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

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Abstract

Empirical evidence shows that both leisure and medical care are important in maintaining health. We build a macro-health model in which taxation and relative health care price are key determinants of the composition of the two inputs in the endogenous accumulation of health capital. In the model, a lower tax wedge leads to using relatively more medical care and less leisure in maintaining health, while a higher relative health care price implies an opposite substitution in quantity (away from medical care towards leisure) that weakens the direct bearing of the higher price on overall health spending. We show that differences in taxation and in relative health care price between the US and Europe can jointly account for a bulk of their differences in health expenditure-GDP ratio and in leisure time allocated for health production. Much of the cross-country difference remains explained by the two channels jointly even when we extend the baseline model to take into account important life cycle characteristics, such as age dependent health depreciation and medical expenditure, as well as differences between working age population and retirees.

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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 is beyond the counting of the US-Europe difference in expenditure on health-related research and development and on education and training of health personnel, neither are there notable cross-country differences in aging or life-cycle dynamics, such as age structure of the population or age-related medical status and expenditure, with which the cross-country difference in medical expenditure-GDP ratio can be squared.

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

We show that one determinant of the composition of 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, and lead to using relatively more leisure and less medical care 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 Europe than in the US, as we document in Section 2. We find that this difference in taxation can account for a significant fraction of the difference in medical expenditure-GDP ratio between the US and Europe.

This account of the US-Europe difference in medical expenditure is accompanied by a simultaneous prediction of our model on cross-country difference in leisure time input as another component of an optimal health investment portfolio. We wish to emphasize from the outset that this portfolio view of health investment is essential for our model's success stated above. Were we to abstract from time input in health production, as we will show below through a counterfactual experiment, higher taxes in Europe than in the US would imply 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 model's prediction on cross-country difference in time input for health production has any empirical support. The model predicts that, since labor and consumption tax rates are higher in Europe than in the US, Europeans would rely more on leisure than Americans when it comes to producing and maintaining good health. As we will show below, this is indeed what is observed from the data and, in fact, the US-Europe difference in taxation can account for a majority of their difference in time input for health production.

These together suggest that difference in taxation can provide a coherent account of the US-Europe difference in the composition of health investment portfolio.

Importance of the taxation channel in accounting for the US-Europe differences in health care spending and time allocation is further attested by a dynamic analysis, which shows that the time series variations in the US-Europe differences in medical expenditure-GDP ratio and time uses could be attributed to a large extent to the time series variations in their difference in the tax wedge (a function of consumption and labor income tax rates) over the period 1970-2007. This exercise is important for yet another reason since, in addition to taxation, there may be other institutional or cultural differences across countries relevant for considering the US-Europe difference in the composition of health investment portfolio. For example, preferences and social norms may also play a role in time allocation. However, in a time period as short as 1970-2007, the US-Europe differences in preferences and cultures are arguably more stable than their differences in the variables examined in this paper, so are less likely to be the dominant factors underlying the changes in the latter.

Another factor that may indeed affect health investment portfolio in an important way is the price of health care goods and services relative to the general price level. As we document below, relative health care price on average is higher in the US than in Europe. In fact, such cross-country difference in relative health care price is often thought of as contributing significantly to the higher overall health spending by Americans than by Europeans. It is thus also fitting to examine the relative health care price effect viewed through the lens of our model on health investment portfolio.

Two countervailing effects on overall health spending arise from a higher relative price of medical care in our model: (1) higher spending per unit of medical consumption, and (2) substitution away from medical care towards other goods or leisure in generating utility and towards time input in producing and maintaining good health. As we show below, in the baseline setting, the effect of (1) dominates that of (2), but 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 expenditure is weakened by the re-balancing of health investment portfolio. Moreover, this re-balancing implies that a higher relative health care price would lead to using relatively more time input and less medical commodity in producing and maintaining good health. Thus, although the US-Europe difference in relative health care price may account for some of their difference in overall health expenditure-GDP ratio, its implication on time allocation is in a direction that is opposite to the data.

To see this last point more transparently, we fit into our model the cross-country distribution of relative health care prices observed from the US and European data, while keeping the cross-country difference in taxation muted. The result shows that, while the relative health care price difference can indeed explain a nontrivial fraction of the difference in overall health spending-GDP ratio between the US and Europe, even though significantly smaller than that explained by the taxation channel, it tends to make Europeans have longer paid work time and shorter leisure time allocated for health production when compared to Americans, whereas the opposite holds in the data.

When we turn on the US-Europe differences in taxation and in relative health care price at the same time, our model can account for a majority of their difference in overall medical expenditure-GDP ratio and in time allocation. Hence differences in taxation and in relative health care price can jointly provide a reasonable account of the US-Europe difference in the composition of health investment portfolio in our baseline model.

The baseline model demonstrates the functioning of the taxation and relative health care price channels by focusing on the behavior of working age population. Yet much of the cross-country difference remains explained by the core mechanism demonstrated through the working of the baseline model even when we extend the model to take into account important life cycle characteristics (such as age dependent health depreciation and medical expenditure, and differences between working age population and retirees), different uses of leisure time (like that devoted to health-enhancing activity versus that spent on "couch potato"), and endogenous survival probability, and when we consider other variations in model features or extensions of the model along other dimensions.

The remaining of the paper is organized as follows. In Section 2, we document empirical evidence that motivates the present study and we review related literature. In Section 3, we present the baseline model, describe calibration, and report main result. In Section 4, we extend the baseline model along three important dimensions and show that much of the main result obtained in the baseline model continues to hold in the extended models. In Section 5, we conduct additional sensitivity analyses. Section 6 concludes the paper.

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 health care expenditures are higher in the US than in many of the European countries not only on aggregate but also within different age groups.[3]

[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 details.

