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Abstract

This paper provides a macroeconomic explanation for the United States suffering from a health disadvantage relative to other rich European countries despite spending much more on health care. We introduce health capital à la Grossman in the neoclassical growth model and assume that its rate of depreciation increases with labor supply. The steady-state share of GDP devoted to health expenditure increases with labor supply, but the relationship between the health capital stock and the number of hours worked is hump-shaped, meaning that there is a country-specific health-maximizing level. We calibrate the model to the United States and assess how much of this 'American Health Puzzle' can be explained by the greater number of hours American workers work. Higher labor supply in the US accounts for 2 to 3 percentage points in extra health expenditure as a share of GDP and between 10% and one-third of the American health disadvantage.

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Keywords: Working Time, Health Capital, Health Expenditure, Health-Maximizing Level of Labor Supply, American Health Puzzle.

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> *"Mutual emulation and desire for a greater gain prompted [workers] to over-work themselves, and to hurt their health by excessive labour."*
>
> *– Adam Smith, The Wealth of Nations, 1776*

1 Introduction

This paper is motivated by what we label the *American Health Puzzle*: the fact that the health of the population of the richest country in the world, the United States, lags behind that of the comparable countries of Western Europe, despite a much greater share of GDP devoted to health expenditure. In 2019, before the COVID-19 pandemic outbreak, the US fared worse on a variety of health indicators: out of 38 OECD countries, it was ranked 29 and 28 in terms of life expectancy at birth and at 65 respectively, 29 in the number of premature avoidable deaths, and 35 for chronic diseases (OECD, 2019). This is all the more surprising as the US is well ahead in pole position in terms of expenditure with resources devoted to health care representing almost 17% of GDP compared to an average of 11% in Western European countries. Although a confluence of factors lie behind both the health disadvantage of Americans and exploding health spending in the US, most proposed explanations – from stark health inequalities driving down the national average to a much greater cost of health care in the US – do not account for the entirety of both phenomena and often fail to connect them.[1]

In this paper, we put forward an additional factor that could explain why Americans are in poorer health than Europeans despite spending much more on health care: the substantially greater number of hours worked in the US. Americans have indeed been working much more than Europeans for quite some time now. At the beginning of the 1980s, both worked approximately the same number of hours, but today Americans work about as much as they did in the 1980s, whereas Europeans work substantially less (Boppart and Krusell, 2020). Drawing on a wealth of empirical evidence from various scientific fields that suggests a detrimental effect of long working hours on health, we believe that it is worth investigating the relation between labor supply, population health and health care expenditure at the macroeconomic level.

To do so, we introduce health capital *à la* Grossman (1972) in a neoclassical growth model with elastic labor supply. We view health as a stock that individuals value *per se*.[2]

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[1] Anne Case and Angus Deaton have also documented a recent increase in what they call 'deaths of despair' that made American life expectancy fall for the first time in decades (Case and Deaton, 2015, 2017). We discuss various explanations of both the health disadvantage and the surge in health expenditure in the US more extensively in section 5.

[2] There can be various motives behind health investments, but Halliday et al. (2019) find that individuals invest in health mainly because of the direct utility a better health status provides.

This health capital stock can be increased via medical investments (usually the consumption of medical commodities, but also health-enhancing activities), but depreciates over time. We consider two versions of the health capital accumulation equation: a baseline in which health investments are the result of health expenditure and the rate of depreciation of health capital is endogenous and increases with labor supply, and an alternative specification in which leisure also enters the health investment function but the rate of depreciation is constant and exogenous. We also consider homothetic and non-homothetic preferences for a total of three different specifications of the model for which we derive our results.

Focusing on the long run, we are able to characterize analytically the steady state as a function of labor supply. We show that preferences for leisure, an exogenous parameter on which we center our comparative statics exercise, affect the endogenous variables of interest only through labor supply. This allows us to investigate how exogenous differences in hours worked coming from preferences for leisure shape cross-country differences in both health and health expenditure. For each specification, we prove three analogous results: (1) existence and uniqueness of the steady state, (2) how the share of GDP devoted to health expenditure varies with preferences for leisure, and (3) the existence of a health-maximizing level of labor supply and therefore of a hump-shaped relation between health and hours worked.

Our contribution is to show that considering the negative health effect of working hours can rationalize the two surprising features of the American Health Puzzle. First, when the rate of depreciation of health capital is endogenous, lower preferences for leisure lead to a higher share of GDP devoted to health care. Despite perfectly homothetic preferences, health spending increases more than consumption as individuals have to offset the extra depreciation of the health capital stock due to longer working hours. When depreciation is exogenous and hours worked enter the health production function instead, the result holds with complementarities between leisure and consumption in preferences, an assumption motivated by empirical evidence.[3] Second, we show that, for a range of parameters values, there is a hump-shaped relation between population health and preferences for leisure–and therefore labor supply. Health first improves with hours worked as the ensuing labor income allows individuals to purchase more medical goods and services. However, health starts to decline with labor supply when diminishing returns set in. Importantly, the existence of a health-maximizing level of preferences for leisure implies that of a health-maximizing level of labor supply, an observable variable. This health-maximizing level is country-specific since it depends on other parameters of the model. If the actual number of hours worked in the

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[3] Empirical evidence on the complementarities can be found in Blundell and Walker (1982) or Ham and Reilly (2002), and are been put forward in a more recent literature studying trends in leisure time in developed countries (Aguiar and Hurst, 2007; Boppart and Krusell, 2020; Boppart and Ngai, 2021).

US lies above this level, our model explains the American Health Puzzle, and a reduction in working time would both improve the health of American workers while reducing the share of GDP devoted to health care.

Whether this is the case is ultimately an empirical question. As a first attempt to provide an answer, we calibrate our model to the US economy. We investigate the effect of a reduction of labor supply and thus quantify to what extent long working hours in the US account for the American Health Puzzle. Because the negative health effect of hours worked possibly materializes later in life, we focus on the health status of older individuals. We then look at how both health and health expenditure vary with the hours worked per worker. In particular, we take advantage of our ability to express the steady state values of both the health capital stock and the share of GDP devoted to health expenditure as a function of labor supply to build a counterfactual in which working time in the US is the same as in the UK or France, two countries on which we have comparable detailed data on the intensive margin of labor supply (Blundell et al., 2011, 2013). In the baseline counterfactual, in which Americans reduce the hours worked per worker to the British level, health expenditure as a share of GDP decrease by 2.6 percentage points down to 13.9%, and the health disadvantage is reduced by around 27%. Using the slightly lower working time in France instead, those numbers become 3.1 and 38% respectively. We then conduct a series of robustness checks, using various health indicators, considering the role of differences health care prices, and different values of the key parameters of the model.

This paper is ultimately about the determinants of health at the macroeconomic level, which are probably a combination of individual decisions and a multitude of broader structural factors (Cutler et al., 2006). Health has already been incorporated in several variants of growth models and has been shown crucial to the process of development (Van Zon and Muysken, 2001; Chakraborty, 2004; Soares, 2005; Cervellati and Sunde, 2011; Dalgaard and Strulik, 2014). However, while the production of health is explicitly modeled, its accumulation and depreciation are not. Health capital has previously been introduced in growth models (Kelly, 2017), but we are the first to our knowledge to combine it with labor supply and make its rate of depreciation endogenous. As in Azomahou et al. (2015), who study the role of different preference structures in the health consumption bundle in determining wages and growth rates, we provide existence and uniqueness results with endogenous labor supply and health capital accumulation. Moreover, although we set ourselves in the broad macroeconomic literature concerned with health, we focus on contemporary differences in population health between rich countries rather than on the role of health at various stages of development. In particular, we put the emphasis on the role of cross-country differences in preferences *vis-à-vis* working time in shaping both the health of countries and the fraction of resources they devote to health care. Ponthière (2010) also considers the potentially detrimental effect of working too much on longevity in a model where individuals have different preferences for leisure and argues that lifestyles do matter for health.

The striking differences between the US and Europe have recently gained attention. Two papers are particularly close to ours. He et al. (2021) investigate the role of taxes in shaping individiuals' portfolio choice between medical spending and healthy leisure activities in the production of health embedded in an OLG lifecycle model. They emphasize the role of health-enhancing leisure time, and therefore argue that differences in taxation resulting in differences in time spent in market work between the US and Europe account for most of the gap in health expenditure. In this paper, even though in our baseline the negative health effect of hours worked comes from the deterioration of health capital, we also consider the effect of leisure in the health production function. We therefore share the idea that the allocation of time matter for the production of health, but put more emphasis on the health effect of differences in labor supply while they concentrate on health expenditure. Fonseca et al. (2023) use an incomplete market heterogeneous agents model augmented with health production to quantify the contribution of health prices in explaining cross-country differences in both health expenditures and health status. They find that substantially greater health prices in the US account for around 60% in differences in health expenditure and half of the health disadvantage. However, they abstract from labor supply decisions and from any negative health effect of hours worked. While both papers use more sophisticated frameworks and provide very rich sets of calibrations that are complementary to our analysis, they lack the theoretical results our parsimonious model can offer.

The outline of the paper is as follows. Section 2 lists empirical evidence from a broad set of studies documenting the negative impact of long hours of work on health, and introduces our two specifications for the health capital accumulation. Section 3 sets up the model and comparative statics results for three versions of the model are presented in Section 4. Section 5 provides detailed empirical evidence for the American Health Puzzle and discusses the related literature to motivate our quantitative exercises. We calibrate the model in Section 6 and run a series of counterfactuals and robustness checks. The last section concludes and proofs are gathered in the appendix.

2 The negative health effect of hours of work

The main assumption of our model is that long hours of work have a detrimental effect on workers' health. In this section, we document empirical evidence to justify the assumption, before presenting the equation that describes the accumulation of health capital, which we then introduce in a neoclassical growth model.

Empirical evidence. According to the *European Working Conditions Survey*, around 30% of workers in the European Union assess that their health is at risk because of their work, and the share of employees who agree with this statement increases with the number of hours worked. While our assumption thus appears consistent with a general popular feeling, there is also vast empirical evidence documenting the negative effect hours of work can have on population health. We believe such evidence gives credit to the Adam Smith quote in the epigraph of the paper.

This evidence stems from various disciplines such as biomedical sciences, public health or occupational epidemiology. Sparks et al. (1997) find small, but significant positive correlations between both physiological and psychological health symptoms and hours of work. White and Beswick (2003) suggest a positive relationship between working hours and fatigue and cardiovascular disorders, and a negative relationship between hours worked and physical health. Working long hours are also associated with depressive state, anxiety, poor sleep condition and coronary heart diseases (Bannai and Tamakoshi, 2014), ischemic heart diseases, stroke, and loss in disability-adjusted life years (Pega et al., 2021), deaths from cardiovascular disease before age 65, as well as infections, diabetes, injuries and musculoskeletal disorders (Ervasti et al., 2021). Furthermore, whereas it is well documented that Americans work longer hours than Europeans, it is much less known that they also work at 'strange' hours, that is at night and on weekend (Hamermesh and Stancanelli, 2015), potentially causing more harmful stress, sleep deprivation and a decline in cognitive function (Leso et al., 2021). Finally, there is also empirical evidence of correlations between a wide range of leisure activities and various health benefits, such as lower blood pressure, waist circumference, body mass index, lower levels of stress and depression, better physical function and mood, or better sleep (Pressman et al., 2009).

The health effect of hours worked can also be indirect. The business cycle matters for health through individual behavior: alcohol and cigarette consumption decline during recessions (Ruhm, 1995; Freeman, 1999; Ruhm and Black, 2002), while physical activity during leisure time increases. Ruhm (2005) points toward the fall in hours of work increasing the non-market time available for lifestyle investments during economic downturns as a potential explanation of healthier behavior. The adverse consequences of economic fluctuations on health may also go through externalities, in particular through pollution that increases mortality from respiratory illnesses or cardiovascular disease and heart conditions (Tapia Granados and Ionides, 2017; Cutler et al., 2016). Note however that our model will not feature such externalities and thus leaves no room for such an inefficient equilibrium.

Health capital and labor supply. To capture the potentially detrimental health effect of long working hours, we introduce in an otherwise standard neoclassical growth model another type of capital from which agents derive direct utility: health capital. We follow Grossman (1972) who conceptualized the idea that health could be viewed as a capital stock that can be increased via investment in medical care $m(t)$ but which also depreciates along the lifecycle.[4] To formalize the effect of hours worked on the health capital stock, we consider that the rate of depreciation of health capital can be an increasing function of individual labor supply $l(t)$, such that $\delta^h(t) = \delta^h[l(t)]$, but also that leisure time $L(t) = 1 - l(t)$ may enter the health investment function in addition to medical expenditure, such that $M(t) = M[m(t), L(t)]$. The health capital accumulation function is therefore defined in the most general specification possible as follows:

$$\dot{h}(t) = M[m(t), L(t)] - \delta^h[l(t)]h(t) \tag{1}$$

Health investments and depreciation. We consider two distinct specifications for the accumulation of health capital in the paper. In the first one, hours worked affect the health capital stock through its rate of depreciation only. The rate of depreciation of health capital is therefore endogenous, and it is assumed to be an increasing and convex function of labor supply, as the damage of hours of work on health may become more severe as individuals work more. In this baseline, labor supply does not enter the health production function through leisure. Health investments are simply the result of health expenditure and are subject to diminishing returns. We assume the following functional forms:

$$\delta^h(t) = zl(t)^\gamma \qquad \text{with} \qquad \gamma > 1 \tag{2}$$

$$M(t) = m(t)^\sigma \qquad \text{with} \qquad \sigma < 1 \tag{3}$$

where z is a scaling parameter.

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[4] Grossman's model of health capital accumulation proved tremendously influential in health economics. Recently, Dalgaard and Strulik (2014, 2015) have proposed another approach to study the demand for health based on the accumulation of health deficits instead, to deal with some shortcomings of the Grossman model. Although we stick to health capital accumulation in this paper, we believe the notion of health deficits is a promising one.

Solving equation (1) in this specification gives the general solution for the health capital stock as a function of medical expenditure and labor supply:

$$h(t) = h_0 e^{-\Lambda(t)} + \int_0^t m(s)^\sigma e^{-\Lambda(s,t)} ds$$

where $\Lambda(t) = z \int_0^t l(s)^\gamma ds$ and $\Lambda(s,t) = z \int_s^t l(\tau)^\gamma d\tau$.

Individuals therefore start with an initial stock of health capital h_0, which remains constant over time in the absence of both work and health expenditure. If individuals supply some labor and do not make any health investments, their health stock will progressively tend to zero. On the other hand, health expenditure increase the health capital stock and counteract the negative effect of labor supply. However, the effect of medical expenditure in period s is discounted by the amount of work between periods s and t. Hence, hours worked in the past have an effect on health expenditure ever since.

We also consider an alternative specification in which the rate of depreciation of health capital remains constant and exogenous. In this specification, hours worked affect the health capital stock through health investments, as leisure $L(t)$ enters the health production function along with health expenditure. For tractability, we assume a Cobb-Douglas function with diminishing returns in both inputs, but we do not restrict ourselves *a priori* to constant returns to scale:

$$\delta^h(t) = \delta^h \qquad \text{with} \qquad \delta^h < 1 \tag{4}$$

$$M(t) = m(t)^\sigma L(t)^\eta \qquad \text{with} \qquad \sigma < 1 \quad \& \quad \eta < 1 \tag{5}$$

Solving equation (1) with this alternative specification gives another general solution for the health capital stock as a function of medical expenditure and labor supply:

$$h(t) = h_0 e^{-\Gamma(t)} + \int_0^t m(s)^\sigma (1 - l(s))^\eta e^{-\Gamma(s,t)} ds \tag{6}$$

where $\Gamma(t) = t\delta^h$ and $\Gamma(s,t) = (t-s)\delta^h$. Because the rate of depreciation of health capital is exogenous and constant, hours worked play no role in the decay of the health capital stock. Labor supply does matter for health investments every period, and health capital depends on cumulative past investments. However, in stark contrast with the first specification, the previous history of hours worked does not discount such investments. Although we consider both specifications, because we believe the first one paints a better description of the dynamics of health capital, we take it as the baseline specification that we will use when calibrating the model.

