time have different weights in preferences. Were the weights the same, an agent would strictly prefer v to l and always choose $l = 0$, and the model here would collapse into the benchmark model presented in Section 3.

The utility-maximization problem for a representative agent is then given by

$$
\begin{aligned}
& \max \mathrm{E} \sum_{t=0}^{\infty} \beta^t U(c_t, v_t, l_t, h_t) \\
& s.t. \\
(1+\tau_c)[c_t + p_m m_t] + k_{t+1} &= (1-\tau_n) w_t n_t + (r_t + 1 - \delta_k) k_t + \Pi_t + T_t \\
h_{t+1} &= (1-\delta_h) h_t + B(m_t^{\theta} v_t^{1-\theta})^{\xi} \\
n_t + v_t + l_t + s_t &= 1,\ s_t = Q h_t^{-\gamma} \\
c_t, k_{t+1} &\geq 0,\ k_0, h_0 \text{ given.}
\end{aligned}
$$

This extended model embeds a mechanism similar to what is described by the intratemporal condition (10) for the benchmark model. This is the Euler equation associated with the optimal composition of the narrowly defined health-enhancing leisure time and health-related consumption in health investment,

$$MRS_{v,c}(t) + MRTS_{v,m}(t) p_m = (1-\tau) w_t, \tag{21}$$

where $MRS_{v,c}(t) \equiv U_v(t)/U_c(t)$ denotes the marginal rate of substitution of health-enhancing leisure time v for health-neutral consumption c, which measures the amount of c that can be saved on with an additional unit of v, while maintaining the same level of utility, and $MRTS_{v,m}(t) \equiv H_v(t)/H_m(t)$ denotes the marginal rate of technical substitution of v for health-related consumption m, which measures the amount of m that can be saved on with one additional unit of v, while maintaining the same level of health production. The left-hand side of equation (21) is thus the benefit from having additional health-enhancing leisure time, while the right-hand side of the equation is the opportunity cost of the health-enhancing leisure time in terms of the foregone labor income on paid work, i.e., the effective wage rate that is monotonically decreasing in the tax wedge.

The extended model also embeds a mechanism as described by the intertemporal condition (11), which combines the Euler equation for optimal health accumulation, with the condition for optimal allocation between health-related consumption and health-neutral consumption.

These, together with an intratemporal Euler equation for health-neutral leisure time l and health-neutral consumption c, $MRS_{l,c}(t) \equiv U_l(t)/U_c(t) = (1-\tau)w_t$, that is specific to the extended model, govern various optimal trade-offs among multiple uses of time and of goods, in generating utility and in producing health. The intuition for how taxation and relative health care price may affect these optimal trade-offs is as similarly described in Section 3.2, with the broadly defined leisure time there divided into here the health-enhancing leisure time and the health-neutral leisure time. This suggests that difference in taxation should continue to explain the US-EU differences in time allocation and health expenditure in this extended model.

To put this into a quantitative perspective, we conduct in this extended model a similar exercise as described in Section 4.2. We begin by noting that the extension above introduces an additional parameter ϕ, which measures the weight of health-enhancing leisure time in utility. We choose the value of ϕ to match the fraction of time endowment that Americans devote to health-enhancing leisure activities.[24] We also recalibrate the six parameters β, λ, ρ, B, θ, and Q, to match the six moment conditions as described in Section 4.1. Values of other parameters are kept the same as in the benchmark model. We then replace the tax rates in the US with those in the European countries to generate our model's predictions about the cross-country differences in the key variables of interest. Our finding is that, in the extended model, the EU-US difference in the tax wedge can explain about 35% of their difference in health expenditure-GDP ratio, about 45% of their difference in health-enhancing leisure time, and almost the entirety of their difference in paid work time.

5.9 Abstracting from Leisure for Maintaining Health? No!

Before closing the paper, we wish to remind the reader of one defining feature of our model that captures the fact that both leisure time and medical care are important for maintaining health. This feature, as is incorporated in the model in a way that is consistent with the empirical evidence, serves as a foundation for our analysis in this paper. Indeed, as is clear throughout the analyses by far, the key to the model's central mechanism lies with the manner in which taxation (and, for that matter, relative health care price) affects the composition of leisure and medical care as they pertain to health production.