[3]See, for example, Hagist and Kotlikoff (2009) for the European countries, and Jung and Tran

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 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 *et al.* 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 *et al.* 2000; Wang and Brown 2004; Brown *et al.* 2005). The recent study by Pressman *et al.* (2009) establishes a general positive link between a wide variety of leisure activities (e.g., having hobbies, playing sports, socializing, spending time unwinding, spending time in nature, visiting friends or family, going on vacation, going to clubs or religious events) and a broad spectrum of health benefits (e.g., lower blood pressure, waist circumference, body mass index, and cortisol measurements, lower levels of stress and depression, stronger and better social networks, better feelings of satisfaction and engagement in lives, better sleep, better physical function and mood). Caldwell (2005), Russell (2009), and Payne *et al.* (2010) provide a comprehensive review of the empirical evidence on the importance of leisure in achieving and maintaining good health, and an intuitive account of the prevention, coping, and transcendence mechanisms through which leisure enhances

(2010) for the US. See, also, Table 2 in Anderson and Hussey (2000).

[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 He and Huang (2013) for a list of references.

physical, mental, social, and cognitive health.[6]

As is explained in the introduction section, one determinant of the composition of the two health inputs is taxation and, therefore, cross-country differences in labor income and consumption tax rates may hold a key to understanding cross-country differences in medical consumption, as well as in time input for health production. The linchpin of our analysis in this paper 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 *et al.* 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

[6] See He and Huang (2013) for a list of references.

[7] Source: McDaniel (2007). The author applies the methodology in Mendoza *et al.* (1994) to calculate a variety of average tax rates over an extended period of time for a number of OECD countries, using national account statistics as a primary source. The 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 *et al.* (2008). They are the average for the period 1970-2004, except for Italy for which it is the average for the period 1988-2004.

percentage of annual discretionary time. Leisure time is then taken as the residual of paid work time following the conventional definition.

The US-EU differences in time allocation continue to hold even if we tease out unpaid work time (e.g., home production time) from the conventionally measured leisure time (i.e., the residual of paid work time). Based on 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 *et al.* 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 16% higher than the European average. These indexes are constructed by He *et al.* (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.[11] These studies typically abstract from health-related issues. On the other hand, there is an emerging class of economic models featuring endogenous health accumulation, which are developed to help understand the rising medical expenditure in the US (e.g., Suen 2006; Hall and Jones 2007; Fonseca *et al.* 2009; Zhao 2014), welfare effects of health care reforms (e.g., Feng 2008; Jung and Tran 2009), implications of health risks for consumption, health expenditure, and allocation of wealth among bonds, stocks, and housing (e.g., Yogo 2009), and implications of employment-based health benefits in the US (e.g., Fang and Gavazza 2011; Huang and Huffman 2014). These studies do not address cross-country difference in health care expenditure and they do not model time input in health production.

3 Baseline Model

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,

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

[9]In addition to constructing these relative price indexes, He *et al.* (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).

[11]See He and Huang (2013) for a list of references.

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 *et al.* (2013).[12]

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,[13] 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.

[12] 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.

[13] 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.

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 $F(K_t, N_t)$ units of output from K_t units of physical capital and N_t units of labor inputs. The production function is of constant returns to scale with 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

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

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,

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

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 decisions 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,

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

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),

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

An equilibrium is characterized by Equations (1)-(3) and (9)-(13), among which (10) and (11) help understand 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 channel by which 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 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, p_m is indeed another factor that may affect health investment portfolio and time allocation. 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, a higher relative health care price tends to generate a longer leisure time and a shorter time on paid work. 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 opposite to the US-EU comparison observed in actual data, while its prediction on cross-country difference in overall health spending-GDP ratio may, in theory, be in line with data observables, depending on whether the effect on the cost per unit of medical consumption dominates that on the composition of health investment portfolio.

Below we parameterize and calibrate the baseline model to get a quantitative feel about the roles of the US-EU differences in taxation and relative health care price in accounting for their differences in health spending-GDP ratio and time allocation.

3.1 Parametrization and Calibration

To parameterize the baseline model, 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 *et al.* 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 (2014), 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 a standard Cobb-Douglas goods production function,

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

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.

To calibrate the parameterized model to the US data, we set share of payment to physical capital in value-added productive factors, α, to 0.36, and 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 *et al.* 2009).

We set $\delta_h = 0.056$ in light of recent estimates that suggest 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). 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 *et al.* (2010), Scholz and Seshadri (2010), and Halliday *et al.* (forthcoming). Given this value, health is highly complementary to health-neutral consumption (i.e., 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 *et al.* (2013). Tax rates (wedge) and relative health care price are as reported in Table 1.

Six remaining parameters in the baseline model 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,[14] a ratio of average working hours to total discretionary time of 0.218 for the period 1970-2004 (e.g., Ohanian *et al.* 2008), a medical expenditure-total consumption ratio of 0.14 (computed from

[14]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.

National Income and Product Account for the period 1970-2007), and a frequency of sick time of 0.021 (computed based on the data reported by Lovell 2004).[15] Table 2 summarizes the benchmark calibration.

3.2 Quantifying the Effect of Taxation

To see the extent to which the observed difference in taxation may account for the observed differences in medical expenditure-GDP ratio and time allocation between the US and Europe, we first compute the steady-state equilibrium with all parameters taking their benchmark values calibrated to the US economy. We next recompute the steady state by replacing the tax rates for the US with those 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 quantify the role of the differences in taxation between these European countries and the US in accounting for 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.[16]

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

[15]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.

[16]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.

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 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.

3.2.1 Decompose the effects of consumption and labor income taxes

We have seen that the US-EU difference in the tax wedge is an important 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 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.

These two analyses together suggest that the US-EU differences in labor income and consumption tax rates both play some quantitatively important roles in shaping their differences in the underlying variables of interest.

3.2.2 The effect of capital income tax

Our baseline model is abstracted from capital income tax. In actuality, capital income tax is quite common among 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 an effect could the US-Europe difference in capital income tax rate have on their difference in health investment portfolio or time allocation? The answer is, “not much”.

This may not be surprising, given that the presence of capital income tax does not 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 reconfigure the benchmark model, taking into account the capital income tax rate in the US economy. This requires to recalibrate 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 very close 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.