Health in the utility function. In the next section, we make the peculiar choice of embedding health capital accumulation in a model with no mortality, in which a representative agent is infinitely-lived. While it may seem in opposition to Grossman's idea of agents optimally choosing the length of their life, there are actually a number of different motives behind individuals' health investment decisions. Halliday et al. (2019) study the determinants of health expenditure over the lifecycle and find that the consumption motive (a good health status directly increases flow utility) is more important than the survival motive (a good health status reduces mortality rates). In other words, individuals mostly value being in good health *per se*, and not because it improves survival probabilities. For this reason, we rather view the health capital stock as an indicator of health status, of morbidity, that individuals care about without necessarily internalizing the effect of a better health on the length of life. We thus assume that the health capital stock directly enters the utility function individuals seek to maximize. Although we do not model endogenous longevity in this paper, we believe that the prevalence of the consumption motive in health investment decisions makes it a reasonable abstraction.

3 The Model

We now plug the health capital accumulation equation in a standard neoclassical growth model with infinitely-lived individuals and endogenous labor supply. Time is continuous and for the sake of simplicity, we assume no population growth. We begin by describing the supply side of the economy with firms, before turning to households' behavior.

3.1 Firms

Firms produce the sole final good of the economy that can be either used for consumption, medical care or saved as investment. Let us consider the following simple Cobb-Douglas production function, common to each firm according to which output $Y(t)$ is produced:

$$Y(t) = A(t)K(t)^{\alpha}[l(t)N(t)]^{1-\alpha} \tag{7}$$

Where $K(t)$ is the stock of capital, $l(t)$ is individual labor supply and $N(t)$ is the number of workers. $A(t)$ is total factor productivity. We remain in an exogenous growth framework and are not interested in the effect of technological progress. We thus assume $A(t)$ is constant and normalize it to one for simplicity. Firms maximize profit, and the familiar first-order conditions arise naturally:

$$
\begin{aligned}
r(t) &= \alpha k(t)^{\alpha-1} l(t)^{1-\alpha} - \delta \qquad (8) \\
w(t) &= (1-\alpha) k(t)^{\alpha} l(t)^{-\alpha} \qquad (9)
\end{aligned}
$$

where $\delta > 0$ is the exogenous rate of depreciation of capital.

3.2 Households

Each period, individuals derive utility from consumption of the final good $c(t)$, their current health status $h(t)$ which corresponds to their stock of health capital at time t, and from leisure time $0 \leq L(t) \leq 1$ which is simply equal to a time endowment normalized to one minus the labor they supply on the market that we denote by $l(t)$, such that $L(t) = 1 - l(t)$. Notice that individuals are infinitely-lived so that there is no mortality in the model. Health therefore influences households behavior only via its impact on their utility only. Individuals therefore seek to maximize an intertemporal utility function U:

$$U = \int_0^{\infty} u[c(t), h(t), 1 - l(t)] e^{-\rho t} dt \qquad (10)$$

where $\rho > 0$ is the rate of time preference. We will consider several functional forms for the per-period utility function $u[c(t), h(t), 1 - l(t)]$, taking homothetic preferences as a baseline, before introducing complementarities between leisure and consumption. Various specifications are described in Section 4.[5]

Individuals hold assets which may take the form of ownership claims on capital or as loans. The two forms of assets are assumed to be perfect substitutes as stores of value so they must pay the same real rate of return $r(t)$. We denote assets per person as $a(t)$. Individuals are competitive and take as given the interest rate $r(t)$ and the wage rate $w(t)$, paid per unit of labor services. The total income received by each individual is therefore the sum of labor income, $w(t)l(t)$, and asset income, $r(t)a(t)$. They use it to consume and purchase medical care $m(t)$ at the relative exogenous price p, and use the rest to accumulate more assets.[6] The individual budget constraint therefore takes the following form:

$$\dot{a}(t) = w(t)l(t) + r(t)a(t) - c(t) - p \cdot m(t) \qquad (11)$$

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[5] Azomahou et al. (2015) study in depth the role of different preferences structures in the health-consumption bundle, but ask different questions about the effect of health on wages and on economic growth in general.

[6] Our model being a one sector model, there is no 'true' relative price between health and consumption. Only one good is produced, and individuals allocate it between consumption and medical investment. $m(t)$ should be interpreted as medical investment in efficiency units, and $p \cdot m(t)$ as actual health expenditure. We nevertheless keep the formulation with the relative price as it will prove useful for calibrating the model.

The households' problem is therefore to choose consumption, medical expenditure and labor supply (three control variables) and assets and health capital (two state variables) to maximize lifetime utility (10), subject to both health capital and assets accumulation equations (1) and (11). Using the first order conditions derived in Appendix A, we obtain the equation governing the leisure-consumption trade-off:

$$-\frac{u_l(t)}{u_c(t)} = w(t) + p\frac{M_l(t) - \delta_l^h(t)h(t)}{M_m(t)} \tag{12}$$

where the left hand side is now the marginal rate of substitution between leisure and consumption, or how much one values leisure in terms of consumption. In standard models, it is just equal to the wage rate $w(t)$. However, the net gains from an additional unit of work is reduced by the negative health effect of hours worked. This potentially comes from two channels depending on the specification we consider: through a decrease in leisure time in the health investment function $M(t)$ or an increase in the depreciation rate of health capital $\delta^h(t)$. Note nonetheless that an increase in labor supply also allows individuals to invest more in health care via medical expenditure $m(t)$, which partly counteracts the negative health effect of working more.

We can derive two quasi-Euler conditions from the first-order conditions, one for consumption and another one for health expenditure. Differentiating equations (29) and (30) (see Appendix A) with respect to time and substituting for the shadow prices using (32) and (33) gives:

$$\begin{aligned} \frac{u_{cc}(t)}{u_c(t)}\dot{c}(t) + \frac{u_{ch}(t)}{u_c(t)}\dot{h}(t) + \frac{u_{cl}(t)}{u_c(t)}\dot{l}(t) + r(t) - \rho &= 0 && (13) \\ \frac{M_{mm}(t)}{M_m(t)}\dot{m}(t) + \frac{M_{ml}(t)}{M_m(t)}\dot{l}(t) + \delta^h(t) - \frac{u_h(t)}{u_c(t)}\frac{M_m(t)}{p} + r(t) &= 0 && (14) \end{aligned}$$

These two equations are very general as we still have not specified any functional form for the instantaneous utility function $u(t)$ as well as both the health investment function $M(t)$ and the depreciation rate of health capital $\delta^h(t)$, but they will simplify substantially when we do so. They will also be useful in finding the steady state of the model, the analysis of which we will turn to shortly.

3.3 Equilibrium

We can now combine the behavior of price-takers households and firms to study the competitive market equilibrium. First, note that the economy is closed so all debts must cancel at each period and assets per person $a(t)$ are just equal to the capital stock per worker $k(t)$.

Now, if we take households' budget constraint (11), replace $a(t)$ by $k(t)$ and substitute for the values of $r(t)$ and $w(t)$ given by equations (8) and (9), we obtain the resource constraint of the economy:

$$\dot{k(t)} = y(t) - c(t) - p \cdot m(t) - \delta k(t) \tag{15}$$

This, together with households' optimization conditions (the equation governing the trade-off between leisure and consumption (12), and the Euler equations for consumption (13) and medical expenditure (14) plus two transversality conditions associated to both physical and health capital, the firms' first order conditions (8) and (9) and market clearing conditions characterize the economy's equilibrium.

3.4 Steady state

We now turn to the steady state analysis, a particular solution of the equilibrium system for which all endogenous variables are constant, and do so for three distinct specifications of the model. In the most general case, setting $\dot{k} = \dot{c} = \dot{m} = \dot{h} = \dot{l} = 0$, substituting for the equilibrium values of the wage rate as well as the interest, and dropping time indices gives us the following system of equations:

$$k^{\alpha} l^{1-\alpha} - c - p \cdot m - \delta k = 0 \tag{16}$$

$$\alpha k^{\alpha-1} l^{1-\alpha} - \delta - \rho = 0 \tag{17}$$

$$\delta^h - \frac{u_h}{u_c} \frac{M_m}{p} + \alpha k^{\alpha-1} l^{1-\alpha} - \delta = 0 \tag{18}$$

$$M - \delta^h h = 0 \tag{19}$$

$$-\frac{u_l}{u_c} - \left((1-\alpha) k^{\alpha} l^{-\alpha} + p \frac{M_l - \delta_l^h h}{M_m} \right) = 0 \tag{20}$$

First, equation (17) can be used to find the steady state capital-to-labor ratio and output as a function of labor supply, which will be useful later for deriving the share of GDP devoted to health expenditure, as well as the following resource constraint:

$$\Theta \left(\frac{\alpha}{\delta + \rho} \right)^{\frac{\alpha}{1-\alpha}} l^* = c^* + p \cdot m^* \tag{21}$$

where $\Theta = \dfrac{(1-\alpha)\delta + \rho}{\delta + \rho}$ is a constant that we define to simplify notation. Finally, substituting again for the capital-to-labor ratio in equation (18) yields:

$$\frac{u_h}{u_c} \frac{M_m}{p} = \rho + \delta^h \tag{22}$$

Equation (22) characterizes the trade-off between consumption and the stock of health capital at the steady state and is going to be at the center of the analysis. It will change according to the different specifications for the utility function, the health production function as well as the depreciation rate of health capital that we will consider below. Equation (20) that governs the leisure-consumption trade-off as well as equation (19) that gives the steady state health capital stock are also going to depend on the various specifications that we choose. The resource constraint given by equation (21) will remain the same.

4 Long-run comparative statics: Three specifications

In this section, we study how preferences for leisure might influence the share of GDP devoted to health expenditure as well as the stock of health capital for three specifications of the model that we label **S1**, **S2**, and **S3**. We do not only consider the two different specifications for the accumulation of health capital described in Section 2, but also vary households' preferences.

S1: Endogenous rate of depreciation of health capital. The specification that we take as our baseline and that we will use in the calibration of the model later is the following: preferences are assumed to be perfectly homothetic, and the negative health effect of hours worked come solely from the endogenous rate of depreciation of health capital. In this specification, the rate of depreciation of health capital and the health production function are therefore given by equations (2) and (3) respectively. Labor supply therefore raises the depreciation rate of health capital $\delta^h(l) = zl^\gamma$, and does so in a convex manner as $\gamma > 1$. Health investments are the results of medical expenditure only, such that $M(m) = m^\sigma$, with $\sigma < 1$ indicating diminishing returns to scale.

Regarding preferences, we stick to a fairly standard Cobb Douglas utility function in log-linear form, featuring consumption, the stock of health capital, and leisure time:

$$u(c(t), h(t), 1 - l(t)) = (1 - \phi) [\nu \log c(t) + (1 - \nu) \log h(t)] + \phi \log(1 - l(t)) \tag{23}$$

where $\phi \in (0, 1)$ characterizes preferences for leisure and is the parameter we will focus in our comparative statics exercises. $\nu \in (0, 1)$ is the taste for consumption relative to health. The motivation for using a simple utility function is two-fold: first, it enables us to express all endogenous variables at the steady state as a function of labor supply and thereby do straightforward comparative statics and second, it allows us to really isolate the effect of hours worked on the demand for health. Whereas Hall and Jones (2007) generate a rising share of health expenditure by assuming that health is a superior good, we show below that it is also possible to obtain the same result with the endogenous depreciation of health capital despite unitary income elasticity.

S2: Leisure in the health production function. We then consider our alternative specification for the accumulation of health capital. The rate of depreciation and the health production function are thus given by equations (4) and (5) respectively. Health investments are the result of leisure time in addition to medical expenditure, such that $M(m, l) = m^{\sigma}(1-l)^{\eta}$. Contrary to our baseline specification, the rate of depreciation δ^h does not depend on labor supply anymore and is exogenous and constant. The negative effect of hours worked on health instead comes from lower investments in health, as leisure enters the health production function.

We keep the same utility function as in the baseline specification (23), such that preferences are again perfectly homothetic. We then show that without the endogenous depreciation of health capital, the share of GDP devoted to health expenditure does not rise with hours worked anymore when the health production function is Cobb-Douglas and there is a unitary elasticity of substitution between medical expenditure and health-improving leisure time.

S3: Complementarities between leisure and consumption. In this third specification, we keep the rate of depreciation of health capital exogenous and constant as well as leisure in the health production function, but we introduce complementarities between leisure and consumption in the utility function such that preferences are non-homothetic. Complementarities between consumption and leisure are also present in the more general lifecycle setting of He et al. (2021). Their introduction is motivated by empirical evidence, provided in particular by Blundell and Walker (1982) and Ham and Reilly (2002). Such complementarities are also at the center of a more recent literature studying trends in leisure time in developped countries (Aguiar and Hurst, 2007; Boppart and Krusell, 2020; Boppart and Ngai, 2021). We therefore consider the following utility function:

$$u(c(t), h(t), 1-l(t)) = (1-\phi)\left[\nu \log c(t) f(1-l(t)) + (1-\nu)\log h(t)\right] + \phi \log(1-l(t)) \quad (24)$$

where $f(1-l(t)) = f(L(t))$ is an increasing function of leisure $L(t) = 1 - l(t)$). Because complementarities quickly make the model not tractable, we consider a simple function that is linear in leisure in the following assumption:

$$\textbf{\textit{A1.}} \quad f(L(t)) = aL(t) + b \quad \text{with} \quad a > 0 \quad \& \quad b > 0 \quad \& \quad a \leq b \quad (25)$$

This specification allows us to uncover the result about the rising health share when the rate of depreciation of health capital is exogenous and the negative health effect of labor supply comes from a lower leisure input in the health production function.

Overview of the results. At the steady state, we provide three main results for each specification: (**1**) existence and uniqueness of the steady state, (**2**) how the share of GDP devoted to health expenditure varies with preferences for leisure, and (**3**) the relationship between the stock of health capital and preferences for leisure. The results are developed in the following subsections and all proofs gathered in Appendix A. The table below nonetheless summarizes every propositions for the three specifications.

	S1 Homothetic preferences + endogenous depreciation	**S2** Homothetic preferences + exogenous depreciation	**S3** Non-homothetic preferences + exogenous depreciation
1	yes	yes	yes if **A1**
2	↓ with ϕ	constant	↓ with ϕ
3	hump-shaped*	hump-shaped*	hump-shaped*

*under conditions on the values of various parameters detailed in Proposition 3

4.1 Existence and uniqueness of the steady state

Before studying how preferences for leisure influence health expenditure as a share of GDP and the stock of health capital, we first need to show that a unique steady state exists. We show in Appendix A how, for all three specifications, we can actually write down steady state expressions for every endogenous variable as a function of labor supply l^* and exogenous parameters. Proving the existence and uniqueness of the steady state then boils down to showing that there exists a unique equilibrium number of hours worked at the steady state. The following proposition holds:

Proposition 1 *For* ***S*1**, ***S*2**, *and* ***S*3**, *there exists a unique steady state in which all endogenous variables* c^*, m^*, l^*, k^*, *and* h^* *are constant.*

Note that for the specification **S3** that features complementarities between consumption and leisure, assumption **A1** is assumed to be satisfied.

Once existence and uniqueness are ensured, we aim to study how the health capital stock and the share of health care expenditure vary with hours worked at the steady state, *all else equal*. Labor supply is naturally endogenous to a number of different parameters that also influence health and health expenditure. To isolate the effect of hours worked, we take advantage of the fact that we are able to analytically characterize the steady state as a function of labor supply, which is in turn a function of preferences for leisure ϕ. Because the parameter ϕ enters the steady state only through labor supply, a variation of labor supply caused by a change in preferences for leisure can be interpreted as exogenous. We investigate how different preferences for leisure affect the health capital stock and health expenditure.

Preferences for leisure are not the only source of cross-country differences in hours worked. Examples are differences in the level of taxation (Prescott, 2004), in the prevalence of trade unions (Alesina et al., 2005), or in career incentives in the labor market (Bell and Freeman, 2001; Gicheva, 2013; Goldin, 2014). However, Blanchard (2004) does suggest that potentially different preferences vis-à-vis leisure and work may be one cause of differences in hours worked between Europe and the US.[7] We want to stress that our parameter ϕ could also be interpreted as a proxy for various labor market phenomena outside the model that would not be correlated with either health or health expenditure.