This portfolio view of health investment is essential for our model's success in accounting for cross-country difference in medical expenditure. If, instead, we follow a more conventional approach and abstract from the time input in health production, then cross-country difference in taxation would generate cross-country difference in medical expenditure-GDP ratio in a direction that is exactly opposite to what is observed in the data: In light of the US-Europe comparison, the mis-specified model

[24] This is the sum of the two categories of time use in the OECD's multi-country time-use survey, namely, *personal care* and *leisure*, which is about 20% (averaged over 1998-2009) for the US. We get an almost identical figure from the American Time Use Survey (ATUS): the two categories of time use in ATUS, namely, *socializing, relaxing, and leisure*, and, *exercise through sports or recreation*, fit our definition of health-enhancing leisure time, which account for 19% and 1.2% of time endowment of Americans for the time period 2003-2007.

predicts that higher consumption and labor income tax rates in Europe than in the US would lead Europeans to spend a greater, rather than a smaller, share of their GDP on medical care than Americans.

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 $\theta = 1$. The benchmark version of the model is then obtained by choosing the values for β, λ, ρ, Q, and B to match the relevant steady-state conditions in the model with the corresponding moment conditions for the US economy for the 1970-2007 or similar periods, as described in Section 4.1, excluding medical expenditure-total consumption ratio from the targeted moment conditions, while keeping all of the other parameters at the values reported in Table 2. The mis-specified model configured above is then used to re-conduct the exercise described in Section 4.2. The mis-specified model predicts that, on average, the EU-US difference in the tax wedge would lead Europeans to spend 0.08% more of their GDP on medical care than Americans, while, in actuality, Europeans on average spend 4.1% less of their GDP on medical care when compared with Americans.

We have conducted many more additional experiments. We do not discuss these additional results here in order to conserve space. Provided that the empirically relevant, portfolio feature of health investment is taken into account, as in all of the analyses prior to this subsection, the basic conclusions about our model's empirical success hold broadly. This is typically the case when we vary other model features (such as to differentiate narrowly defined health-enhancing leisure time from health-neutral leisure time) or parameter values (such as the depreciation rate of health capital) within their empirically plausible specifications. In general, these variations in model features or parameter values have some quantitative influence on the results – sometimes very modestly, and other times to a greater degree – but in no case they alter the qualitative nature of the results.

6 Conclusion

We have documented two sets of empirical observations of the past many years. First, the US has spent a larger fraction of its GDP on health care and devoted more time to paid work and less time to leisure, 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 US 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 relationship may have to do with another empirically relevant fact that we have also documented in this paper, that is, both leisure and medical care

are important for maintaining health.

To this end, we have developed a general equilibrium macroeconomic model which features an endogenous choice of health investment portfolio that is influenced by taxation and relative health care price. We have used the model to establish three sets of main results. First, to a large extent the US-EU differences in health spending-GDP ratio and in time allocation could have been attributed to their differences in taxation, especially in labor income and (to a smaller extent) consumption tax rates, though their difference in capital income tax rate could have played a negligible role. Second, the US-EU difference in relative health care price could have attributed to some of their difference in overall health spending-GDP ratio, but its prediction on cross-country difference in time allocation is in a direction that is exactly opposite to the US-EU comparison: it predicts that Europeans would have spent more time on paid work and less time on leisure when compared with Americans, whereas as we have documented in the paper the opposite is true in the data. Third, the US-EU differences in taxation and in relative health care price jointly provide a fairly successful account for their differences in all of the underlying variables of interest, explaining 62% of their difference in health expenditure-GDP ratio, 84.3% of their difference in time spent on paid work, and 87.5% of their difference in time spent on health-enhancing leisure activity.

We have conducted many sensitivity and counterfactual analyses, and found that our results hold quite generally, as long as the empirically motivated, portfolio view of health investment is taken into account, which is essential for fitting our model to the data. While our focus in the present paper is on cross-country differences in health expenditure-GDP ratio and in time allocation, this portfolio feature of health investment could also be pertinent to other issues of potential interest. For instance, He, Huang, and Hung (2012) find that this portfolio view of health investment is important for understanding the joint cyclical behaviors of medical expenditure and health capital in modern industrialized economies. In light of this finding, and ours in the current paper, a systematic investigation of a broad set of macro-health issues for which this empirical motivated feature of health production may be relevant should be elevated to the top of the research agenda.