3.2.3 Accounting for data on working age population

The taxation channel works most effectively for working age population since it is the working class that pay labor income taxes. As shown in Section 2, health spending is higher in the US than in Europe both in aggregate and within different age groups. When attention is restricted to accounting for the data on working age population's health expenditures, the model's explanatory power can naturally be strengthened, as to be illustrated below.

Table 2 in Anderson and Hussey (2000) 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 to 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 the taxation channel, we calibrate the baseline model to the US economy in 1995, and then repeat the exercise described in Section 3.2 by replacing the US tax rates in 1995 with those in the other three countries in those corresponding years.[17] 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.

3.2.4 A time series test of the taxation channel

Importance of the taxation channel in accounting for the US-Europe differences in health spending and time allocation is further attested by a "difference-in-indifference" analysis, which shows that the time series variations in the US-Europe differences in medical expenditure-GDP ratio and time uses could be attributed to a large extent to the time series variations in their difference in the tax wedge.

For example, from 1970 to 2007, the Europe-US difference in the tax wedge widened by 5.4%, while the US-Europe differences in medical expenditure-GDP ratio and time spent on paid work widened by 4.5% and 4.6%, respectively. To see to what extents the latter two numbers can be explained by the former, we compute the transition dynamics for the US and each of the eight European countries associated with their changing tax rates over time, assuming that these economies were in their initial steady states in 1970. To fix the initial steady state for the US, we calibrate the baseline model by using US tax rates in 1970 and choosing the six parameters β, λ, ρ, B, θ, and Q to match the six moment conditions described in Section 3.1 but for US data in 1970, while keeping all of the other parameters to their benchmark values reported in Table 2.[18] We then compute the initial steady state for each of

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

[18] US data in 1970 imply, among other things, a tax wedge of 0.252, a medical expenditure-output ratio of 0.071, a non-medical consumption-output ratio of 0.677, and a ratio of working hours to total discretionary time of 0.211. Due to data availability, the frequency of sick time is kept at its benchmark value of 0.021.

the European countries by replacing the US tax rates with that country's tax rates in 1970. The model-implied initial gaps in health spending-GDP ratio and labor supply between the US and the European countries so computed are due solely to their differences in the tax wedge in 1970.

Taking these initial conditions as given, we feed the time series of actual (for the period 1970-2007) and projected (for years beyond 2007) tax rates for each country into the baseline model and solve the transition dynamics under the assumption that the economy reaches a new steady state 90 periods after it begins from the initial steady state in 1970. We next compute the US-EU gaps in health care expenditure-GDP ratio and labor supply in 2007 based on the simulation results.[19] The changes in these gaps from their initial values in 1970 as predicted by the model can then be contrasted with their empirical counterparts observed in the data. These contrasts can give us a glimpse into the extent to which the widening US-EU gaps in health spending-GDP ratio and labor supply could be attributed to the widening EU-US gap in the tax wedge over the period 1970-2007.

The results are quantitatively quite significant. Take for example the case where tax rates are projected to increase at their average growth rates over the 1971-2007 period for years thereafter before leveling off in 2020.[20] Simulations of the model in this case show that the widening gap in the tax wedge between Europe and the US from 1970 to 2007 can explain on average more than 18% of the widening gap in health care expenditure-GDP ratio, while at the same time more than 44% of the widening gap in time spent on paid work, between the US and the Eurozone over this period. In particular, the taxation channel explains a significant fraction of the widening gap in health care expenditure-GDP ratio and time spent on paid work for six out of the eight European countries in our sample – 29.4% and 74% for Belgium, 20.3% and 72% for Finland, 34.1% and 42% for France, 17.7% and 25.1% for Germany, 22.4% and 90% for Italy, and 25.1% and 43% for Spain.[21]

The dynamic analysis in this section is important for yet another reason since, in addition to taxation, there may be other institutional (or cultural) difference across countries relevant for considering the US-Europe difference in the composition of health investment portfolio. For example, preferences and social norms may also play a role in time allocation.[22] However, in a time period as short as our sample,

[19]Due to lack of time series data, we set relative health care price to unity across all countries at all time in all simulations for the dynamic analysis in this section.

[20]We have also simulated the model under alternative assumptions about projected tax rates for years beyond 2007 but do not find quantitatively significant changes in results.

[21]The analysis for Italy is for the period starting in 1988. See Footnotes 1, 7, 8, and 16.

[22]See He and Huang (2013) for a list of references that argue along this line.

the US-Europe differences in preferences and cultures are arguably more stable than their differences in the variables examined in this paper, so are less likely to be the dominant factors underlying the changes in the latter.

3.3 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-Europe 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) – implying that the effect of relative health care price difference on the cost per unit of medical consumption dominates its effect on the composition of health investment portfolio – it generates cross-country difference in time allocation in a direction opposite to the data (except for Italy). Quantitatively, as the last row of Table 4 shows, the US-Europe difference in relative health care price accounts for 16.7% of their difference in medical expenditure-GDP ratio, but it also 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.

3.4 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-Europe differences in taxation and in relative health care price jointly provide a fairly successful account of 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% of their difference in time spent on paid work, and 87% of their difference in time spent on health-enhancing leisure activity.

It is a fairly robust result of this paper that differences in taxation and in relative health care price can jointly provide a reasonable account of the differences in health expenditure and in time allocation between the US and Europe. In what follows, we extend the baseline model along many dimensions and conduct many sensitivity analyses to show that this basic conclusion holds quite generally. As we will see, the various model extensions or variations in model features or parameter values can have some quantitative influence on the results – sometimes strengthened, and other times weakened – but in no case they will alter the general conclusion.

4 Extended Models

In this section, we extend the baseline model studied above along three dimensions. In the first extension, we introduce a survival motive on top of the consumption and investment motives for health care. In the second extension, we differentiate leisure time activity that is health-enhancing from those that are not. In the third extension, we take into account important life cycle characteristics, such as age dependent health depreciation and medical expenditure, as well as differences between working age population and retirees. As we will show below, the basic conclusion obtained in the baseline model continues to hold in these extended models.