The first step is therefore to show how labor supply varies with preferences for leisure ϕ. The following lemma holds in all three specifications:

Lemma 1 *For* $\boldsymbol{S1}$, $\boldsymbol{S2}$, *and* $\boldsymbol{S3}$, *steady state labor supply* l^* *decreases with preferences for leisure* ϕ: $\dfrac{\partial l^*}{\partial \phi} < 0$.

In the following subsections, we leverage this result to show how the share of GDP devoted to health spending and the stock of health capital vary with leisure preferences.

4.2 The rising share of health expenditure

We now aim to study how health expenditure as a share of GDP varies with hours worked at the steady state, *all else equal*. Now that we know that labor supply naturally decreases with preferences for leisure, we can study how preferences for leisure affect the share of GDP devoted to health expenditure through the number of hours worked. We can express that share as a function of steady-state labor supply for all three specifications of the model:

$$\frac{p \cdot m(l^*)}{y(l^*)} = \begin{cases} \dfrac{\Theta\sigma}{\sigma + V\Delta(l^*)} & \text{for } \mathbf{S1} \\ \dfrac{\Theta\sigma}{\sigma + V\Delta} & \text{for } \mathbf{S2} \\ \dfrac{\Theta\sigma}{\sigma + V\Delta f(1-l^*)} & \text{for } \mathbf{S3} \end{cases} \tag{26}$$

where $V = \dfrac{\nu}{1-\nu}$ is a constant that characterizes the taste for consumption relative to health. $\Delta(l^*) = 1 + \rho/\delta^h(l^*)$ is a term that depends on the depreciation rate of health

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[7] Heterogeneity of preferences across countries are a well-known source of concern for international welfare comparisons, and Bargain et al. (2013) show that preferences with respect to the consumption-leisure trade-off are indeed heterogeneous across countries.

capital. As it decreases with labor supply, so does the share of GDP devoted to health expenditure. In **S1**, the negative health effect of hours worked does indeed lead individuals to increase health expenditure relative to consumption as labor supply increases, despite perfectly homothetic preferences. On the contrary, $\Delta = 1 + \rho/\delta^h$ is a constant in both **S2** and **S3** when the rate of depreciation of health capital is exogenous. Keeping preferences homothetic as in **S2**, labor supply no longer affects the consumption ratio to health spending and therefore their share of GDP. The effect of labor supply is reintroduced in **S3** but instead comes from $f(1 - l^*)$, the complementarities between leisure and consumption: an increase in hours worked reduces the marginal utility of consumption and therefore leads individuals to spend relatively more in terms of medical expenditure.

The effect on health expenditure as a share of GDP of more hours worked due to lower preferences for leisure is characterized for all three specifications in the following proposition:

Proposition 2 *The share of GDP devoted to health expenditure decreases with preferences for leisure in* ***S*1** *and* ***S*3***, and is constant in* ***S*2***.*

This is the first substantial result of the paper, and it is intuitively straightforward. In all specifications, lower preferences for leisure raise steady-state labor supply. In our baseline specification **S1**, the resulting additional hours of work increase the health capital stock's depreciation rate. The marginal rate of substitution between the stock of health capital and consumption increases, and individuals are willing to increase their demand for health care relative to consumption. In other words, they use the proceeds of their extra labor income to increase both consumption and healthcare expenditure, but because they have to offset the extra depreciation of their health capital, they increase medical spending more than consumption. Recall that the Engel curves should be linear with our baseline log-linear Cobb-Douglas utility function. Introducing a negative health effect of hours of work through the depreciation rate of health capital makes the demand for health care non-homothetic, despite perfectly homothetic preferences.

This is no longer the case in **S2** in which the rate of depreciation of health capital is exogenous and constant and the negative effect of hours worked comes through leisure in the health production function instead. However, the depreciation of health capital still matters through Δ, and an exogenous increase of this parameter does raise the share of GDP devoted to health care. Therefore, a greater depreciation of health capital in the US could still be a source of difference in health expenditure between the US and Europe.

In the presence of complementarities between leisure and consumption as in **S3**, lower preferences for leisure resulting in a greater labor supply do increase the share of GDP devoted to health expenditure. Let us stress that the mechanism is not the same as in the baseline model: such additional expenses do not come from the need to offset the extra depreciation of health capital but rather from the reduced marginal utility of consumption due to less leisure time. Complementarities between consumption and leisure thus help explain why the demand for health rises with labor supply and could be a source of differences in health spending as a share of GDP between countries with different preferences for leisure.

4.3 Preferences for leisure and the health capital stock

In this subsection, we study the relationship between preferences for leisure and the steady state stock of health capital. Again, we leverage the fact that preferences for leisure affect health solely through labor supply. The derivative of the health capital stock with respect to preferences for leisure at the steady state can therefore be written as follows:[8]

$$\frac{\partial h^*}{\partial \phi} = \begin{cases} \dfrac{\partial l^*}{\partial \phi} \underbrace{h(l^*) \left\{ \sigma \dfrac{m'(l^*)}{m(l^*)} - \dfrac{\gamma}{l^*} \right\}}_{h'(l^*)} & \text{for } \mathbf{S1} \\ \dfrac{\partial l^*}{\partial \phi} \underbrace{h(l^*) \left\{ \sigma \dfrac{m'(l^*)}{m(l^*)} - \dfrac{\eta}{1-l^*} \right\}}_{h'(l^*)} & \text{for } \mathbf{S2} \text{ and } \mathbf{S3} \end{cases} \tag{27}$$

In all three specifications, the sign of this derivative is ambiguous. A decrease in leisure preferences will improve health only if the resulting rise in health expenditure from the greater labor income more than offset than the negative health effect of a greater number of hours worked. In **S1**, this negative effect comes from the greater rate of depreciation of health capital that needs to be offset, while in **S2** and **S3**, it comes from the lower leisure input in the health production function. In every specification, depending on values of parameters pertaining to the production and depreciation of health, there exists a non-monotonic between preferences for leisure and the stock of health capital that is described in the following proposition:

Proposition 3 *There exists a unique health-maximizing level of preferences for leisure* $\tilde{\phi}$ *below which the health capital stock increases with preferences for leisure* ($\partial h^*/\partial \phi > 0$ *for* $\phi < \tilde{\phi}$) *and above which it decreases with preferences for leisure* ($\partial h^*/\partial \phi < 0$ *for* $\phi > \tilde{\phi}$),

- ***S1****: if and only if* $\dfrac{\gamma}{1+\gamma} < \sigma < \dfrac{\gamma + \chi V}{1+\gamma-\chi}$ *where* $\chi = \dfrac{(1-\alpha)}{\Theta}$ *and* $V = \dfrac{\nu}{1-\nu}$
- ***S2****: if and only if* $\sigma < \dfrac{\chi}{1-\chi} V \Delta$
- ***S3****: if and only if* $l^*(0) > \bar{l}$ *with* $\bar{l} < 1$ *a constant.*

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[8] Note that the functions depicted in the equation with a slight abuse in notation, in particular $m(l^*)$, actually differ across specifications (see Appendix A)

There is, therefore, a hump-shaped relationship between preferences for leisure and the steady state stock of health capital in all three specifications, contingent on the value of some parameters. The returns to health expenditure σ appear to be important, as well as the curvature of the depreciation rate γ in **S1**. More specifically, when $\sigma < \frac{\gamma}{1+\gamma}$, such that the returns to health expenditure are too low relative to the curvature of the depreciation rate of health capital, lower preferences for leisure that raise steady-state labor supply always decrease the steady-state stock of health capital. The additional medical goods and services that can be purchased with the increase in labor income are not enough to counteract the extra depreciation of the health capital stock brought by the greater number of hours worked. On the other hand, if $\sigma > \frac{\gamma + \chi V}{1+\gamma-\chi}$, the returns to health investments are strong enough to more than fully offset that extra depreciation. Health status is, therefore, a strictly decreasing function of preferences for leisure because individuals can always 'buy back' the health they lost by working more.

The same logic is at play in **S2** and **S3**, except the relationship can never be strictly negative. In **S2**, if the returns to health expenditure are so great that $\sigma > \frac{\chi}{1-\chi} V\Delta$, health-maximizing preferences for leisure would turn negative. This means that even with no preferences for leisure in the utility function ($\phi = 0$), the resulting working time would not be high enough to generate a negative health effect, and health spending, therefore, always offsets the negative health effect of lower leisure time. In **S3**, the proposition also hinges on the fact that labor supply needs to be high enough in the absence of preferences for leisure ($\phi = 0$) for diminishing returns to set in, although we cannot characterize the threshold analytically. When the returns to health investments σ and other parameters are such that there exists a health-maximizing level of preferences for leisure, a hump-shaped relationship emerges between such preferences and the steady state stock of health capital.

4.4 The health-maximizing level of labor supply

A direct corollary of the existence of a health-maximizing level of preferences for leisure, coupled with the fact that preferences for leisure influence the other endogenous variables of the model only though labor supply, is the existence of a health-maximizing level of labor supply: $\tilde{l} = l^*(\tilde{\phi})$. Preferences for leisure then determine whether labor supply $l^*(\phi)$ actually lies below or above its health-maximizing level at the steady state. This, in turn, drives the effect of a local increase or decrease of hours worked on population health. In addition to being more intuitive, expressing the results in terms of an observable variable (labor supply, or hours worked) rather than an unobservable variable (preferences for leisure) will be useful when taking the model to the data in Section 6. The inverted U-shaped relationship between health and hours worked is depicted in Figure 1.

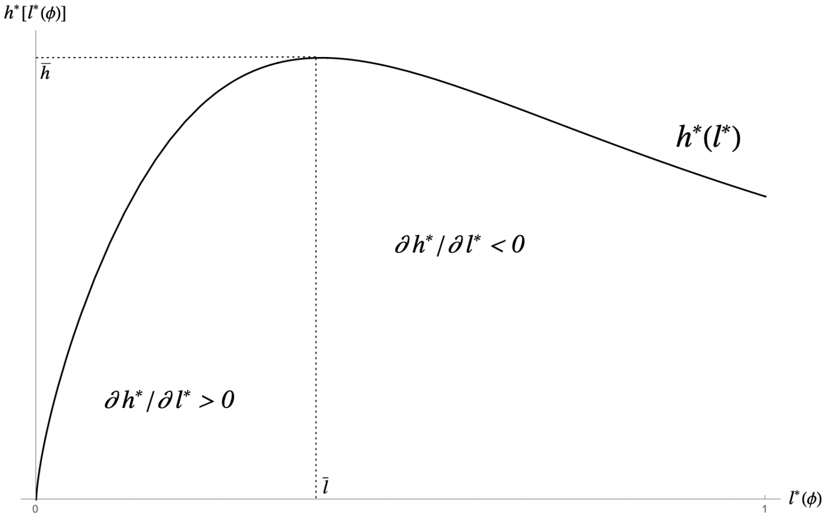

Figure 1: The non-monotonic relationship between health and labor supply.

Health first improves for low values of $l^*(\phi)$ because the purchase of medical goods and services allowed by the additional labor income are more than enough to offset the extra work-related depreciation in **S1**, or because the leisure input in the health production function is still substantial in **S2** and **S3**. However, in **S1**, health starts to deteriorate past some point because of the combination of the convex increase of the depreciation rate of health capital and the diminishing returns to health care spending. In **S2** and **S3**, diminishing returns to health care expenditure also reduce the positive effect on the health capital stock, and further decreases in leisure time also make the stock of health capital fall.

It is possible for an economy with strong preferences for leisure ($\phi > \tilde{\phi}$), and thus a low labor supply, to improve the health of the population by increasing working time. Note that the greater labor supply will increase output. While the level of consumption increases as a result, health spending does so more than proportionally in **S1** and **S3** and take up a larger share of GDP. On the contrary, an economy with low preferences for leisure ($\phi < \tilde{\phi}$) and a high labor supply can reduce the number of hours worked to raise the health capital stock while reducing the share of GDP devoted to health care in both specifications. However, the better health status and the additional leisure time would come at the expense of consumption. There is therefore an implicit trade-off at the steady state between leisure and consumption when improving health, a result reminiscent of Ponthière (2011).[9]

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[9] Ponthière (2011) documents the possibility of 'overconsumption' equilibria. Noting that consumption has a non-monotonic effect on population health, he argues that individuals not internalizing such an effect can choose a level of consumption that is greater than the one that would maximize life expectancy. The mechanism at play here is not the same as there is no externalities of neither consumption nor income on health. However, individuals with a low taste for leisure may choose a number of hours worked (and thus a level of income and consumption) that exceeds the health-maximizing level, even though they do so optimally.

Another implication of the non-monotonicity of the relationship between the health capital stock and labor supply is that it is possible to achieve the same level of health (other than the maximum level) with two different values of the preferences for leisure, hence two different number of hours worked. Two societies can therefore attain a similar health status while differing in both their levels of consumption and leisure, and most importantly in the share of resources they devote to health care: an economy with a strong distaste for work will enjoy a substantial amount of leisure time at the expense of some consumption, but will assign a lower fraction of its resources on medical care, while an economy that does not suffer from a high disutility of work will enjoy a greater output, therefore more consumption in absolute value, but will spend a large amount of its wealth on health care to offset the negative effect of the extra labor supplied.

5 The American Puzzle: Evidence and Literature

The theoretical model analyzed in the previous section suggests that, because the relationship between the health capital stock and labor supply is non-monotonic, health does not necessarily improve despite a greater fraction of resources allocated to health care. The aim of this section is therefore to document a set of stylized facts that we think constitute what we label the American Health Puzzle, and discuss the literature related to each issue: the greater number of hours worked by Americans, their health disadvantage relative to their counterparts in Western European countries, and the much higher share of GDP devoted to health expenditure in the US. This motivates the calibration of the model in the next section, in which we investigate what part of the differences in health and in the share of GDP devoted to health expenditure as a share of GDP that can be explained by differences in hours worked between the US and comparable European countries.

The overworked American. The *Overworked American* is the title of a provocative book by Juliet B. Schor published in the early 1990s in which she argued that American workers had increased the amount of work they supplied, both to the market and at home (Schor, 1992). While her explanation proved controversial, she was right in noting that something occurred in the US in the course of the 1970s and the 1980s. A comprehensive International Labor Organization's report, *Working Time Around the World* (Messenger et al., 2007), noted that the twentieth century was characterized by a long process of reduction of working time around the developed world. However, for reasons that are outside the scope of this paper, the US put a halt on this process and stopped reducing hours of work, while Western European countries continued to do so. As a result, today, Americans work about as much as they did in the 1980s while Europeans work substantially less.

Macroeconomic aggregates can however be misleading, and the greater number of hours supplied to the labor market in the US compared to Europe could very well be due to differences in employment rates, the extensive margin of labor supply. The distinction is important because our theory of the American Health Puzzle is based on a negative effect of long working hours on individuals' health, individuals who are thus employed and working. It turns out that the difference in aggregate hours between the US and Western European countries stems mostly from the intensive margin of labor. Blanchard (2004) compares the US and France and decomposes the change in hours worked per capita between 1970 and 2000 into changes in hours worked per worker, the employment and participation rates, and demographics, and finds that despite a lower employment rate, the decline in labor supply in France is mainly driven by lower hours worked per worker. Blundell et al. (2011, 2013) add the UK as a middle ground with aggregate hours between the US and France to the picture. They show that the declining pattern of hours worked per worker in the UK is the same as in France, such that the difference between the UK and the US is entirely due to differences in individual hours worked. More recently, Bick et al. (2019) reached the same conclusion for a larger set of countries: both a lower number of weeks worked and shorter weekly hours per worker explain the differences in aggregate labor supply between the US and Western Europe.

The unhealthy American. A defining feature of development since the end of the Industrial Revolution is a steady improvement in the health of individuals. The most widely-used proxy for population health, life expectancy at birth, has indeed seen a marked increase in all developed countries during the 20th century. However, improvements have slowed down in the US: although life expectancy at birth was roughly equal to that of Western Europe in the early 1980s, it now lags behind that of most rich countries at 79 years relative to the 81 years OECD average or to 82 years in Western Europe.[10]

Various measures of self-reported health status and biological markers of disease confirm the rough picture painted by aggregate life expectancy. Americans report a higher disease burden, especially lung diseases, myocardial infarction, heart diseases and strokes, and diabetes (Banks et al., 2006). The disadvantage affects all age groups up to age 75 for multiple diseases, biological and behavioral risk factors, and despite stark inequalities in the US — in terms of race, income and wealth particularly —, it is actually pervasive across the socioeconomic distribution such that Americans who are white, relatively wealthy and insured,

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[10] This deceleration of US life expectancy improvement relative to other comparable countries is consistent for both men and women, although it is more pronounced for women.

are still in poorer health than their Europeans counterparts (Martinson et al., 2011; Avendano et al., 2009, 2010). Overall, Americans who reach age 50 are in poorer health (Woolf and Aron, 2013).