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Table 1: US and European Data: Long Run Averages

Country	$\tilde{\mathbf{m}}/\mathbf{y}^a$ (%)	$\mathbf{n}^b$ (%)	$\mathbf{l}^c$ (%)	${\tau_n}^d$ (%)	${\tau_c}^e$ (%)	τ^f (%)	${p_m}^g$
Belgium	7.4	16.6	71	42.0	17.6	50.7	1.02
Finland	7.2	20.3	68	38.0	22.1	49.1	1.14
France	8.5	16.9	68	38.3	23.9	50.2	1.11
Germany	9.1	18.0	69	40.8	14.8	48.4	0.94
Italy	8.0	15.0	67	39.7	18.9	49.3	1.24
Netherlands	8.0	15.8	68	43.5	16.6	51.6	0.94
Spain	6.2	17.0	67	28.6	13.3	36.9	0.92
UK	6.3	20.5	66	28.3	16.1	38.3	1.05
Euro Mean	7.6	17.5	68	37.5	18.0	47.0	1.04
US	11.4	21.8	64	21.0	8.3	27.1	1.20

Table 2: Benchmark Values of Parameters

Parameter		Value
	Preferences	
β	subjective discount factor	0.9686
λ	share of consumption in the consumption-health bundle	0.2601
η	elasticity of substitution between consumption and health	8.70
ρ	share of leisure relative to the consumption-health bundle	1.4728
	Goods Production	
α	share of physical capital in value-added inputs	0.36
δ_k	depreciation rate of physical capital	0.076
	Health Accumulation	
θ	share of medical commodity in health investment	0.4207
ω	elasticity of substitution between health care and leisure	1.0
ξ	returns to scale of health investment	1.0
B	level of technology in health production	0.0863
δ_h	depreciation rate of health capital	0.056
	Sick Time	
γ	elasticity of sick time with respect to health capital	1.0
Q	scaling factor	0.0071
	Taxation	
τ_n	labor income tax rate	0.21
τ_c	consumption tax rate	0.083
τ	tax wedge	0.271
	Relative Price of Health Care	
p_m	price of health care relative to health-neutral commodity	1.2

Table 3: EU-US Differences in Health Spending-GDP Ratio and in Allocation of Time among Multiple Uses: Data vs. Model's Predictions based on Cross-Country Variations in Taxation

Country	**Data**			**Model**			**Data Explained by Model**		
	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$
Belgium	-0.040	-0.052	0.07	-0.0234	-0.0485	0.0445	59%	93%	64%
Finland	-0.042	-0.015	0.04	-0.0218	-0.0452	0.0415	52%	301%	104%
France	-0.029	-0.049	0.04	-0.0229	-0.0474	0.0435	79%	97%	109%
Germany	-0.023	-0.038	0.05	-0.0210	-0.0434	0.0399	91%	114%	80%
Italy	-0.058	-0.079	0.03	-0.0230	-0.0463	0.0427	40%	59%	142%
Netherlands	-0.034	-0.060	0.04	-0.0244	-0.0505	0.0463	72%	84%	116%
Spain	-0.052	-0.048	0.03	-0.0092	-0.0191	0.0177	18%	40%	59%
UK	-0.051	-0.013	0.02	-0.0105	-0.0216	0.0201	21%	166%	100%
Euro Mean	-0.041	-0.044	0.04	-0.0195	-0.0403	0.0371	**47.5%**	**91%**	**93%**

Table 4: EU-US Differences in Health Spending-GDP Ratio and in Allocation of Time among Multiple Uses: Data vs. Model's Predictions based on Cross-Country Variations in Relative Health Care Price