4.1 Endogenous Survival Probability

A recent macro-health literature captures a survival motive for health investment by allowing health capital to affect survival prospect (e.g., Hall and Jones 2007, Zhao 2014, Halliday *et al.* forthcoming). Following this approach, we augment our baseline model to include endogenous survival probability as a function of health capital,

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

where ψ_t denotes the probability of surviving through period t conditional on having survived through period $t-1$. We assume that $\Psi(h_t)$ is an increasing function of h_t, with $\Psi(h_0) = 1$, in order to capture the idea that greater health capital improves survival prospect.

The expected, discounted lifetime utility is now given by

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

where the inclusion of a constant term b into the period utility function here is crucial in order to guarantee that the value of period utility is always positive so that it is worth enhancing life expectancy (i.e., Hall and Jones 2007).

The Euler equation associated with the optimal composition of leisure time and health-related commodity inputs in health production is the same as in the baseline model, as captured by Equation (10). The incorporation of the endogenous survival probability leads to the following modification to the Euler equation for optimal intertemporal allocation of consumption of the health-neutral commodity (combined with the condition for optimal accumulation in physical capital),

$$U_c(t) = \beta \mathrm{E_t}\Psi(h_{t+1})\left[U_c(t+1)(r_{t+1} + 1 - \delta_k)\right]. \tag{19}$$

A more dramatic modification occurs to the Euler equation for optimal health accumulation (combined with the condition for optimal intratemporal allocation between health-related consumption and health-neutral consumption) as follows,

$$\begin{aligned}&\beta \mathrm{E_t}\Psi(h_{t+1})[U_h(t+1) + \frac{\Psi'(h_{t+1})}{\Psi(h_{t+1})}U(t+1) - (1-\tau)w_{t+1}S'(h_{t+1})U_c(t+1)\\ &+(1-\delta_h)\frac{U_c(t+1)}{H_m(t+1)}p_m] = \frac{U_c(t)}{H_m(t)}p_m,\end{aligned} \tag{20}$$

where $U(t+1) \equiv U(c_{t+1}, l_{t+1}, h_{t+1}) + b$. In addition to augmentation of the discount factor with the conditional survival probability $\Psi(h_{t+1})$ in getting the present value of expected future benefit from having one additional unit of health capital at date $t+1$, the future benefit itself also includes a new component $[\Psi'(h_{t+1})/\Psi(h_{t+1})]U(t+1)$, representing an extra utility gain from the extended life expectancy brought about by the additional unit of health capital.

For the quantitative exercise conducted below, we parameterize the conditional survival probability function following Zhao (2014):

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

This extended model has all parameters of the baseline model plus two additional parameters, κ and b. All of the baseline parameters take their benchmark values reported in Table 2, except for β, λ, ρ, θ, Q, and B, which are determined jointly with κ and b, by matching six steady-state conditions in this extended model with the corresponding moment conditions for the US economy described in Section 3.1, plus using two additional matches between the extended model and the US data.

First, in the steady state of this extended model, $1 - \Psi(h) = 1/e^{\kappa h}$ corresponds to population's death rate in the steady state. Setting $1/e^{\kappa h}$ to the long-run average death rate over the period 1970-2007 in the US, which is 0.87%, gives rise to one additional match between the extended model and the US data.

Second, the term b in the period utility function has a direct bearing on the value of statistical life (VSL) studied in the literature (e.g., Viscusi and Aldy 2003). In our model, as in Hall and Jones (2007) and Zhao (2014), VSL corresponds to the marginal cost of saving a life. In terms of our model's notations, this is measured by taking inverse of the marginal effect of health care spending on survival probability, or, VSL $= p_m/[\partial\Psi(h)/\partial m] = p_m/[(\partial\Psi/\partial h') \times (\partial h'/\partial m)]$. Substituting the steady-state versions of (10) and (19) into the steady-state version of (20) then yields the following relation between b and the mean VSL,

$$\frac{\beta(U+b)}{U_c} = \frac{\text{VSL}}{r+1-\delta_k}\left[r + \delta_h - \delta_k + \left(H_l + \frac{H_m}{p_m}\frac{U_l}{U_c}\right)S'(h) - \frac{H_m}{p_m}\frac{U_h}{U_c}\right].$$

The parameter b is thus calibrated to match the mean VSL in our model to the mean VSL for working-age Americans in 2000, which is about \$3.5 million (constant 2000 \$).[23] In addition, we verify that b so calibrated is indeed big enough to guarantee that the flow utility is always positive under all circumstances in our simulations.

[23]This number is calculated following Hall and Jones (2007). See Table 1 in their paper. The US Food and Nutrition Service (USDA) and Environmental Protection Agency (EPA) use \$3.5-3.9 million (constant 2000 \$) as their benchmark VSL (see, also, Viscusi and Aldy 2003).

Using the calibrated model we can conduct the exercises described in Sections 3.2-3.4. As the last row of Table 6 shows, this extended model with survival motive generates results much in line with the baseline model: On average,

- the US-Europe difference in the tax wedge accounts for 52.2%, 96%, and 96.9% of their differences in health spending-GDP ratio, time spent on paid work, and on health-enhancing leisure activity, respectively;
- the US-Europe difference in relative health care price accounts for 14.8% of their difference in health spending-GDP ratio, and its implication on time allocation is in the same direction as in the baseline model that is opposite to the data;
- the US-Europe differences in the tax wedge and in relative health care price together account for 62.9%, 86%, and 88.7% of their differences in health spending-GDP ratio, time spent on paid work, and on health-enhancing leisure activity, respectively.

Thus, the taxation and relative health care price channels together explain more of the cross-country difference in health spending-GDP ratio than each of the two channels separately, but less of the cross-country difference in time allocation than the taxation channel alone, similarly as in the baseline model.

4.2 Differentiating Different Types of Leisure

In the baseline model, leisure time is defined as non-sick time spent away from paid work, which not only directly generates utility but in its entirety is 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 almost entirely reflects 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 embodied in the baseline model may indeed account for the US-EU difference in the health-enhancing leisure time. This will be confirmed using the following extended model that formally divides the broadly defined leisure time into health-enhancing leisure time and health-neutral leisure time.