A variety of factors have been put forward to explain the poorer health of Americans, from 'deaths of despair' and a dramatic opioids epidemics (Case and Deaton, 2015, 2017), to obesity and smoking (Crimmins et al., 2011), including inequalities in the face of a private and costly health insurance system. However, we want to emphasize a point also made by Avendano and Kawachi (2014): there is no single factor that can account for the whole gap in life expectancy and health status more generally between the United States and other rich countries, but rather a multitude from which it is difficult to disentangle each one separately. We therefore view all those potential explanations as complementary and attempt in this paper to provide yet another rationale for this worrying health gap.

The overspending American. At the beginning of the 1980s, Americans already devoted a larger fraction of their resources on health care than European, but the difference was of around one percentage point. The gap has been growing ever since and is now close to six percentage points. There are several potential explanations for the rise in health expenditure in rich countries.

On the demand side, Hall and Jones (2007) argue that the increase in medical spending that comes along with development is optimal and results from the fact that health is a superior good. When the marginal utility of consumption diminishes faster than that of life extension, people devote a larger fraction of their income to health care as the economy gets richer.[11] On the supply side, explanations rely on technological change: the invention of new and expensive medical technologies raises the marginal product of medical care in producing health and causes health spending to rise (Newhouse, 1992; Suen et al., 2005). According to Cutler (1995), technology accounts for 49% of the growth in real health care spending per capita between 1940 and 1990. However, such macroeconomic explanations justify an increasing share of health spending along economic development, they fail to account for cross-country differences, and especially for why the US is spending so much more on health care that its Europeans counterparts, for such mixed results.

The usual suspect behind the substantial difference in health expenditure between the US and European countries is the much higher relative price of health care goods and services in the US (Cutler and Ly, 2011; Lorenzoni et al., 2014; Horenstein and Santos, 2019). He et al. (2021) provide their own estimates of the price of health care relative to consumption

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[11] Hall and Jones (2007) even predict that the share of health expenditure in the US could very well reach 30% of GDP by the middle of the century.

goods for the US and a set of rich European countries: health care prices are 20% higher than other goods and services in the US, but only 4% higher in Europe on average. Doing a simple accounting exercise, taking the share of GDP devoted to health expenditure in 2015 in the US, the UK and France (16.5%, 9.9% and 11.4% respectively) and dividing by the corresponding relative price of health care (1.2, 1.05 and 1.11 respectively), we find that differences in relative prices account for about a third of the differences in the actual fraction of resources allocated to health care. Fonseca et al. (2023) estimate an even greater price of health care in the US relative to Europe and find that it accounts for around 60% of the difference in health expenditure, and about half of the difference in health status. Therefore, although the greater price of health care in the US is definitely one of the main factor behind the difference in health spending relative to Europe, it leaves a substantial portion of the gap unexplained.

6 Calibration: Accounting for the American Health Puzzle

We now calibrate the baseline specification of our model to the US economy in 2015.[12] The objective is to quantify the effect of an exogenous reduction of the number of hours worked on the share of health care expenditure and the health capital stock, at the steady state. More specifically, we want the model to replicate the health status of older workers, as well as the share of health care expenditure and the number of hours worked.

To assess in which direction a shift of working time would affect US health, we need to know whether preferences for leisure lie below or above the health-maximizing level. In other words, we want to uncover the shape of the health capital stock–labor supply schedule and see where the actual number of hours worked in the US stands relative to the health-maximizing level $\tilde{l}$. Once the model is calibrated to match a number of US moments in the data, we run a counterfactual in which the number of hours worked per worker in the US is reduced exogenously through preferences for leisure to that of two comparable European countries: the UK and France. This allows us to quantify the part of the gap in both health status and health care expenditure that is solely due to differences in hours of work, and assess a potential health improvement with a reduction of in the share of health expenditure. We choose the UK and France because we have excellent data on the intensive margin of labor that have been collected by Blundell et al. (2011, 2013) using detailed and harmonized

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[12] The first specification described in Section 4, with an endogenous rate of depreciation of health capital and homothetic preferences.

microdata, making them suitable for cross-country comparisons.[13]

A specific warning is welcomed before entering the details of the calibration. There is always a gap between the theoretical and the empirical part of a macroeconomic study, particularly when it is a representative agent model that abstracts from the rich heterogeneity observed in the real world. In addition to these usual difficulties, there are specific obstacles arising from the fact that several parameters, particularly those pertaining to the health production function and rate of depreciation of health capital, have not yet been empirically estimated. We attempt to overcome this radical uncertainty by considering a large range of plausible values for these parameters and providing a rich set of robustness exercises. On top of that, it turns out that the more accessible basis for comparing health outcomes at the international level is life expectancy data. This is a clear hiatus with regard to the health variable considered in the theoretical section, analogous to a latent health variable in an econometric model. Instead, we use various health indicators that we transform to make them correspond to the stock of health capital in our model. We recognize that there is some part of arbitrariness in the way we proceed that can be considered as best as a shortcut. This is why the results shown here cannot be considered more than an exploratory exercise, but we hope that this will encourage other researchers to establish more solidly the empirical foundations of the relationships we have suggested here.

6.1 Calibration of parameters

General parameters. Some parameters of the model are calibrated as is standard in the literature. We take the rate of interest to be equal to 4%, which allows us to set $\rho = 0.04$. We also know that at the steady state, investment is just equal to the depreciation of capital. With an investment-to-output ratio of 0.2 and a capital-to-output ratio of 2.5, this gives us $\delta = 0.08$. Finally, turning to the share of capital in the production function we obtain $\alpha = 0.3$, in line with standard calibrations of growth models.

Model-specific parameters. For the relative price of health care, we use the estimates in He et al. (2021) and set $p = 1.2$. We still have a bunch of parameters to pin down: the returns to health investments σ, the relative taste for consumption ν, preferences for leisure ϕ, the slope of the depreciation rate of health capital relative to labor supply γ and a scaling parameter z.

Let us start with the rate of depreciation of health capital, δ^h. Empirical estimates of such a rate are scarce: Scholz and Seshadri (2011) calibrate it around 5.6%, while Lawver

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[13] The data have then been extended up to 2015 by Antoine Bozio who kindly agreed to make them available to us.

(2012) set it between 0 and 5% for individuals experiencing no change in health status between two periods. We therefore take $\delta^h = 2.5\%$ as a benchmark and will investigate later how the calibration results are affected by different values of δ^h. We then set $\gamma = 2$ in our baseline and calibrate the scaling parameter z accordingly. Because the curvature of the depreciation rate of health capital with respect to hours worked is a key parameter of our model, we will also consider a lower value $\gamma = 1.5$.

We remain with three parameters to set (ν, ϕ and σ), but only two data moments to match: the number of hours worked per worker annually, which we transform into a fraction of the sole unit of time individuals are endowed with by dividing it by 365*16 as is common in the literature (with 1943 hours worked per worker in 2015, this gives us $l^*_{us} = 0.3327$), and the share of GDP devoted to health care expenditure according to the OECD (16.5% of GDP in 2015). Empirical estimates of the returns to health investments are also scarce but the evidence point toward decreasing returns. We therefore set $\sigma = 0.8$ as a benchmark value that we change later for some robustness checks. We can now look at equation (35) for health expenditure as a share of GDP as a function of labor supply and solve it for the relative taste of consumption ν, using $\sigma = 0.8$ and $l^*_{us} = 0.3327$.

Finally, we are left with preferences for leisure ϕ. This is straightforward, we simply solve equation (36) for ϕ, using $l^*_{us} = 0.3327$ and the value of the parameters already calibrated.

The relation between the health capital stock and health status. We view the stock of health capital as an indicator of health status. However, health capital has no direct connection with any real health indicator. To quantify the health effect of variations in hours worked, we therefore need to establish a relation between such the stock given by the model and some health indicator. Because the harmful effects of working long hours potentially materialize at the end of the working life only, we focus on workers of a certain age already. Furthermore, working time in the US and Europe diverged around 1980 such that in 2015, Americans had been working more than Europeans for 35 years (Blundell et al., 2011). Assuming that individuals start working around 20, workers aged 55-65 in 2015 in the US had consistently worked more than Europeans over their working life. The difference in health status that is caused by differences in hours worked should therefore be more apparent for those workers, on which we focus in our calibration.

As for the health indicator, we choose the survival probabilities of individuals aged between 55 and 64 years that we take from the Human Mortality Database life tables. Survival probabilities, or inverse mortality rates, despite being absent of our model, are strongly correlated with health status. We view individuals as valuing health *per se* and making medical investments to attain a desired stock of health capital maximizing their utility.[14] We then need to link this stock with the survival probability we observe in the data.

We argue that using a logistic function that transforms the health capital stock into such a probability is relevant since it yields a value between 0 and 1, is convex for low value of health capital indicating originally large gains from medical investments and becomes concave as the health capital stock increases, indicating decreasing returns. Let therefore be T the survival probability between age 55 and 64. To compute this probability, we use the death probabilities between age 55-59 and 60-64 from the Human Mortality Database, q_{55-59} and q_{60-64} respectively. We obtain $T = (1 - q_{55-59})(1 - q_{60-64}) = 0.915$ for the US in 2015 and define:

$$T = \frac{T_0}{T_0 + (1 - T_0)e^{-\psi \cdot h^*}} \tag{28}$$

where T_0 is the survival probability when the health capital stock is zero. To pin down its value, we set it equal to the probability of surviving at age 55-64 before the take-off of scientific advances in medicine. We therefore go as far back as possible in the data available in the Human Mortality Database, which brings us to France in the early 19th century. Life expectancy had not started to increase at the pace it did in the 20th century and we interpret it as if the accumulation of health capital had not started yet. We therefore take from the Human Mortality Database the same death probabilities for France in 1816 as a benchmark and hence set $T_0 = (1 - q^{1816}_{55-59})(1 - q^{1816}_{60-64}) = 0.719$. Using the value of h^* given by the model once every other parameter is found, we can the calibrate ψ, the steepness of the logistic function.

We thus have assigned a value to each parameter, the next table summarizes the calibrated values:

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[14] We thereby put the emphasis on the consumption motive for the demand for health care highlighted by Halliday et al. (2019).

Parameter		Target	Value
α	Capital share	Capital/output ratio	0.3
δ	Capital rate of depreciation	Investment/output ratio	0.08
ρ	Discount factor	Interest rate	0.04
γ	Health capital depreciation	Chosen	2
σ	Returns to health investment	Chosen	0.8
z	Scaling parameter	US rate of depreciation	0.226
p	Relative price of health care goods	He et al. (2021)	1.2
T_0	Survival probability without health capital	Survival probability (age 55-64, 1816)	0.719
ψ	Steepness of the logistic function	Survival probability (age 55-64, 2015)	0.309
ν	Relative preferences for consumption	Share of health expenditure	0.542
ϕ	Preferences for leisure	Hours worked	0.389

Table 1. Values of calibrated parameters

6.2 What if Americans worked as much as Europeans?

Now that the model is calibrated to the US economy, we know the shape of the health-labor supply schedule. We can also compute the health-maximizing level of labor supply to see whether the actual number of hours worked per worker in the US lies below or above it. To account for the American Health Puzzle, hours worked in the US should lie above the health-maximizing level, such that a reduction of labor supply would reduce the health expenditure share of GDP but improve health.

Calibration exercise. We conduct a simple exercise to assess the effect of an exogenous reduction of the average working time in the US on both the share of health care expenditure and health status. More specifically, we ask the model what would happen if Americans worked as much as Europeans. This allows us to assess how much of the gap in both health expenditure and mortality between the US and Europe–the American Health Puzzle–can be accounted for by the greater number of hours worked in the US.

Naturally, there are many potential sources of differences in hours worked between the US and Europe, from varying levels of taxation to different institutional structures of the labor market, but also factors that would also influence the demand for health and health itself, such as the returns to health expenditure.[15] While we remain agnostic about the main reasons why Americans work substantially more than Europeans, we consider an hypothetical variation of hours worked coming from preferences for leisure that are exogenous

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[15] Differences in the sectoral composition of employment across the three countries could potentially be correlated to differences in health if the negative health effect of hours worked were heterogeneous between blue and white-collar workers. However such differences are small and cannot explain the lower health of the Americans *vis-à-vis* the British and the French: OECD data indicates that the share of services in the US is 81,1%, against 82,6% in the UK and 78,5% in France.

to other variables of interest, which is in line with the comparative statics exercise of Section 4.

Our strategy is then straightforward: once we have calibrated the model, we artificially set US preferences for leisure so that it matches not American but European labor supply instead, and then solve the model for steady state health expenditure as a share of GDP and the health capital stock, all else equal. Our model can therefore help us quantify the reduction in the share of GDP devoted to health care that would follow such an exogenous reduction of working time, as well as its effect on health.

Baseline calibration. We choose the UK and France as our benchmark Western European countries, and re-calibrate US preferences for leisure to match labor supply at the intensive margin in both countries, using the same data source (Blundell et al., 2011). We then compute the variation in health expenditure as a share of GDP, the change in health status proxied by survival probabilities and expressed as the number of deaths per 100,000 people, and for both the fraction of the gap with the European country considered that is explained by the difference in hours worked.[16] The results are summarized in the following table:

$\boldsymbol{l^*}$	$\boldsymbol{\tilde{l}}$	$\boldsymbol{(p \cdot m/y)^*}$		**Deaths per 100,000**	
		Δ	**% explained**	**Δ**	**% explained**
$\boldsymbol{l_{uk} = 0.2836}$	0.188	−2.6 p.p	39.4%	−631	27.6%
$\boldsymbol{l_{fr} = 0.2750}$	0.188	−3 p.p	58.8%	−725	38.4%

$\boldsymbol{l^*}$: labor supply, $\boldsymbol{\tilde{l}}$: health-maximizing level of labor supply, $\boldsymbol{(p \cdot m/y)^*}$: steady state health expenditure as a share of GDP.

Table 2. Reduction of hours worked in the US (baseline calibration).

Our baseline calibration therefore tells us that, all else equal, a reduction of hours worked per worker in the US would lead to both a reduction in the share of GDP devoted to health care, and a reduction in mortality at age 55-64. The reduction in health expenditure is sizable: it explains almost 40% of the actual gap in health spending as a share of GDP with the UK and around 60% of that with France. Despite lower health expenditure, the steady state health capital stock increases and this translates into an improved health status, as shown here by better survival probabilities at between ages 55 and 64. Again, the effect is

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[16] The number of deaths per 100,000 people is obtained by taking the difference between the actual survival probability at ages 55-64 in the US and the counterfactual probability given by the model and multiplying by 100,000. The percentage of the gap with the UK or France is then computed using the same survival probabilities between 55 and 64 for both countries in 2015 from the Human Mortality Database.

of a non-negligible magnitude: the decline in mortality amounts to several hundreds deaths that would avoided per hundred thousand people. Looking at the actual population of that age category of around 40 millions in the US in 2015, this amounts to a number of lives saved between 250,000 and 300,000. While such numbers should not be taken as face value given the multitude of factors impacting individuals' mortality that are not taken into account by our model, but rather as an indication that long working hours in the US can indeed explain part of the American health disadvantage. The baseline specification of our model tells us that around a third of the excess mortality at older ages in the US can be attributed to the greater number of hours worked.