Country	**Data**			**Model**			**Data Explained by Model**		
	$\boldsymbol{\Delta(\tilde{m}/y)}$	$\boldsymbol{\Delta n}$	$\boldsymbol{\Delta l}$	$\boldsymbol{\Delta(\tilde{m}/y)}$	$\boldsymbol{\Delta n}$	$\boldsymbol{\Delta l}$	$\boldsymbol{\Delta(\tilde{m}/y)}$	$\boldsymbol{\Delta n}$	$\boldsymbol{\Delta l}$
Belgium	-0.040	-0.052	0.07	-0.0078	0.0043	-0.0034	20%	-8%	-5%
Finland	-0.042	-0.015	0.04	-0.0025	0.0013	-0.0011	6%	-9%	-3%
France	-0.029	-0.049	0.04	-0.0038	0.0020	-0.0016	13%	-4%	-4%
Germany	-0.023	-0.038	0.05	-0.0116	0.0064	-0.0051	50%	-17%	-10%
Italy	-0.058	-0.079	0.03	0.0017	-0.0009	0.0007	-2.9%	1%	2.3%
Netherlands	-0.034	-0.060	0.04	-0.0116	0.0064	-0.0051	34%	-11%	-13%
Spain	-0.052	-0.048	0.03	-0.0125	0.0069	-0.0055	24%	-14%	-18%
UK	-0.051	-0.013	0.02	-0.0067	0.0036	-0.0029	13%	-28%	-15%
Euro Mean	-0.041	-0.044	0.04	-0.0069	0.0038	-0.0030	**16.8%**	**-8.6%**	**-7.5%**

Table 5: EU-US Differences in Health Spending-GDP Ratio and in Allocation of Time among Multiple Uses: Data vs. Model's Predictions based on Cross-Country Variations in Taxation and Relative Health Care Price

Country	**Data**			**Model**			**Data Explained by Model**		
	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$
Belgium	-0.040	-0.052	0.07	-0.0301	-0.0453	0.0423	75%	87%	60%
Finland	-0.042	-0.015	0.04	-0.0240	-0.0441	0.0408	57%	294%	102%
France	-0.029	-0.049	0.04	-0.0262	-0.0458	0.0424	90%	93%	106%
Germany	-0.023	-0.038	0.05	-0.0310	-0.0384	0.0364	135%	101%	73%
Italy	-0.058	-0.079	0.03	-0.0215	-0.0470	0.0432	37%	60%	144%
Netherlands	-0.034	-0.060	0.04	-0.0342	-0.0457	0.0430	101%	76%	108%
Spain	-0.052	-0.048	0.03	-0.0211	-0.0128	0.0129	41%	27%	43%
UK	-0.051	-0.013	0.02	-0.0167	-0.0184	0.0176	33%	142%	88%
Euro Mean	-0.041	-0.044	0.04	-0.0255	-0.0373	0.0350	**62%**	**84.3%**	**87.5%**

Table 6: EU-US Differences in Health Spending-GDP Ratio and Labor Supply: Data vs. Model's Predictions based on Time Series Cross-Country Variations in Taxation

Countries	$\triangle\boldsymbol{\tau}$	$\triangle\frac{M}{Y}$ **Data**	$\triangle\frac{M}{Y}$ **Model**	**Exp**	$\triangle$**n Data***	$\triangle$**n Model**	**Exp**
Belgium	7.98%	-0.034	-0.010	28%	-0.043	-0.033	76%
Finland	11.31%	-0.066	-0.013	19%	-0.042	-0.031	76%
France	9.34%	-0.034	-0.011	32%	-0.065	-0.029	45%
Germany	7.54%	-0.046	-0.008	17%	-0.081	-0.021	26%
Italy*	2.43%	-0.036	-0.006	17%	-0.030	-0.030	101%
Netherlands**	-1.27%	-0.049	0.016	-32%	-0.020	-0.015	57%
Spain	9.78%	-0.041	-0.009	23%	-0.046	-0.022	47%
UK	-1.61%	-0.051	-0.002	5%	-0.044	-0.012	28%
Euro Mean	5.69%	-0.045	-0.008	**18**%	-0.046	-0.022	**48%**

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m/y data for Italy is only available for the period 1988-2007.

m/y data for Netherlands is only available for the period 1972-2007.

n data for all countries are available for period 1970-2004..