To proceed, let's denote by v health-enhancing leisure time and l health-neutral leisure time. The time constraint then becomes

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

Since it is v 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[24]

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

This extended model embeds a mechanism similar to the one described by the intratemporal condition (10) for the baseline 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, where 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 these trade-offs work is similar to that described in Section 3, with the broadly defined leisure time there divided between the health-enhancing leisure time and the

[24]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 baseline model presented in Section 3.

health-neutral leisure time here. This suggests that results similar to those obtained in the baseline model should continue to hold in this extended model in accounting for the US-Europe differences in time allocation and health expenditure.

To put this in a more concrete perspective, we conduct in this extended model the exercises described in Sections 3.2-3.4. We begin by noting that the above extension introduces an additional parameter ϕ measuring the weight of health-enhancing leisure time in utility. In each exercise we choose the value of ϕ to match the fraction of time endowment that Americans devote to health-enhancing leisure activities.[25] We also recalibrate the six parameters β, λ, ρ, B, θ, and Q, to match the six moment conditions as described in Section 3.1. Values of the other parameters are kept the same as in the benchmark calibration of the baseline model. We then replace in sequel the tax wedge, relative health care price, and both, for the US with those for each of the eight European countries, to generate our model's predictions about the cross-country differences in the key variables of interest.

As the last row of Table 7 shows, this extended model with different types of leisure generates results broadly similar to those in the baseline model: On average,

- the US-Europe difference in the tax wedge accounts for 34.4%, the entirety, and 44.8% of their differences in health spending-GDP ratio, time spent on paid work, and on health-enhancing leisure activity, respectively;

- the US-Europe difference in relative health care price accounts for 19.5% of their difference in health spending-GDP ratio, and its implication on time allocation is in the same direction as in the baseline model that is opposite to the data;

- the US-Europe differences in the tax wedge and in relative health care price together account for 52.3%, 94.5%, and 30.2% of their differences in health spending-GDP ratio, time spent on paid work, and on health-enhancing leisure activity, respectively.

Thus, once again, and similarly as in the baseline model, the taxation and relative health care price channels together explain more of the cross-country difference in health spending-GDP ratio than each of the two channels separately, but less of the cross-country difference in time allocation than the taxation channel alone.

[25]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.

4.3 A Life Cycle Overlapping Generations Model

Recall from Section 2 that health expenditures are higher in the US than in Europe not only in aggregate but within different age groups. The baseline model focuses on the behavior of working age population to demonstrate the functioning of taxation and relative health care price channels, which are less applicable to the retiree group. For retirees, labor income tax becomes irrelevant, although consumption tax and relative health care price continue to matter. This is why the explanatory power of the taxation channel can be strengthened in the baseline model when attention is restricted to accounting for the data on working age population's health expenditures, as illustrated in Section 3.2.3.

In this section, we continue to focus on the national health expenditure data as the empirical target, and we study to what extents the explanatory powers of the taxation and relative health care price channels are affected in accounting for the US-Europe differences in their national health expenditures (and time uses) when we extend the baseline model to a life cycle overlapping generations (OLG) environment.

We assume that in each period there is a continuum of agents with unit measure living in the economy. An agent starts working at age 1, retires at age j_R, and then lives through age J. From the perspective of first entering into the labor market, the expected lifetime utility of the agent is given by

$$\mathrm{E}\sum_{j=1}^{J}\beta^{j-1}U(c_j,l_j,h_j),$$

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

$$\begin{aligned}(1+\tau_c)(c_j+p_m m_j)+a_{j+1} &= (1-\tau_n)w_j n_j+(1+r_j)a_j+T,\\ n_j+l_j+s_j &= 1,\end{aligned}$$

after retiring, i.e., for $j\in[j_R,J]$,

$$\begin{aligned}(1+\tau_c)(c_j+p_m m_j)+a_{j+1} &= (1+r_j)a_j+T,\\ l_j+s_j &= 1,\end{aligned}$$

where a_j denotes her net asset position held at age j, and we assume that she holds zero asset both when first entering the labor force and when finally leaving the world and that she faces a borrowing constraint over the lifespan,

$$a_1=a_J=0,\ \ a_j\geq 0,\ \text{ for } j\in(1,J).$$

Another defining feature of the model is that health depreciation is age dependent,

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

where $\{\delta_{h_j}\}_{j\in[1,J)}$ are configured to match the life cycle patterns of health status. This configuration of age specific health depreciation rate profile, together with proper calibration of the elasticity of substitution between consumption and health in the utility function, make the model consistent with the life cycle patterns of health expenditures, which can increase substantially with age and be concentrated in the last years of life (e.g., Jung and Tran 2010; Halliday *et al.* forthcoming).

Other features of the model are the same as those of the baseline model.

Definition 1 *A stationary recursive equilibrium is a collection of individual value functions $V_j(a_j, h_j)$ and policy rules $C_j(a_j, h_j)$, $M_j(a_j, h_j)$, $A_j(a_j, h_j)$, and $N_j(a_j, h_j)$, for every age j, together with aggregate consumption C, health expenditure M, stock of physical capital K, labor input N, and wage and interest rates w and r, such that:*

1. *Given wage and interest rates (as well as prices and tax rates), individual value functions and policy rules solve an agent's dynamic programming problem.*

2. *Aggregate measures are consistent with aggregation across different age groups,*

$$\begin{aligned} C &= \sum_{j=1}^{J} C_j(a_j, h_j)/J, \\ M &= \sum_{j=1}^{J} M_j(a_j, h_j)/J, \\ K &= \sum_{j=1}^{J} A_j(a_j, h_j)/J, \\ N &= \sum_{j=1}^{j_R-1} N_j(a_j, h_j)/(j_R - 1). \end{aligned}$$

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

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

4. *Government budget constraint is satisfied,*

$$\tau_c(C + p_m M) + \tau_n w N = T.$$

5. Goods market clears,

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

For quantitative analysis, we parameterize the model using the same functional forms adopted in Section 3.1 for utility, goods and health productions, and sick time, and we assume that one model period corresponds to five years and an agent enters into the labor force at age 20, retires at age 65, and dies at age 90. This latter assumption implies $j_R = 10$ and $J = 16$.