Accounting for differences in health care prices. Higher health care prices in the US are often invoked as one of the main sources of differences in the share of GDP devoted to health expenditure between the US and Europe (Fonseca et al., 2023). In the baseline calibration, we have considered the effect of reduction in hours worked in the US all else equal, including prices. We now compute the same counterfactual, but using also the relative price of health care of European countries ($p = 1.05$ for the UK and $p = 1.11$ for France) that we take from He et al. (2021). We therefore set preferences for leisure such that labor supply in the US equals that of both the UK and France, and compute the change in both health and health expenditure when the relative price of health care also falls to European levels. The results are displayed in the following table:

$\boldsymbol{l^*}$	$\boldsymbol{\tilde{l}}$	$\boldsymbol{(p \cdot m/y)^*}$		**Deaths per 100,000**	
		$\boldsymbol{\Delta}$	**% explained**	$\boldsymbol{\Delta}$	**% explained**
$\boldsymbol{l_{uk} = 0.2836}$	0.188	−4.3 p.p	65.2%	−1791	78.3%
$\boldsymbol{l_{fr} = 0.2750}$	0.188	−4.1 p.p	80.4%	−1406	74.5%

$\boldsymbol{l^*}$: labor supply, $\boldsymbol{\tilde{l}}$: health-maximizing level of labor supply, $\boldsymbol{(p \cdot m/y)^*}$: steady state health expenditure as a share of GDP.

Table 3. Reduction of hours worked and the relative price of health care in the US (baseline calibration).

This calibration results leads us to think that the impact of health care prices differences matters as much as the deviation in working hours. Comparing the results of Table 3 to those of Table 2 shows the price gap alone explains half of the deviation in health between the US and the UK and about a third between the US and France. For expenditures, the role of health care price is lower than that of working hours because of the unitary price elasticity of the demand for health.

6.3 Robustness checks

We now conduct a series of robustness checks to see whether the quantitative results of our baseline calibration hold. In particular, we run the same exercise using different values for the few free parameters, in particular the returns to health expenditure σ and the curvature of the rate of depreciation of health capital γ. We also change our target for the rate of depreciation of health capital δ^h. Finally, we consider another health indicator and calibrate the model for a different year for which it is available.

Variation in the returns to health expenditure. We now run the same exercise using different values of the returns to health investments σ, along with variations in the rate of depreciation of health capital δ^h via the scaling parameter z. The whole range of results for comparison with both the UK and France is compiled in tables 7 and 8 in Appendix B.1. The first thing to notice is that, for most specifications, hours worked in the US do indeed lie above the health-maximizing level.[17] As a result, reducing hours worked to the European level improves mortality despite the decrease in the share of health expenditure.

Intuitively, the higher the depreciation rate of health capital, the lower the reduction in health expenditure but the greater the gains in terms of health. Indeed, a high rate of work-related depreciation of the health capital stock implies substantial benefits from an exogenous reduction of working time but requires, all else equal, more resources to be devoted to health care to offset the depreciation. Different values of σ do not alter the results for the share of health expenditure, only the difference in health status explained by a greater labor supply. The explanatory power of long working hours for the American health disadvantage decreases with the returns to medical investments, because the extra depreciation induced by a greater number of hours worked is more easily offset by additional health spending.

In the specification with the highest returns to health expenditure ($\sigma = 0.9$) coupled to the lowest depreciation rate ($\delta^h = 1\%$), reducing hours worked in the US actually has a negative effect on survival probabilities at old age. We thus uncover the case where steady state labor supply lies below the level that maximizes the health capital stock, and the loss of labor income that follows the reduction of working time and the ensuing fall in health expenditure are too large relative to the small mortality gains.

Variation in the curvature of depreciation. Because the curvature of the depreciation rate of health capital with respect to labor supply is a key ingredient of our theory, but no

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[17] Recall that the health-maximizing level does not depend on preferences for leisure and is therefore not affected by the magnitude of the change of labor supply we consider.

empirical estimate of the parameter γ exists to our knowledge, we run another counterfactual using both a lower and a higher value. We also allow the target for the depreciation rate to vary and calibrate the scaling parameter z accordingly, but keep the returns to health expenditure at their baseline level $\sigma = 0.8$. The result are reported in tables 9 and 10 in Appendix B.2.

Increasing the value of the curvature parameter γ naturally increases the explanatory power of the model, especially in terms of the difference in health status. This is even more pronounced when the level of the depreciation rate is high as a greater curvature implies a more substantial health effect following a reduction in hours worked. Again, when the level of the depreciation rate is high, the fall in health expenditure as a share of GDP is reduced as greater expenses are required to offset the depreciation and keep the steady state health capital stock constant. With lower value of the curvature parameter γ, the health capital stock either increases less following a reduction in hours worked, or even decreases when labor supply fall below the greater health-maximizing level when the depreciation rate is low in level. Differences in health expenditure accounted for by differences in labor supply are also reduced when γ is low, but they remain sizable.

Using other indicators of health status. Because health capital does not naturally correspond to any real health indicator, we need to establish a relationship between the stock generated by the model and some indicator suitable for cross-country comparisons. So far, we have used mortality rates to compute survival probabilities of individuals aged between 55 and 64 years as a plausible proxy for health status. For an additional robustness check, we draw inspiration from Fonseca et al. (2023) who study the role of health prices in cross-county differences in health expenditure and use the prevalence of limitations in activities of daily (ADLs) in individuals age 50 to 75 as a measure of health status.

Such prevalence is computed and harmonized using the 2004 Survey of Health, Ageing and Retirement in Europe (SHARE) for France, the 2004 Health and Retirement Study (HRS) for the US, and 2002–2003 English Longitudinal Study of Aging (ELSA) for the UK.[18] Taking their estimates allows us to conduct the same calibration exercise at a different point in time, in 2004, using data for the share of health expenditure and hours worked per worker from the same data source as in our baseline but for that year.[19] To relate the health capital stock to the prevalence of limitations in ADLs, we again rely upon the logistic

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[18] See Chan et al. (2012) for a discussion about the suitability of those three sources for international comparisons.

[19] It should be noted that a limitation of our parsimonious growth model is that the share of health expenditure and the health capital stock are constant at the steady state. Along a more sophisticated balanced growth path, various driving forces would make them increase at constant but potentially different rate as in Hall and Jones (2007). Because we abstract from such forces, the difference stem from different values of relative taste parameters in the new calibration.

function (28) to transform the stock generated by the model into a share. The parameter T becomes the prevalence of people *without* limitations in ADLs in the US.[20] To pin down T_0, the prevalence without limitations in ADLs in the absence of health capital, we would ideally need data on ADLs before progress in population health that unfortunately do not exist. Instead, we assume that the prevalence of people without limitations in ADLs grew at the same rate as other measures of population health. We therefore take the oldest data on life expectancy at age 45 from the Human Mortality Database which is again for France in 1816 as a rough proxy for health status before any accumulation of health capital, and the same measure for the US in 2004 to compute the growth rate and infer T_0. We then calibrate the steepness parameter of the logistic function ψ using the steady state stock of health capital given by the model once every other parameter is calibrated.

The result of this new calibration are reported in the following table, displaying the effect of a reduction in hours worked in the US to the British and French levels on both health and health expenditure in 2004.

$\boldsymbol{l^*}$	$\boldsymbol{\tilde{l}}$	$\boldsymbol{(p \cdot m/y)^*}$		**Risk per 100,000**	
		$\boldsymbol{\Delta}$	**% explained**	$\boldsymbol{\Delta}$	**% explained**
$\boldsymbol{l_{uk} = 0.2841}$	0.208	−1.8 p.p	29.0%	−424	19.2%
$\boldsymbol{l_{fr} = 0.2764}$	0.208	−2 p.p	46.5%	−476	13.2%

$\boldsymbol{l^*}$: labor supply, $\boldsymbol{\tilde{l}}$: health-maximizing level of labor supply, $\boldsymbol{(p \cdot m/y)^*}$: steady state health expenditure as a share of GDP.

Table 4. Reduction of hours worked in the US (calibration for 2004, using ADLs as an indicator of health status).

Again, the reduction of hours worked in the US leads to a substantial reduction of the share of GDP devoted to health expenditure. This alternative calibration for 2004 suggests that labor supply in the US was above the health-maximizing level. Despite the reduction in the fraction of resources allocated to health expenditure, the health capital stock increases leading to a fall in the prevalence of people living with ADLs. We report the results obtained by varying the returns to health expenditure, and both the curvature and the level of the depreciation rate of health capital in Appendix B.3.

Fonseca et al. (2023) also report detailed statistics about the prevalence of various health conditions in the US and Europe. Because the negative effect of long working hours on various heart diseases is well documented (Bannai and Tamakoshi, 2014; Pega et al., 2021; Ervasti et al., 2021; Lavigne-Robichaud et al., 2023), we also do the same exercise using the

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[20] As the logistic function is increasing with health capital, T is actually one minus the prevalence of limitations in ADLs taken from Fonseca et al. (2023).

prevalence of heart disease in the population age 50 to 75. This prevalence is around 55% higher in the US than in France. As Fonseca et al. (2023) do not have a number for the UK, we infer it using data on the age standardized death rate from coronary heart diseases from the World Health Organization to such that differences in the prevalence rate match differences in death rates. Our calculations indicate that the prevalence of heart diseases at age 50–75 in the UK (13.4%) lies between that of the US (15.9%) and that of France (10.3%). Using the same strategy to calibrate parameters of the logistic function, the results are close to the calibration using ADLs, except the fraction of the gap in health between the US and France that is explained is reduced. Indeed, despite a greater fall in the prevalence of people with heart diseases than in the prevalence of people with ADLs, the larger initial gap is reduced by a lesser percentage.

l^*	$\tilde{l}$	$(p \cdot m/y)^*$		Risk per 100,000	
		Δ	**% explained**	**Δ**	**% explained**
$l_{uk} = 0.2841$	0.208	−1.8 p.p	29.0%	−456	18.2%
$l_{fr} = 0.2764$	0.208	−2 p.p	46.5%	−513	9.2%

l^*: labor supply, $\tilde{l}$: health-maximizing level of labor supply, $(p \cdot m/y)^*$: steady state health expenditure as a share of GDP.

Table 5. Reduction of hours worked in the US (calibration for 2004, using the prevalence of heart diseases as health status).

6.4 What if Europeans worked as much as Americans?

By calibrating our model to the US and looking at the effect of a reduction of working time to European levels on mortality and health expenditure, we have assessed to what extent such differences in labor supply can account for the American Health Puzzle. While hours worked in the US clearly lie above the health-maximizing level, one may ask whether it is also the case in the UK or France. To answer the question, we now calibrate the model to both countries and see where their respective number of hours worked situate on the health-labor supply schedule.

The reverse counterfactual. To investigate what would happen to both health and health expenditure if Europeans worked as much as Americans, we use the same calibration strategy. We keep the same values for standard parameters such as the discount rate ρ, the share of capital in aggregate production α and the depreciation rate of physical capital δ. We also keep the curvature of the rate of depreciation of health capital $\gamma = 2$, the returns to medical spending $\sigma = 0.8$ as in our baseline calibration. The scaling parameter z at the same values as those calibrated to the US, thereby assuming that the relationship between hours of work and the depreciation of health is the same in the US and Europe. The relative price of health care is again taken from He et al. (2021) and we set $p = 1.05$ for the UK and $p = 1.11$ for France.

Finally, preferences for leisure ϕ are chosen to match labor supply in both countries, $l^*_{uk} = 0.2841$ and $l^*_{fr} = 0.2764$, the relative taste for consumption ν is then calibrated to yield a share of health expenditure equal to 9.9% of GDP in the UK and 11.4% in France (OECD data for 2015), and the steepness of the logistic function ψ to fit survival probabilities of British and French workers aged 55-64 in 2015 from the Human Mortality Database. We also take data on hours worked per worker and health expenditure data for 2004 to conduct the same counterfactual using the prevalence of people age 50–75 with limitations in ADLs as in the previous subsection.

Once the model is calibrated to both countries, we solve for both health expenditure as a share of GDP and the steady state health capital stock, but set preferences for leisure to match hours worked in the US instead. The results for the two specifications are reported in the table below, while robustness checks with various parameters values can be found in Appendix B.4:

Specification	$\tilde{l}$		$\Delta(p \cdot m/y)^*$		**Δ Deaths per 100,000**	
$(l_{us} = 0.3327)$	**UK**	**France**	**UK**	**France**	**UK**	**France**
2015, survival proba.	0.202	0.195	+2.0p.p.	+2.7p.p	501	640
2004, ADLs prev.	0.208	0.199	+1.7p.p.	+2.4p.p	435	541

Table 6. Increase in hours worked in the UK and France (US labor supply, with $\sigma = 0.8$ and $\gamma = 2$, with survival probabilities and prevalence of limitations in ADLs as health status)

Perhaps surprisingly, although the actual number of hours worked per worker in both the UK and France is much closer to the health-maximizing level than in the US, it is still higher. As a result, an increase in working time in both countries would increase mortality at ages 55-64, despite a raise in health expenditure as a share of GDP. The extra labor income obtained by working additional hours is partly used to increase consumption, but health expenditure increase more than proportionally to compensate for the depreciation of the health capital stock. However, except in specifications in which the work-induced depreciation rate and its curvature are very low and the returns to medical investment are very high (see Appendix B.4), the increase in GDP is not enough to offset the forgone health and mortality rises.

While it was expected for the US, the calibration of our model suggests that Europeans also work more hours than what would maximize the health of the working population. Because we model cross-country differences in labor supply as the result of different preferences for leisure, we abstain from any claim about welfare. Instead, we argue that our model suggests that rich countries–and the US especially–trade-off some of their health for greater labor income and consumption.

Broader cross-country comparisons? Cross-country comparisons require harmonized datasets, especially on hours worked per worker are sources and methods of measurement may differ. We focused on the US, the UK, and France to leverage the detailed data on the intensive margin of labor supply of Blundell et al. (2011, 2013). Other developed countries, Japan in particular, may appear as outliers as they fare better in terms of both health and health expenditure despite an apparently greater number of hours worked. However, we believe that this can also be rationalized in our model by a different shape of the health capital stock–labor supply schedule. Different values of parameters, especially the returns to medical expenditure that account for the efficiency of the health care system, and the preferences for health that can encompass a variety of societal and cultural factors, affect both the health-maximizing number of hours worked and the maximum health status that can theoretically be achieved.

In the case of Japan for which available data on labor supply either contradict the idea that Japanese labor supply is much greater than the US, or is not suitable for cross-country comparisons. For our baseline year of 2015, the OECD estimates that average annual hours worked per workers were 1811 in the US, but only 1607 in Japan. OECD data on labor supply comes with a warning however and are indeed not suited for cross-country comparisons at any given point in time Looking at the trend instead, hours worked per workers in Japan have fallen by around 40% between 1970 and 2015, against 7% in the US. More comparable data can be found in the new Penn World Table (Feenstra et al., 2015), but they indicate that hours worked per year in Japan (1757) are around the same as in the US (1770).

We nevertheless calibrate the model to uncover the health capital stock–labor supply schedule for Japan, and show that labor supply is likely to lie above the health-maximizing level. The results are displayed in Appendix C. Our model therefore suggests that a reduction in hours worked in Japan could also improve the health performance of the country and reduce the share of GDP it allocates to health care. However, we refrain from making any comparisons with either the US or Europe.

7 Conclusion

In this paper, we aim to explain what we label the *American Health Puzzle*: the fact that the US suffer from a considerable health disadvantage relative to Europe despite spending much more on health care. We argue that, if one assumes that hours worked have a negative health effect, the greater labor supply at the intensive margin in the US can account for a non-negligible part of the difference in both health and health expenditure between the US and comparable Western European countries.

We show that introducing health capital *à la* Grossman in a simple neoclassical growth model can rationalize the stylized facts as countries with lower preferences for leisure work and earn more, but have to use the proceeds of the extra labor income to offset the depreciation of their health, which may or may not be enough. While the endogenous depreciation rate of health capital allows to generate a rising share of GDP devoted to health expenditure with perfectly homothetic preferences, we also explore the role of complementarities between consumption and leisure and provide another demand-side explanation of why health expenditure are so much greater in the US than in other developed country.

More importantly, we show that a hump-shaped relationship between health and labor supply is plausible, implying the existence of a health-maximizing level that depends on various parameters of the model and is thus country-specific. The effect of an exogenous increase or reduction in hours worked on the health of the population in any country is contingent on whether actual labor supply lies below or above this health-maximizing level. Our calibration suggests that labor supply in the US is indeed above this threshold, but perhaps surprisingly, it is also the case for France and the UK.

More generally, our model indicates the existence of a trade-off between consumption and population health. Prescott (2004) famously argued that differences in GDP per capita between the US and Europe were mostly due to the labor factor. While the US is richer in per capita terms than European countries, this paper argues that it might be possible that the higher consumption level comes at the cost of a poorer health status for American workers. Although in this paper, we consider differences in working time between the US and Europe as the result of different preferences regarding work and leisure–and therefore implicitly view long working hours in the US as optimal from the point of view of Americans–, it is possible and even likely that workers either do not fully internalize the negative health effect of hours worked or are constrained to work long hours because of deeper structural factors. Introducing such features is left for further research that may open the possibility for inefficient equilibria and policy prescriptions.

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Declaration of Competing Interests

None

Data availability statement

Share of health expenditure. Data on the share of GDP devoted to health expenditure are taken from the OECD: `https://data.oecd.org/healthres/health-spending.htm`.

Survival probabilities. Data on survival probabilities can be found in the life tables from the Human Mortality Database: `https://www.mortality.org/`.

Hours worked per workers. Data on hours worked per workers have been collected by Blundell et al. (2011, 2013) and been extended up to 2015 by Antoine Bozio who kindly shared them with us.

Other health indicators. Data on the prevalence of limitations in ADLs are taken from Fonseca et al. (2023) for the US and France, and from Chan et al. (2012) for the UK. Data on the prevalence of heart diseases are taken from Fonseca et al. (2023) for the US and France. For the UK, our own calculation is based on data from the World Health Organization taken from: https://www.worldlifeexpectancy.com/cause-of-death/coronary-heart-disease/by-country/.

Relative price of health care. Data on the relative price of health care are taken from He et al. (2021).

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A Appendix

A.1 First order conditions

We set up the following present-value Hamiltonian:

$$\mathcal{H} = u[c(t), h(t), 1-l(t)]e^{-\rho t} + \lambda(t)[w(t)l(t) + r(t)a(t) - c(t) - p\cdot m(t)] + \mu(t)[M(t) - \delta^h(t)h(t)]$$

The first-order conditions are as follow:

$$\frac{\partial \mathcal{H}}{\partial c(t)} = 0 \quad \Leftrightarrow \quad u_c(t)e^{-\rho t} = \lambda(t) \tag{29}$$

$$\frac{\partial \mathcal{H}}{\partial m(t)} = 0 \quad \Leftrightarrow \quad M_m(t)\mu(t) = p\lambda(t) \tag{30}$$

$$\frac{\partial \mathcal{H}}{\partial l(t)} = 0 \quad \Leftrightarrow \quad -u_l(t)e^{-\rho t} = \lambda w(t) + \mu(t)\left[M_l(t) - \delta_l^h(t)h(t)\right] \tag{31}$$

$$\dot{\lambda}(t) = -\frac{\partial \mathcal{H}}{\partial a(t)} \quad \Leftrightarrow \quad \dot{\lambda}(t) = -r(t)\lambda \tag{32}$$

$$\dot{\mu}(t) = -\frac{\partial \mathcal{H}}{\partial h(t)} \quad \Leftrightarrow \quad \dot{\mu}(t) = -u_h(t)e^{-\rho t} + \mu(t)\delta^h(t) \tag{33}$$

A.2 Solving for the steady state

In this section, we solve for the steady state of the model. We show that it is possible to express the main endogenous variables as functions of labor supply in all three specifications, which will help us in our comparative statics exercises later on.

S1: Endogenous rate of depreciation of health capital. Inserting equations (2) and (3) into equation (19) and rearranging gives the steady state stock of health capital:

$$h^* = \frac{m^{*\sigma}}{zl^{*\gamma}} \tag{34}$$

Equation (22) becomes:

$$\frac{1-\nu}{\nu}\frac{c^*}{h^*}\frac{\sigma m^{*\sigma-1}}{p} = \rho + zl^{*\gamma} \tag{35}$$

Using equation (34) to substitute for the steady state stock of health capital, this becomes:

$$\frac{c^*}{m^*} = p \cdot \frac{V}{\sigma}\underbrace{\left(1 + \frac{\rho}{zl^{*\gamma}}\right)}_{=\Delta(l^*)} \tag{36}$$

where $V = \dfrac{\nu}{1-\nu}$ is a constant that characterizes the taste for consumption relative to health, and $\Delta(l^*) = 1 + \dfrac{\rho}{zl^{*\gamma}}$ is a term that depends on the depreciation rate of health capital. As it decreases with labor supply, so does the ratio c^*/m^*. The negative health effect of hours worked therefore leads individuals to increase health expenditure relative to consumption as labor supply increases, despite perfectly homothetic preferences.

Using the resource constraint (21) we can now solve for c^* and m^* as a function of steady state labor supply l^*, before solving for l^* itself. Denoting $A = \Theta\left(\frac{\alpha}{\delta+\rho}\right)^{\frac{\alpha}{1-\alpha}}$, we obtain:

$$\begin{aligned} c(l^*) &= Al^*\frac{V\Delta(l^*)}{\sigma + V\Delta(l^*)} && (37)\\ m(l^*) &= \frac{\sigma}{p}Al^*\frac{1}{\sigma+V\Delta(l^*)} && (38)\end{aligned}$$

The steady state health capital stock can therefore also be expressed as a function of labor supply:

$$h(l^*) = \frac{m(l^*)^\sigma}{zl^{*\gamma}} \tag{39}$$

Now that we have solved for every endogenous variables *as functions of labor supply*, to fully characterize the steady state we now need to solve for l^* in turn. In this baseline specification, equation (20) governing the leisure-consumption trade-off becomes:

$$\underbrace{\frac{\phi}{1-l^*}\cdot\frac{c(l^*)}{(1-\phi)\nu}}_{-u_l/u_c} = \underbrace{(1-\alpha)\left(\frac{\alpha}{\delta+\rho}\right)^{\frac{\alpha}{1-\alpha}}}_{w} - p\frac{\gamma}{\sigma}\frac{m(l^*)}{l^*} \tag{40}$$

Substituting for $c^*(l^*)$ and $m^*(l^*)$ and rearranging yields an equation for l^*:

$$\frac{\phi}{1-\phi}\frac{l^*}{1-l^*} = \nu\chi - (\gamma-\chi)\sigma(1-\nu)\frac{1}{\Delta(l^*)} \tag{41}$$

where $\chi = \frac{w}{A} = \frac{(1-\alpha)(\delta+\rho)}{(1-\alpha)\delta+\rho} < 1$. We study the solution to this equation when proving Proposition 1 below.

S2: Leisure in the health production function. Substituting for leisure $L^* = 1 - l^*$ in (5) gives:

$$M(m^*, 1-l^*) = m^{*\sigma}(1-l^*)^\eta \tag{42}$$

Inserting equation (42) into (19), we can find the steady state health capital stock as a function of health expenditure and leisure time:

$$h^* = \frac{m^{*\sigma}(1-l^*)^{*\eta}}{\delta^h} \tag{43}$$

With this specification, equation (22) governing the trade-off between health and consumption becomes after some substitutions:

$$\frac{c^*}{m^*} = \frac{p}{\sigma} V \underbrace{\left[1 + \frac{\rho}{\delta^h}\right]}_{\Delta} \tag{44}$$

Using the resource constraint (21), we can again solve for consumption and medical expenditure as a function of steady state labor supply:

$$c(l^*) = Al^* \frac{V\Delta}{\sigma + V\Delta} \tag{45}$$

$$m(l^*) = Al^* \frac{\sigma / p}{\sigma + V\Delta} \tag{46}$$

Unsurprisingly, with homothetic preferences in consumption and health and a constant exogenous rate of depreciation of health capital, both health expenditure and consumption are linear functions of labor supply. The steady state health capital stock can also be expressed as a function of labor supply:

$$h(l^*) = \frac{m(l^*)^\sigma (1 - l^*)^{*\eta}}{\delta^h} \tag{47}$$

Finally, steady state labor supply is given by the equation (20) governing the leisure-consumption trade-off:

$$\underbrace{\frac{\phi}{1 - l^*} \cdot \frac{c(l^*)}{(1 - \phi)\nu}}_{-u_l/u_c} = \underbrace{(1 - \alpha)\left(\frac{\alpha}{\delta + \rho}\right)^{\frac{\alpha}{1-\alpha}}}_{w} - p\frac{\eta}{\sigma}\frac{m(l^*)}{1 - l^*} \tag{48}$$

Substituting for $m(l^*)$ and $c(l^*)$, we obtain an equation for l^*:

$$\frac{\phi}{(1 - \phi)\nu} \frac{V\Delta}{\sigma + V\Delta} \frac{l^*}{1 - l^*} = \chi - \eta \frac{1}{\sigma + V\Delta} \frac{l^*}{1 - l^*} \tag{49}$$

where $\chi = \dfrac{w}{A} = \dfrac{(1 - \alpha)(\delta + \rho)}{(1 - \alpha)\delta + \rho} < 1$ again.

With an exogenous rate of depreciation of health capital, we actually have an analytical solution for l^*:

$$l^* = \frac{\chi\left[\sigma(1 - \nu) + \nu\Delta\right]}{\frac{\phi}{1-\phi}\Delta + (1 - \nu)\eta + \chi\left[\sigma(1 - \nu) + \nu\Delta\right]} \tag{50}$$

S3: Complementarities between leisure and consumption. With this specification, equation (22) governing the trade-off between health and consumption becomes after some substitutions:

$$\frac{c^*}{m^*} = \frac{p}{\sigma} V \underbrace{\left[1 + \frac{\rho}{\delta^h}\right]}_{\Delta} f(1-l^*) \tag{51}$$

Notice that $\Delta = 1+\rho/\delta^h$ is still a constant. The effect of labor supply on the consumption to health expenditure ratio now comes from complementarities between leisure and consumption: an increase in hours worked reduces the marginal utility of consumption and therefore leads individuals to spend relatively more in terms of medical expenditure.

Using the resource constraint, we can again solve for both consumption and medical expenditure as a function of labor supply:

$$c(l^*) = Al^* \frac{V\Delta f(1-l^*)}{\sigma + V\Delta f(1-l^*)} \tag{52}$$

$$m(l^*) = Al^* \frac{\sigma/p}{\sigma + V\Delta f(1-l^*)} \tag{53}$$

Once we have expressed every endogenous variable as functions of steady state labor supply, we turn to the equation governing the consumption-leisure trade-off to show that there exists a unique solution for l^*, thereby ensuring the existence and uniqueness of the steady state.

$$\underbrace{\frac{(1-\phi)\nu \log c(l^*) f'(1-l^*) + \phi}{1-l^*} \cdot \frac{c(l^*)}{(1-\phi)\nu}}_{-u_l/u_c} = \underbrace{(1-\alpha)\left(\frac{\alpha}{\delta+\rho}\right)^{\frac{\alpha}{1-\alpha}}}_{w} - p\frac{\eta}{\sigma}\frac{m(l^*)}{1-l^*}$$

Substituting for the ratio c^* and m^* and rearranging, we obtain:

$$\nu \log c(l^*) f'(1-l^*) + \left(\frac{\phi}{1-\phi} + \frac{(1-\nu)\eta}{\Delta f(1-l^*)}\right)\frac{1}{1-l^*} = \frac{\nu w}{c(l^*)} \tag{54}$$

We study the solution to this equation when proving Proposition 1 below.

A.3 Proof of proposition 1

In this section, we prove the existence and uniqueness of the steady state in each specification.

S1: Endogenous rate of depreciation of health capital. To prove existence and uniqueness, we must show that equation (41) has a unique solution. The left-hand-side of the equation is straightforward: it is an increasing and convex function of l^* that goes from 0 to ∞. Turning to the right-hand-side, let us start by studying the function $\Delta(l^*) = 1 + \frac{\rho}{z l^{*\gamma}}$. First the derivative: $\Delta'(l^*) = -\frac{\rho\gamma}{z l^{*1+\gamma}} < 0$. It follows that $1/\Delta(l^*)$ is strictly increasing in l^*. Because $\gamma > 1$ by assumption and $\chi < 1$, $\gamma - \chi > 0$ and the right-hand side is thus strictly decreasing in l^*. Both existence and uniqueness are ensured if and only if the right-hand side is positive for $l^* = 0$, which is always the case as it is tends to $\nu\chi > 0$. **QED.**

S2: Leisure in the health production function. There is a unique solution for l^* given by (50). As we have expressed all other endogenous variables as functions of l^*, this implies the existence of a unique steady state. **QED.**

S3: Complementarities between leisure and consumption. The objective is to show that equation (54) has a unique solution. Let us first consider the behavior of $c(l^*)$. Using equation (52), we have:

$$c'(l^*) = c(l^*) \left\{ \frac{1}{l^*} - \frac{f'(1-l^*)}{f(1-l^*)} \frac{\sigma}{\sigma + V\Delta f(1-l^*)} \right\} \tag{55}$$

Note that complementarities could make consumption eventually decrease with hours worked as low levels of leisure would drastically reduce the marginal utility of consumption. Looking at the above equation, we can immediately see that this is the case if $f'(0) = \infty$ for example. For consumption to always be an increasing function of labor supply, the following needs to hold:

$$\frac{f(1-l^*)}{f'(1-l^*)} > l^* \cdot \frac{\sigma}{\sigma + V\Delta f(1-l^*)} \tag{56}$$

The left-hand side is strictly decreasing in l^* while the right-hand side is strictly increasing. For this condition to always hold, it is necessary that it does for $l^* = 1$, which is the case under assumption ***A*1**:

$$\frac{f(0)}{f'(0)} = \frac{b}{a} \geq 1 > \frac{\sigma}{\sigma + V\Delta b}$$

Now, let us go back to the analysis of equation (54). As $c'(l^*) > 0$, it is straightforward to see that the right-hand side is strictly decreasing in l^*. Furthermore, it is always positive and bounded by $\nu w / c(0) = \infty$ and $\nu w / c(1) > 0$.

Now, let us turn to the left-hand side that we denote $\mathcal{L}(l^*)$. First, notice that $\mathcal{L}(0) = -\infty$ and $\mathcal{L}(1) = +\infty$. From the intermediate value theorem, we know that there is therefore at least one solution to equation (54). The derivative with respect to l^* is:

$$\begin{aligned} \mathcal{L}'(l^*) &= \nu \frac{c'(l^*)}{c(l^*)} f'(1-l^*) - \nu \log c(l^*) f''(1-l^*) \\ &+ \frac{(1-\nu)\eta}{\Delta} \frac{f'(1-l^*)}{f(1-l^*)^2} \frac{1}{1-l^*} + \left(\frac{\phi}{1-\phi} + \frac{(1-\nu)\eta}{\Delta} \frac{1}{f(1-l^*)} \right) \frac{1}{1-l^*} \end{aligned} \tag{57}$$

If $\mathcal{L}'(l^*)$ is strictly positive, uniqueness follows. However, the sign is ambiguous as all terms are positive except the term $-\nu \log c(l^*) f''(1-l^*)$ which is negative for $c(l^*) < 1$. Because the function f is linear in leisure, $f''(1-l^*)=0$, such that:

$$\begin{aligned}\mathcal{L}'(l^*) &= \nu\frac{c'(l^*)}{c(l^*)}f'(1-l^*)+\frac{(1-\nu)\eta}{\Delta}\frac{f'(1-l^*)}{f(1-l^*)^2}\frac{1}{1-l^*} \\ &+ \left(\frac{\phi}{1-\phi}+\frac{(1-\nu)\eta}{\Delta}\frac{1}{f(1-l^*)}\right)\frac{1}{1-l^*}>0 \qquad (58)\end{aligned}$$

When $A1$ is satisfied, $\mathcal{L}(l^*)$ is strictly increasing, and as $\mathcal{L}(0)=-\infty<\nu w/c(0)$ and $\mathcal{L}(\infty)=+\infty>\nu w/c(1)$, equation (54) has a unique solution in l^*. **QED.**

A.4 Proof of Lemma 1

In this section, we prove that labor supply decreases with preferences for leisure for each specification.