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

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

based on the study by Halliday *et al.* (forthcoming). The three parameters d_0, d_1, and d_2 are calibrated to match three moment conditions of health status over the life cycle, and their resulting values are $d_0 = -4.3$, $d_1 = 0.31$, and $d_2 = 0.004$. The calibrated health depreciation rate increases over the life cycle. We then calibrate η to 1.1, which governs the elasticity of substitution between consumption and health in the utility function, to match an important moment condition regarding the life cycle patterns of health care expenditures, in particular, the ratio of medical expenditures for ages 65-79 to those for ages 20-64, which is equal to 2.16. These choices of parameter values allow the model to capture how quickly medical expenditures may rise with age.[26]

To conduct each of the exercises described in Sections 3.2-3.4 in this life cycle OLG environment, we recalibrate the subjective discount factor, β, the parameter measuring the importance of non-medical consumption in the utility function, λ, the parameter measuring the importance of leisure in the utility function, ρ, the share of medical goods input in health production, θ, and the two scaling parameters, Q and B, to match six stationary equilibrium conditions in the OLG model with the corresponding moment conditions for the US economy described in Section 3.1. Values of the other parameters remain the same as in the benchmark calibration of the baseline model, where δ_k is adjusted for the five-year low frequency so as to be consistent with a 7.6% annual depreciation rate of physical capital.

As the last row of Table 8 shows, the explanatory power of the taxation channel is smaller in this life cycle OLG environment than in the baseline model, because labor

[26] In these calibration exercises, the moments of actual data are computed from Medical Expenditure Panel Survey (MEPS). See Halliday *et al.* (forthcoming) for details.

income tax becomes irrelevant for retirees, but it remains quantitatively significant, because consumption tax continues to matter for retirees and both labor income and consumption taxes matter for working age people just as in the baseline model: On average, the US-Europe difference in the tax wedge still accounts for 25.5%, 43.9%, and 45.6% of their differences in *national* health expenditure-GDP ratio, time spent on paid work, and on health-enhancing leisure activity, respectively.

It is worth noting that, opposite to the baseline model, in the OLG environment the relative health care price channel goes against data on cross-country difference in *national* health spending-GDP ratio, but qualitatively in line (though quantitatively insignificantly) with data on cross-country difference in time allocation. The reason for the contrasting results between the two settings is as follows. In the baseline model difference in the income effect associated with difference in health care price is largely muted because of workers' re-balancing between time and goods inputs in maintaining health, e.g., everything else equal American workers facing a higher health care price would work less and use more time and less medical inputs in maintaining health. Such re-balancing between multiple uses of time and health care demand is why in the baseline model the health care price channel goes against data on cross-country difference in time allocation. In the OLG setting, difference in the income effect due to difference in health care price is much magnified, because of nonapplicability of such re-balancing between multiple time uses to retirees, which together with age-dependent health status imply a higher marginal propensity to consuming health care by retirees than by workers. The larger and inelastic demand for health care after retirement in the face of a lower health care price thus implies a greater permanent income effect that, everything else equal, would lead people across all ages (but especially retirees) to consume more medical commodity and working age people to consume more leisure as well. In fact, this income effect is so large that it dominates the direct effect of the lower health care price on overall health expenditure and also slightly more than offsets the re-balancing effect on time allocation by workers. This is why in the OLG setting the lower health care price in Europe than in the US by itself tends to result in a higher *national* health expenditure-GDP ratio, and slightly lower labor supply and more health-enhancing leisure time in Europe than in the US.

While the health care price channel moves the OLG model closer to data along the dimension of time allocation but farther from data along the dimension of health expenditure compared to the baseline model, the effects are small compared to those of the taxation channel. As a result, our general conclusion based on the core mechanism demonstrated through the working of the baseline model in Section 3 continues to hold in the life cycle OLG setting. As can be seen from the last row of Table 8, in the OLG model the two channels together account for more of the cross-country differences in *national* health expenditure-GDP ratio and time allocation than each of the two channels separately, with the explained fractions of the data being 27.8%, 45.7%, and 49.8%, respectively.

5 Additional Sensitivity Analyses

To conserve space, in what follows, we only report some additional results focusing on analyzing the sensitivity of the taxation channel. In all analyses to be conducted below, results for the benchmark case are obtained by keeping all parameters to their 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 when we vary certain features of the model or parameter values, as will be noted whenever this is the case, so that the benchmark case remains consistent with the US economy. The model predicted cross-country differences in health spending-GDP ratio and time allocation due to their differences in taxation are then obtained by replacing the tax rates in the US with those in each of the eight European countries.

5.1 Health-Leisure Complementarity 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),

$$U(c_t, l_t, h_t) = \frac{\log[\lambda(c_t^{\rho} l_t^{1-\rho})^{1-\eta} + (1-\lambda)h_t^{1-\eta}]}{1-\eta}. \tag{22}$$

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 3.1, 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 specified in (22) implies that, health is complementary to not only consumption but leisure. This is to say that, being healthy helps enjoy not only consumption but 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 (22). This is done by repeating the exercise in Section 3.2 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 52.9% of their difference in health spending-GDP ratio, 81% of their difference in paid work time, and 89% 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 3.2 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 (22).[27] 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.

5.2 Consumption-Leisure Trade-Off in Preferences

As shown in Section 3, the consumption-leisure trade-off in preferences as illustrated by the first term of Equation (10) is one component of the model's mechanism. To see how robust our results are to the strength of this trade-off, we consider a generalized form of the period utility function in (17) given by

$$U(c_t, l_t, h_t) = \frac{\log[\lambda c_t^{1-\eta} + (1-\lambda) h_t^{1-\eta}]}{1-\eta} + \rho \frac{l_t^{1-\frac{1}{\mu}}}{1-\frac{1}{\mu}}. \tag{23}$$

Clearly, (17) is a special case of (23) with μ set to 1. We can show that μ determines the Frisch labor supply elasticity so it affects the strength of the consumption-leisure

[27] To understand the intuition behind this, recall that higher taxes result in less medical spending, more time spent on leisure and less on paid work, and that this is the case under either specification of the period utility function. If health and leisure are complementary to each other, as is the case under the period utility function (22), then 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), compared to the case with the period utility function (17). This is why the explanatory power of the taxation channel is strengthened for health spending-GDP ratio but weakened for time allocation, when the utility specification (17) is replaced with (22).

trade-off in preferences. When we lower μ, we lower the labor supply elasticity and weaken the strength of the trade-off. It is interesting to see to what extent our results will be weakened when we reduce μ to some extremely low values.