S1: Endogenous rate of depreciation of health capital. Labor supply is given by equation (41), the comparative static follows directly from the Implicit Function Theorem noting that the left-hand side is increasing in ϕ and in l^* and the right-hand side is decreasing in l^*. **QED.**

S2: Leisure in the health production function. Studying the limit of (50), it is straightforward to see that $l^*(1)=0$ and that $l^*(0)=\frac{\chi[\sigma(1-\nu)+\nu\Delta]}{(1-\nu)\eta+\chi[\sigma(1-\nu)+\nu\Delta]}<1$. Furthermore, we can show that the derivative of $l^*=\frac{\chi[\sigma(1-\nu)+\nu\Delta]}{\frac{\phi}{1-\phi}\Delta+(1-\nu)\eta+\chi[\sigma(1-\nu)+\nu\Delta]}$ with respect to ϕ is negative. **QED.**

S3: Complementarities between leisure and consumption. Labor supply is given by equation (54), the comparative static follows directly from the Implicit Function Theorem noting that the left-hand side is increasing in ϕ and in l^* and the right-hand side is decreasing in l^*. **QED.**

A.5 Proof of proposition 2

In this subsection, we prove that the share of GDP devoted to health expenditure rises in **S1** and **S3**, but remains constant in **S2**. To simplify notation, let us first define $\mathcal{M}(l^*)=\frac{p\cdot m(l^*)}{y(l^*)}$.

S1: Endogenous rate of depreciation of health capital. To see that the share of GDP devoted to health expenditure decreases with preferences for leisure, it is enough and straightforward to derive equation (26) with respect to preferences for leisure ϕ, which gives:

$$\frac{\partial\mathcal{M}(l^*)}{\partial\phi}=\frac{\partial l^*}{\partial\phi}\mathcal{M}'(l^*)=\frac{\partial l^*}{\partial\phi}\left(\frac{(1-\alpha)\delta+\rho}{\rho+\delta}\right)\frac{-\sigma V\Delta'(l^*)}{[\sigma+V\Delta(l^*)]^2}<0 \qquad (59)$$

Since $\Delta'(l^*) < 0$, the negative sign follows immediately from Lemma 1. **QED.**

S2: Leisure in the health production function. Labor supply l^* and preferences for leisure ϕ do not appear in equation (26), such that $\partial \mathcal{M}/\partial \phi = 0$. **QED.**

S3: Complementarities between leisure and consumption. To see that the share of GDP devoted to health expenditure decreases with preferences for leisure, it is enough and straightforward to derive equation (26) with respect to preferences for leisure ϕ, which gives:

$$\frac{\partial \mathcal{M}(l^*)}{\partial \phi} = \frac{\partial l^*}{\partial \phi} \frac{(1-\alpha)\delta + \rho}{\rho + \delta} \frac{\sigma V \Delta f'(1-l^*)}{[\sigma + V\Delta f(1-l^*)]^2} < 0 \tag{60}$$

Because $f'(1-l^*) > 0$ and $\partial l^*/\partial \phi < 0$, the derivative above is negative. **QED.**

A.6 Proof of proposition 3

In this section, we show that there is a non-monotonous relationship between preferences for leisure and the stock of health capital at the steady state.

S1: Endogenous rate of depreciation of health capital. Differentiating (38) with respect to l^* gives $\dfrac{m'(l^*)}{m(l^*)} = \dfrac{1}{l^*} - l^* \dfrac{V\Delta'(l^*)}{\sigma + V\Delta(l^*)}$. Substituting for $\Delta(l^*)$ and $\Delta'(l^*)$ plugging everything back into (27) yields:

$$\frac{\partial h^*}{\partial \phi} = \frac{\partial l^*}{\partial \phi} h(l^*) \left\{ \frac{\sigma}{l^*} \left[1 + \frac{\gamma \rho V}{(\sigma + V) z l^{*\gamma} + \rho V} \right] - \frac{\gamma}{l^*} \right\}$$

Because $\partial l^*/\partial \phi < 0$, $\partial h^*/\partial \phi$ will be of the opposite sign as the term in curly bracket. To show that there is a non-monotonic relationship between preferences for leisure and the steady state health capital stock, we need to show that the following equation has a unique solution in ϕ:

$$\frac{\partial h^*}{\partial \phi} = 0 \Leftrightarrow 1 + \frac{\gamma \rho V}{(\sigma + V) z l^*(\phi)^\gamma + \rho V} = \frac{\gamma}{\sigma}$$

It is straightforward to see that the left-hand side strictly decreases with $l^*(\phi)$. It follows from Lemma 1 that it is an increasing function of ϕ. For a unique solution to exist, two conditions are required:

$$1 + \frac{\gamma \rho V}{(\sigma + V) z l^*(0)^\gamma + \rho V} < \frac{\gamma}{\sigma} \quad \& \quad 1 + \frac{\gamma \rho V}{(\sigma + V) z l^*(1)^\gamma + \rho V} > \frac{\gamma}{\sigma}$$

$l^*(1) = 0$ as the marginal utility of leisure goes to infinity. Therefore:

$$1 + \frac{\gamma \rho V}{(\sigma + V) z l^*(1)^\gamma + \rho V} > \frac{\gamma}{\sigma} \Leftrightarrow \sigma > \frac{\gamma}{1+\gamma}$$

Note that when $\phi = 0$, we do not necessarily have a corner solution $l^*(0) = 1$ as leisure has a health benefit. Solving equation (41) for $\phi = 0$ yields an upper bound for $l^*(\phi)$:

$$l^*(0) = \left(\frac{\rho}{z} \frac{V\chi}{(\gamma - \chi)\sigma - V\chi} \right)^{\frac{1}{\gamma}}$$

which is indeed lower than one if $\gamma > \chi \left[1 + \left(1 + \frac{\rho}{z} \right) \frac{V}{\sigma} \right]$. Using this, we obtain after rearranging:

$$1 + \frac{\gamma \rho V}{(\sigma + V) z l^*(0)^\gamma + \rho V} < \frac{\gamma}{\sigma} \Leftrightarrow \sigma < \frac{\gamma + \chi V}{1 + \gamma - \chi}$$

Therefore, there exists a unique value $\tilde{\phi}$ such that $\partial h^* / \partial \phi = 0$, below which $\partial h^* / \partial \phi > 0$ and above which $\partial h^* / \partial \phi < 0$, if and only if $\frac{\gamma}{1+\gamma} < \sigma < \frac{\gamma + \chi V}{1 + \gamma - \chi}$. **QED.**

S2: Leisure in the health production function. As seen in equation (46), $m(l^*)$ is linear in l^* and the derivative simply becomes:

$$\frac{\partial h^*}{\partial \phi} = \frac{\partial l^*}{\partial \phi} \underbrace{h(l^*) \left\{ \frac{\sigma}{l^*} - \frac{\eta}{1 - l^*} \right\}}_{h'(l^*)} \tag{61}$$

It is straightforward to solve $\partial h^* / \partial \phi = 0$:

$$\frac{\partial h^*}{\partial \phi} = 0 \Leftrightarrow l^*(\phi) = \frac{\sigma}{\eta + \sigma} \tag{62}$$

Using the expression for $l^*(\phi)$ we can actually solve for the level of preferences for leisure that maximizes the steady state health capital stock $\tilde{\phi}$:

$$\tilde{\phi} = \frac{\eta \left[\chi \nu \Delta - (1 - \chi) \sigma (1 - \nu) \right]}{\sigma \Delta + \eta \left[\chi \nu \Delta - (1 - \chi) \sigma (1 - \nu) \right]} \tag{63}$$

Therefore, there exists a positive health-maximizing level of preferences for leisure $\tilde{\phi}$ if and only if $\chi \nu \Delta - (1 - \chi) \sigma (1 - \nu) > 0$, or rearranging: $\sigma < \frac{\chi}{1 - \chi} V \Delta$. **QED.**

S3: Complementarities between leisure and consumption. Using equation (53) and deriving with respect to l^* yields:

$$\frac{m'(l^*)}{m(l^*)} = \frac{1}{l^*} + \frac{V\Delta f'(1-l^*)}{\sigma + V\Delta f(1-l^*)} \tag{64}$$

Substituting this in equation (**??**) gives:

$$\frac{\partial h^*}{\partial \phi} = 0 \Leftrightarrow \underbrace{\frac{1}{l^*(\phi)} + \frac{V\Delta f'(1-l^*(\phi))}{\sigma + V\Delta f(1-l^*(\phi))}}_{\mathcal{F}(\phi)} = \underbrace{\frac{\eta}{\sigma}\frac{1}{1-l^*(\phi)}}_{\mathcal{G}(\phi)} \tag{65}$$

First, because $l^{*\prime}(\phi) < 0$, notice that $\mathcal{G}'(\phi) < 0$. Taking the derivative of $\mathcal{F}(\phi)$, we get:

$$\mathcal{F}'(\phi) = l^{*\prime}(\phi)\left\{-\frac{1}{l^*(\phi)^2} + \frac{-V\Delta f''(1-l^*(\phi))}{\sigma + V\Delta f(1-l^*(\phi))} + \left(\frac{V\Delta f'(1-l^*(\phi))}{\sigma + V\Delta f(1-l^*(\phi))}\right)^2\right\} \tag{66}$$

Because the function f is linear, $f''(1-l^*) = 0$ and:

$$\mathcal{F}'(l^*(\phi)) = l^{*\prime}(\phi)\left\{-\frac{1}{l^*(\phi)^2} + \left(\frac{V\Delta f'(1-l^*(\phi))}{\sigma + V\Delta f(1-l^*(\phi))}\right)^2\right\} \tag{67}$$

The function $\mathcal{F}(\phi)$ to be strictly increasing if and only if:

$$\left(\frac{V\Delta f'(1-l^*(\phi))}{\sigma + V\Delta f(1-l^*(\phi))}\right)^2 < \frac{1}{l^*(\phi)2} \tag{68}$$

Which is satisifed under assumption ***A1*** as:

$$\left(\frac{V\Delta a}{\sigma + V\Delta b}\right)^2 < 1 \leq \frac{1}{l^*(\phi)^2} \tag{69}$$

Finally, notice that as $l^*(1) = 0$, $\mathcal{F}(\infty) = +\infty > \mathcal{G}(\infty) = \eta/\sigma$. When $\phi = 0$, there exists a $l^*(0) < 1$ that satisfies equation (54) but we cannot solve for it analytically. Existence and uniqueness of a health-maximizing level of labor supply is then ensured if and only if $\mathcal{F}(0) = 1 + \frac{V\Delta f'(1-l^*(0))}{\sigma + V\Delta f(1-l^*(0))} < \mathcal{G}(0) = \frac{\eta}{\sigma}\frac{l^*(0)}{1-l^*(0)}$. This inequality implicitly defines a threshold $\bar{l}$ such that $\mathcal{F}(0) < \mathcal{G}(0)$ if $l^*(0) > \bar{l}$. When that is not the case, the steady state health capital stock always increases with preferences for leisure as even no preferences for leisure leads to a number of hours worked $l^*(0)$ that is below the health-maximizing the level. **QED.**

B Calibration: Robustness checks

B.1 Variation in the returns to health expenditure.

Specification		$\tilde{l}$	$(p \cdot m/y)^*$		Deaths per 100,000	
($l^* = 0.2836$)			Δ	% expl.	Δ	% expl.
$\delta^h = 1\%$	$\sigma = 0.7$	0.122	−3.2p.p.	48.5%	−642	28.1%
	$\sigma = 0.8$	0.254	−3.2p.p.	48.5%	−226	9.9%
	$\sigma = 0.9$	0.350	−3.2p.p.	48.5%	193	-
$\delta^h = 2.5\%$	$\sigma = 0.7$	0.090	−2.6p.p.	39.4%	−993	43.4%
	$\sigma = 0.8$	0.188	−2.6p.p.	39.4%	−631	27.6%
	$\sigma = 0.9$	0.259	−2.6p.p.	39.4%	−266	11.6%
$\delta^h = 5\%$	$\sigma = 0.7$	0.068	−1.9p.p.	28.8%	−1329	58.1%
	$\sigma = 0.8$	0.142	−1.9p.p.	28.8%	−1019	44.6%
	$\sigma = 0.9$	0.196	−1.9p.p.	28.8%	−706	30.9%

l^*: labor supply, $\tilde{l}$: health-maximizing level of labor supply, $(p \cdot m/y)^*$: steady state health expenditure as a share of GDP.

Table 7. Reduction of hours worked in the US (UK labor supply, various specifications)

Specification		$\tilde{l}$	$(p \cdot m/y)^*$		Deaths per 100,000	
($l^* = 0.2750$)			Δ	% expl.	Δ	% expl.
$\delta^h = 1\%$	$\sigma = 0.7$	0.122	−3.8p.p.	74.5%	−744	39.4%
	$\sigma = 0.8$	0.253	−3.8p.p.	74.5%	−247	13.1%
	$\sigma = 0.9$	0.350	−3.8p.p.	74.5%	255	-
$\delta^h = 2.5\%$	$\sigma = 0.7$	0.090	−3p.p.	58.8%	−1158	61.4%
	$\sigma = 0.8$	0.188	−3p.p.	58.8%	−725	38.4%
	$\sigma = 0.9$	0.259	−3p.p.	58.8%	−288	15.3%
$\delta^h = 5\%$	$\sigma = 0.7$	0.068	−2.3p.p.	45.1%	−1556	82.5%
	$\sigma = 0.8$	0.142	−2.3p.p.	45.1%	−1187	62.9%
	$\sigma = 0.9$	0.196	−2.3p.p.	45.1%	−813	43.1%

l^*: labor supply, $\tilde{l}$: health-maximizing level of labor supply, $(p \cdot m/y)^*$: steady state health expenditure as a share of GDP.

Table 8. Reduction of hours worked in the US (FR labor supply, various specifications)

B.2 Variation in the curvature of depreciation.

Specification		$\tilde{l}$	$(p \cdot m/y)^*$		**Deaths per 100,000**	
$(l^* = 0.2836)$			Δ	**% expl.**	Δ	**% expl.**
$\delta^h = 1\%$	$\gamma = 1.5$	0.385	-2.4p.p.	36.4%	170	-
	$\gamma = 2$	0.253	-3.2p.p.	48.5%	-226	9.9%
	$\gamma = 2.5$	0.207	-3.9p.p.	59.1%	-607	26.5%
$\delta^h = 2.5\%$	$\gamma = 1.5$	0.258	-1.9p.p.	28.8%	-139	6.1%
	$\gamma = 2$	0.188	-2.6p.p.	39.4%	-631	27.6%
	$\gamma = 2.5$	0.163	-3.2p.p.	48.5%	-1103	48.2%
$\delta^h = 5\%$	$\gamma = 1.5$	0.177	-1.4p.p.	21.2%	-433	19%
	$\gamma = 2$	0.142	-1.9p.p.	28.8%	-1019	44.6%
	$\gamma = 2.5$	0.130	-2.4p.p.	36.4%	-1581	69.1%

l^*: labor supply, $\tilde{l}$: health-maximizing level of labor supply, $(p \cdot m/y)^*$: steady state health expenditure as a share of GDP.

Table 9. Reduction of hours worked in the US (UK labor supply, various specifications)

Specification		$\tilde{l}$	$(p \cdot m/y)^*$		**Deaths per 100,000**	
$(l^* = 0.2750)$			Δ	**% expl.**	Δ	**% expl.**
$\delta^h = 1\%$	$\gamma = 1.5$	0.385	-2.9p.p.	56.9%	215	-
	$\gamma = 2$	0.253	-3.8p.p.	74.5%	-247	13.1%
	$\gamma = 2.5$	0.207	-4.6p.p.	90.2%	-689	36.5%
$\delta^h = 2.5\%$	$\gamma = 1.5$	0.258	-2.3p.p.	45.1%	-151	8.0%
	$\gamma = 2$	0.188	-3p.p.	58.8%	-725	38.4%
	$\gamma = 2.5$	0.163	-3.8p.p.	74.5%	-1272	67.4%
$\delta^h = 5\%$	$\gamma = 1.5$	0.177	-1.7p.p.	33.3%	-502	26.6%
	$\gamma = 2$	0.142	-2.3p.p.	45.1%	-1187	62.9%
	$\gamma = 2.5$	0.130	-2.9p.p.	56.9%	-1837	97.4%

l^*: labor supply, $\tilde{l}$: health-maximizing level of labor supply, $(p \cdot m/y)^*$: steady state health expenditure as a share of GDP.