As a reference point, recall in the benchmark calibration with $\mu = 1$, the US-EU difference in the tax wedge explain 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. When we reduce μ significantly, to 0.5, the model's accounts of the respective differences are lowered modestly, to 41.2%, 82%, and 83.5%. When we lower μ further, to 0.3, the model's explanatory powers edge down moderately, to 34.6%, 72.1%, and 73.3%, respectively. Finally, even when we set μ to an extremely low value, 0.1, the US-EU difference in the tax wedge still accounts for 16.4% of their difference in health expenditure-GDP ratio, 43.5% of their difference in time spent on paid work, and 44.1% of their difference in time spent on health-enhancing leisure activity.

5.3 Health Production Technology

As also shown in Section 3, the medical care-leisure trade-off in maintaining health as illustrated by the second term of Equation (10) and the trade-off between medical and non-medical consumption in maintaining health and in delivering utility as prescribed by Equation (11) are two other components of the model's mechanism. The strengths of these trade-offs are affected by the health production function (16), in particular, the elasticity of substitution between medical commodity and leisure time inputs in health production, ω, and the degree of returns to scale in the health production technology, ξ. We here check the robustness of our results with respect to variations in the values of these two parameters.

The empirical estimates of ω by He *et al.* (2013) range from 0.74 to 1.36. The value 1 adopted in the benchmark calibration lies in the middle of this range. While variations of ω within this range do not significantly affect the model's account of the US-EU difference in time allocation, they do have some quantitatively more significant influence on the model's power in explaining the US-EU difference in medical expenditure-GDP ratio. As we lower ω, such power wanes, and vice versa. But, even when we reduce ω to the lower bound of the empirically reasonable range reported by He *et al.* (2013), the US-EU difference in the tax wedge still accounts for 22.3% of their difference in health spending-GDP ratio, and the entirety of their differences in time spent on paid work and on health-enhancing leisure activity.

The value 1 adopted in the benchmark calibration for ξ is consistent with much of the macro-health literature, which goes back to Grossman (1972). Nevertheless, Ehrlich and Chuma (1990) argue that some degree of decreasing returns to scale may be more appropriate for health production technology in this type of models. When we lower ξ to 0.5, a value suggested by Ehrlich and Chuma (1990), the US-EU difference in the tax wedge accounts for 55% 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.

5.4 Tax Shelter of Health Care Goods and Services

In the baseline model, all types of goods and services are subject to a homogenous consumption tax rate. Yet, some features of the health care systems in the US (e.g., employment-based tax subsidy) and Europe (e.g., universal health care) may lead one to argue that there are heavy government subsidizations on health care expenditures. That said, if we assume in the model a tax shelter on medical commodity for both the US and Europe, the results obtained above will not change much. What seems more interesting is how much the results will be affected if we impose a tax shelter on medical commodity for the US but not for Europe, or vice versa.

When we assume a tax shelter on medical goods and services for the US but not for Europe, the US-Europe difference in the tax wedge accounts for 55% of their difference in health expenditure-GDP ratio and almost all of their differences in time allocation. Conversely, when we assume a tax shelter on medical commodity for Europe but not for the US, the US-Europe difference in the tax wedge accounts for 33% of their difference in health spending-GDP ratio, 76% of their difference in paid work time, and 82% of their difference in health-enhancing leisure time.

5.5 Perils of Abstracting Leisure from Health Production

The feature that not only medical care but leisure is important in maintaining health, which is incorporated in the baseline model in a way consistent with empirical evidence, serves as a foundation for the model's success in accounting for cross-country differences in medical expenditure. For example, if we abstract from the time input in health production, then cross-country differences in taxation would generate cross-country differences in medical expenditure-GDP ratio in a direction that is opposite to what is observed in the data: In such a mis-specified model, 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 3.1, 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 in this way is then used to re-conduct the exercise described in Section 3.2. 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 to Americans.

We have undertaken many more sensitivity analyses than could be reported here. We do not discuss all of the results in this paper in order to conserve space, but in all of these additional experiments our basic conclusion holds broadly. This is typically the case when we vary other model features or parameter values 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 basic conclusions of the paper provided that the empirically motivated leisure time input is not abstracted away from health production.

6 Concluding Remarks

We have documented two sets of empirical observations over 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 health-enhancing leisure time activities, when compared to most comparably rich European countries. Second, labor income and consumption tax rates are considerably lower, while relative health care price is generally higher, in the 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 link may have to do with another empirically relevant fact, which is also documented in this paper, that is, both leisure and medical care are important in maintaining health.

This fact that leisure and medical care are both important in maintaining health can be pertinent to other issues of potential interest. For instance, He *et al.* (2015) 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 these findings, 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

Definitions and sources of data:

a. Health expenditure to GDP ratio–OECD Health Data 2010. Here $\tilde{m} \equiv p_m m$ and $y \equiv F(k, n; z)$.

b. Fraction of time spent on paid work–Ohanian, Raffo, and Rogerson (2008) and OECD (2011).

c. Fraction of time spent on health-enhancing leisure activity–OECD (2011).

d. Labor income tax rate–McDaniel (2007).

e. Consumption tax rate–McDaniel (2007).

f. Tax wedge–Authors' calculation based on d and e.

g. Relative price of health care–He, Huang, and Hung (2013).