Table 10. Reduction of hours worked in the US (FR labor supply, various specifications)

B.3 Using another health indicator.

Specification		$\tilde{l}$	$(p \cdot m/y)^*$		**Risk per 100,000**	
$(l^* = 0.2836)$			Δ	**% expl.**	Δ	**% expl.**
$\delta^h = 1\%$	$\sigma = 0.7$	0.141	-2.2p.p.	35.5%	-425	19.2%
	$\sigma = 0.8$	0.294	-2.2p.p.	35.5%	-47	2.1%
	$\sigma = 0.9$	0.406	-2.2p.p.	35.5%	327	-
$\delta^h = 2.5\%$	$\sigma = 0.7$	0.1	-1.8p.p.	29.0%	-756	34.4%
	$\sigma = 0.8$	0.208	-1.8p.p.	29.0%	-424	19.2%
	$\sigma = 0.9$	0.287	-1.8p.p.	29.0%	-94	4.3%
$\delta^h = 5\%$	$\sigma = 0.7$	0.074	-1.3p.p.	21.0%	-1081	49.1%
	$\sigma = 0.8$	0.154	-1.3p.p.	21.0%	-793	36.1%
	$\sigma = 0.9$	0.212	-1.3p.p.	21.0%	-507	23.0%

l^*: labor supply, $\tilde{l}$: health-maximizing level of labor supply, $(p \cdot m/y)^*$: steady state health expenditure as a share of GDP.

Table 11. Reduction of hours worked in the US (UK labor supply, various specifications using the prevalence in ADLs as health status)

Specification		$\tilde{l}$	$(p \cdot m/y)^*$		**Risk per 100,000**	
$(l^* = 0.2750)$			Δ	**% expl.**	Δ	**% expl.**
$\delta^h = 1\%$	$\sigma = 0.7$	0.141	-2.5p.p.	58.1%	-482	13.4%
	$\sigma = 0.8$	0.294	-2.5p.p.	58.1%	-40	1.1%
	$\sigma = 0.9$	0.406	-2.5p.p.	58.1%	378	-
$\delta^h = 2.5\%$	$\sigma = 0.7$	0.1	-2p.p.	24.1%	-868	34.4%
	$\sigma = 0.8$	0.208	-2p.p.	46.5%	-476	13.2%
	$\sigma = 0.9$	0.287	-2p.p.	46.5%	-88	2.4%
$\delta^h = 5\%$	$\sigma = 0.7$	0.074	-1.6p.p.	37.2%	-1248	34.7%
	$\sigma = 0.8$	0.154	-1.6p.p.	37.2%	-908	25.2%
	$\sigma = 0.9$	0.212	-1.6p.p.	37.2%	-571	15.8%

l^*: labor supply, $\tilde{l}$: health-maximizing level of labor supply, $(p \cdot m/y)^*$: steady state health expenditure as a share of GDP.

Table 12. Reduction of hours worked in the US (FR labor supply, various specifications using the prevalence in ADLs as health status)

Specification		$\tilde{l}$	$(\boldsymbol{p \cdot m/y})^*$		**Risk per 100,000**	
$(l^* = \mathbf{0.2836})$			$\boldsymbol{\Delta}$	**% expl.**	$\boldsymbol{\Delta}$	**% expl.**
$\boldsymbol{\delta^h} = \mathbf{1}\%$	$\gamma = \mathbf{1.5}$	0.467	−1.7p.p.	27.4%	254	-
	$\gamma = \mathbf{2}$	0.294	−2.2p.p.	35.5%	−47	2.1%
	$\gamma = \mathbf{2.5}$	0.234	−2.7p.p.	43.5%	−341	15.5%
$\boldsymbol{\delta^h} = \mathbf{2.5}\%$	$\gamma = \mathbf{1.5}$	0.295	−1.3p.p.	21.0%	−30	1.4%
	$\gamma = \mathbf{2}$	0.208	−1.8p.p.	29.0%	−424	19.2%
	$\gamma = \mathbf{2.5}$	0.177	−2.2p.p.	35.5%	−809	36.8%
$\boldsymbol{\delta^h} = \mathbf{5}\%$	$\gamma = \mathbf{1.5}$	0.197	−1.0p.p.	16.1%	−304	13.8%
	$\gamma = \mathbf{2}$	0.154	−1.3p.p.	21.0%	−793	36.1%
	$\gamma = \mathbf{2.5}$	0.139	−1.7p.p.	27.4%	−1273	57.9%

$\boldsymbol{l^*}$: labor supply, $\tilde{\boldsymbol{l}}$: health-maximizing level of labor supply, $(\boldsymbol{p \cdot m/y})^*$: steady state health expenditure as a share of GDP.

Table 13. Reduction of hours worked in the US (UK labor supply, various specifications using the prevalence in ADLs as health status)

Specification		$\tilde{l}$	$(\boldsymbol{p \cdot m/y})^*$		**Risk per 100,000**	
$(l^* = \mathbf{0.2750})$			$\boldsymbol{\Delta}$	**% expl.**	$\boldsymbol{\Delta}$	**% expl.**
$\boldsymbol{\delta^h} = \mathbf{1}\%$	$\gamma = \mathbf{1.5}$	0.467	−1.9p.p.	44.2%	305	-
	$\gamma = \mathbf{2}$	0.294	−2.5p.p.	58.1%	−40	1.1%
	$\gamma = \mathbf{2.5}$	0.234	−3.0p.p.	69.8%	−376	10.4%
$\boldsymbol{\delta^h} = \mathbf{2.5}\%$	$\gamma = \mathbf{1.5}$	0.295	−1.5p.p.	34.9%	−24	0.7%
	$\gamma = \mathbf{2}$	0.208	−2p.p.	46.5%	−476	13.2%
	$\gamma = \mathbf{2.5}$	0.177	−2.5p.p.	58.1%	−917	25.5%
$\boldsymbol{\delta^h} = \mathbf{5}\%$	$\gamma = \mathbf{1.5}$	0.197	−1.2p.p.	27.9%	−345	9.6%
	$\gamma = \mathbf{2}$	0.154	−1.6p.p.	37.2%	−908	25.2%
	$\gamma = \mathbf{2.5}$	0.139	−2.0p.p.	46.5%	−1459	40.5%

$\boldsymbol{l^*}$: labor supply, $\tilde{\boldsymbol{l}}$: health-maximizing level of labor supply, $(\boldsymbol{p \cdot m/y})^*$: steady state health expenditure as a share of GDP.

Table 14. Reduction of hours worked in the US (FR labor supply, various specifications using the prevalence in ADLs as health status)

B.4 Reverse counterfactual: What if Europeans worked as much as Americans?

Specification		$\tilde{l}$		$\Delta(p \cdot m/y)^*$		**Δ Deaths per 100,000**	
$(l_{us} = 0.3327)$		**UK**	**France**	**UK**	**France**	**UK**	**France**
$\delta^h = 1\%$	$\sigma = 0.7$	0.133	0.126	+2.5p.p.	+3.4p.p	515	819
	$\sigma = 0.8$	0.277	0.263	+2.5p.p.	+3.4p.p	108	347
	$\sigma = 0.9$	0.383	0.363	+2.5p.p.	+3.4p.p	−291	−116
$\delta^h = 2.5\%$	$\sigma = 0.7$	0.097	0.094	+2.0p.p.	+2.7p.p.	865	1297
	$\sigma = 0.8$	0.202	0.195	+2.0p.p.	+2.7p.p.	501	886
	$\sigma = 0.9$	0.279	0.269	+2.0p.p.	+2.7p.p.	142	480
$\delta^h = 5\%$	$\sigma = 0.7$	0.072	0.071	+1.4p.p.	+2.0p.p	1214	1719
	$\sigma = 0.8$	0.151	0.147	+1.4p.p	+2.0p.p	894	1364
	$\sigma = 0.9$	0.208	0.204	+1.4p.p	+2.0p.p	578	1012

Table 15. Increase in hours worked in the UK and France (US labor supply, various specifications with $\gamma = 2$)

Specification		$\tilde{l}$		$\Delta(p \cdot m/y)^*$		**Δ Deaths per 100,000**	
$(l_{us} = 0.3327)$		**UK**	**France**	**UK**	**France**	**UK**	**France**
$\delta^h = 1\%$	$\gamma = 1.5$	0.443	0.415	+1.8p.p.	+2.5p.p	-246	-261
	$\gamma = 2$	0.277	0.263	+2.5p.p.	+3.4p.p	108	185
	$\gamma = 2.5$	0.220	0.210	+3.3p.p.	+4.5p.p	468	640
$\delta^h = 2.5\%$	$\gamma = 1.5$	0.287	0.275	+1.4p.p.	+1.9p.p.	50	85
	$\gamma = 2$	0.202	0.195	+2.0p.p.	+2.7p.p.	501	640
	$\gamma = 2.5$	0.172	0.166	+2.5p.p.	+3.5p.p.	953	1197
$\delta^h = 5\%$	$\gamma = 1.5$	0.194	0.188	+1.0p.p.	+1.4p.p	343	429
	$\gamma = 2$	0.151	0.147	+1.4p.p	+2.0p.p	894	1101
	$\gamma = 2.5$	0.136	0.134	+1.8p.p	+2.6p.p	1447	1771

Table 16. Increase in hours worked in the UK and France (US labor supply, various specifications with $\sigma = 0.8$)

Specification		$\tilde{l}$		$\boldsymbol{\Delta(p \cdot m/y)^*}$		**Δ Risk per 100,000**	
($\boldsymbol{l_{us} = 0.3327}$)		**UK**	**France**	**UK**	**France**	**UK**	**France**
$\boldsymbol{\delta^h = 1\%}$	$\boldsymbol{\sigma = 0.7}$	0.139	0.131	+2.2p.p.	+3.1p.p	443	565
	$\boldsymbol{\sigma = 0.8}$	0.290	0.272	+2.2p.p.	+3.1p.p	59	128
	$\boldsymbol{\sigma = 0.9}$	0.401	0.376	+2.2p.p.	+3.1p.p	−325	−305
$\boldsymbol{\delta^h = 2.5\%}$	$\boldsymbol{\sigma = 0.7}$	0.100	0.096	+1.7p.p.	+2.4p.p.	771	928
	$\boldsymbol{\sigma = 0.8}$	0.208	0.199	+1.7p.p.	+2.4p.p.	435	541
	$\boldsymbol{\sigma = 0.9}$	0.287	0.275	+1.7p.p.	+2.4p.p.	98	156
$\boldsymbol{\delta^h = 5\%}$	$\boldsymbol{\sigma = 0.7}$	0.074	0.072	+1.2p.p.	+1.8p.p	1093	1291
	$\boldsymbol{\sigma = 0.8}$	0.154	0.150	+1.2p.p	+1.8p.p	804	954
	$\boldsymbol{\sigma = 0.9}$	0.213	0.207	+1.2p.p	+1.8p.p	514	618

Table 17. Increase in hours worked in the UK and France (US labor supply, various specifications with $\gamma = 2$ using the prevalence of ADLs as health status)

Specification		$\tilde{l}$		$\boldsymbol{\Delta(p \cdot m/y)^*}$		**Δ Risk per 100,000**	
($\boldsymbol{l_{us} = 0.3327}$)		**UK**	**France**	**UK**	**France**	**UK**	**France**
$\boldsymbol{\delta^h = 1\%}$	$\boldsymbol{\gamma = 1.5}$	0.470	0.434	+1.6p.p.	+2.3p.p	-265	-261
	$\boldsymbol{\gamma = 2}$	0.290	0.272	+2.2p.p.	+3.1p.p	59	128
	$\boldsymbol{\gamma = 2.5}$	0.229	0.216	+2.9p.p.	+4.1p.p	382	520
$\boldsymbol{\delta^h = 2.5\%}$	$\boldsymbol{\gamma = 1.5}$	0.298	0.283	+1.2p.p.	+1.8p.p.	24	56
	$\boldsymbol{\gamma = 2}$	0.208	0.199	+1.7p.p.	+2.4p.p.	435	541
	$\boldsymbol{\gamma = 2.5}$	0.176	0.170	+2.2p.p.	+3.2p.p.	839	1021
$\boldsymbol{\delta^h = 5\%}$	$\boldsymbol{\gamma = 1.5}$	0.199	0.192	+0.9p.p.	+1.3p.p	304	369
	$\boldsymbol{\gamma = 2}$	0.154	0.150	+1.2p.p	+1.8p.p	804	954
	$\boldsymbol{\gamma = 2.5}$	0.139	0.136	+1.6p.p	+2.3p.p	1292	1530

Table 18. Increase in hours worked in the UK and France (US labor supply, various specifications with $\sigma = 0.8$ using the prevalence of ADLs as health status)

C The case of Japan

Japan may at first appear as an outlier at odds with the story told by our theoretical model and our calibration exercise. It is well known that among developed nations, Japan enjoys one of the very highest life expectancy and fares much better than other rich countries (and especially the US) on a variety of health indicators. At the same time, Japan is often thought of as a country where working hours are particularly long, which seems to contradict the main proposition of this paper.

However, looking at available data on actual hours worked per workers in Japan paints a different picture. Although not suited for international comparison at any given point in time, OECD data indicate that Japanese workers work substantially less hours than their American counterparts and clearly display a steady decline in labor supply over the last forty years. The Penn World Table (Feenstra et al., 2015) puts the number of hours worked in Japan only slightly below that of the US. A substantial fraction of the Japanese workforce nevertheless work long hours (Iwasaki et al., 2006). Japanese workers who do put in long hours are likely to experience negative health symptoms, from cardiovascular diseases to mental disorders and suicidal thoughts (Yamauchi et al., 2017; Takahashi, 2019). A phenomenon of death from overwork (often caused by heart attack or stroke at work) is prominent enough in Japanese society that it has been given a name: *Karoshi* (Kanai, 2009).

Why seemingly long working hours as well as their negative health effect are not apparent looking at aggregate data is beyond the scope of this paper. However, we believe that the situation of Japan is compatible with our theory, provided we allow for different values of key parameters. The returns to health expenditure as well as the rate of depreciation of health capital could very well be different than in the US and Western Europe, for a variety of reasons ranging from a better functionning health care system to differences in cultural health behavior and physiological characteristics. For such reasons, Japan having a better health than the US does not rule out the possibility that its number of hours worked per workers nevertheless lie above the health-maximizing level. If Japanese preferences for leisure are such that labor supply is indeed above the health-maximizing level, then a reduction in working hours would have beneficial effect, both on the share of GDP devoted to health expenditure and on the health of the population itself.

As a simple exercise and a tentative answer to this 'Japanese Puzzle', we calibrate the model for Japan in 2015. To do so, we keep the same values for most standards parameters such as the discount rate ρ, the share of capital in aggregate production α and the depreciation rate of physical capital δ and use the same calibration strategy as in our baseline.

In a conservative assumption, we set the relative price of health care to the European level estimated by He et al. (2021) as we do not have data for Japan. We let σ vary between 0.7 and 0.9 and γ between 1.5 and 2.5 as in our robustness checks for the US. We calibrate preferences for leisure ϕ to match Japanese labor supply, using data from the Penn World Table ($l^*_{jp} = 0.3009$), the relative taste for consumption ν is calibrated to fit the share of health expenditure equal to 10.8% in 2015. We again use survival probabilities between age 55–64 computed from the life tables of the Human Mortality Database and calibrate the parameters of the logistic function accordingly.

Once the model is calibrated, we do not conduct any kind of counterfactual but instead compute the health maximizing level of labor supply in specifications in which both the returns to health expenditure σ and the curvature of the rate of depreciation of health capital γ vary. The results are displayed in the table below and indeed, for most specifications, Japanese labor supply does lie above the health-maximizing level. Except in the specification when the returns to health expenditure are high ($\sigma > 0.9$) relative to the curvature of the depreciation rate ($\gamma = 1.5$), a reduction in hours worked would have the same kind of beneficial effects on both health and health expenditure as in the US.

$\boldsymbol{l^*_{jp} = 0.3009}$		γ		
	$\tilde{l}$	**1.5**	**2**	**2.5**
	0.7	0.151	0.089	0.000
σ	**0.8**	0.262	0.185	0.158
	0.9	0.381	0.256	0.221

Table 18: Health-maximizing labor supply for various values of the parameters of the health capital function