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 Time Allocation: Data vs. Baseline Model's Predictions based on Cross-Country Variations in Taxation

Country	**Data**			**Model**			**Data Explained by Model**		
	$\boldsymbol{\Delta}(\tilde{\mathbf{m}}/\mathbf{y})$	$\boldsymbol{\Delta}\mathbf{n}$	$\boldsymbol{\Delta}\mathbf{l}$	$\boldsymbol{\Delta}(\tilde{\mathbf{m}}/\mathbf{y})$	$\boldsymbol{\Delta}\mathbf{n}$	$\boldsymbol{\Delta}\mathbf{l}$	$\boldsymbol{\Delta}(\tilde{\mathbf{m}}/\mathbf{y})$	$\boldsymbol{\Delta}\mathbf{n}$	$\boldsymbol{\Delta}\mathbf{l}$
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	0.037	**47.5%**	**91%**	**93%**

Table 4: EU-US Differences in Health Spending-GDP Ratio and Time Allocation: Data vs. Baseline Model's Predictions based on Cross-Country Variations in 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	-0.0078	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	**16.7%**	**-8.5%**	**-7.5%**

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

Country	**Data**			**Model**			**Data Explained by Model**		
	$\boldsymbol{\Delta}(\tilde{\mathbf{m}}/\mathbf{y})$	$\boldsymbol{\Delta}\mathbf{n}$	$\boldsymbol{\Delta}\mathbf{l}$	$\boldsymbol{\Delta}(\tilde{\mathbf{m}}/\mathbf{y})$	$\boldsymbol{\Delta}\mathbf{n}$	$\boldsymbol{\Delta}\mathbf{l}$	$\boldsymbol{\Delta}(\tilde{\mathbf{m}}/\mathbf{y})$	$\boldsymbol{\Delta}\mathbf{n}$	$\boldsymbol{\Delta}\mathbf{l}$
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	-0.0256	-0.0372	0.0348	**62%**	**84%**	**87%**

Table 6: Data Explained by the Extended Model with Endogenous Survival Probability

Country	**Taxation Channel**			**Price Channel**			**Both Channels**		
	$\boldsymbol{\Delta(\tilde{m}/y)}$	$\boldsymbol{\Delta n}$	$\boldsymbol{\Delta l}$	$\boldsymbol{\Delta(\tilde{m}/y)}$	$\boldsymbol{\Delta n}$	$\boldsymbol{\Delta l}$	$\boldsymbol{\Delta(\tilde{m}/y)}$	$\boldsymbol{\Delta n}$	$\boldsymbol{\Delta l}$
Belgium	64.3%	98.5%	66.4%	17.3%	-10%	-6%	76%	88.5%	61.2%
Finland	56.7%	316%	108%	5.2%	-11%	-3.5%	60.3%	305%	105%
France	86.6%	101%	113%	11.4%	-5.3%	-5.3%	94.2%	96.8%	109%
Germany	99.1%	119%	83.2%	44.8%	-20.5%	-12.6%	132%	100%	72.2%
Italy	45.7%	63.8%	153%	-2.6%	13.9%	3%	39.8%	65.6%	156%
Netherlands	79.1%	89%	121%	30.3%	-13%	-15.8%	99.7%	76.5%	107%
Spain	18.9%	41.1%	60.7%	21.6%	-17.5%	-22.7%	38.5%	24.2%	39.7%
UK	21.8%	171%	103%	11.6%	-34.6%	-18%	32%	138%	86.5%
Euro Mean	**52.2%**	**96%**	**96.9%**	**14.8%**	**-10.4%**	**-9.3%**	**62.9%**	**86%**	**88.7%**

Table 7: Data Explained by the Extended Model with Different Types of Leisure

Country	Taxation Channel			Price Channel			Both Channels		
	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$
Belgium	42.8%	102%	28.7%	23%	-7%	-9%	63.3%	98%	20%
Finland	37.9%	332%	20.3%	7%	-8%	-2.2%	44.3%	326%	18%
France	57.6%	106%	-28%	15.2%	-3.6%	4.7%	71.4%	103%	-24%
Germany	66.6%	126%	19.5%	6%	-14.4%	-10%	119%	115%	9.5%
Italy	27.8%	64.5%	0%	-3.4%	0.9%	0%	25%	65.2%	0%
Netherlands	52.4%	92.5%	44.5%	40%	-9.1%	-2.1%	88%	86%	25%
Spain	12.9%	44.2%	36%	28.3%	-12.2%	-47%	40%	33.2%	-9%
UK	14.9%	185%	20.5%	15.3%	-23.8%	-12.5%	30%	163%	8.5%
Euro Mean	**34.4%**	**100.3%**	**44.8%**	**19.5%**	**-7.3%**	**-15.7%**	**52.3%**	**94.5%**	**30.2%**

Table 8: Data Explained by the Life Cycle Overlapping Generations Model

Country	**Taxation Channel**			**Price Channel**			**Both Channels**		
	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$	$\mathbf{\Delta(\tilde{m}/y)}$	$\mathbf{\Delta n}$	$\mathbf{\Delta l}$
Belgium	28.1%	42.1%	29.5%	-12.2%	0%	0.9%	9.2%	45.1%	34.1%
Finland	23.2%	145%	52%	0.3%	0%	0.1%	34.8%	135.42%	48.1%
France	39.5%	44.7%	51.7%	-33.3%	3.19%	5.5%	55.4%	47.83%	55.9%
Germany	32.4%	53.5%	38.4%	7.7%	0%	1.5%	19%	61.7%	48%
Italy	25%	31.7%	81.5%	-2.9%	0%	-0.2%	44.3%	31.7%	78.8%
Netherlands	30.8%	39.1%	55.5%	4.9%	2.6%	5.8%	21.4%	39.1%	59.8%
Spain	18.9%	19.6%	27.5%	-14.6%	3.26%	9%	17.3%	22.8%	38.3%
UK	17.7%	84.2%	49.2%	-2.6%	-24.04%	-12.2%	20.8%	84.13%	54.3%
Euro Mean	**25.5%**	**43.9%**	**45.6%**	**-6.6%**	**0.4%**	**1.9%**	**27.8%**	**45.7%**	**49.8%**