

Are Recessions Good for Your Health? When Ruhm Meets GHH*

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Abstract

This paper first documents several important business cycle properties of health status and health expenditures in US. We find that health expenditures are pro-cyclical while health status is counter-cyclical. We then develop a stochastic dynamic general equilibrium model with endogenous health accumulation. The model has four distinguished features: 1). Health enters into utility function; 2) Health enters into production function; 3). Both goods and time input are used to produce health stock; 4). Depreciation rate of health stock negatively depends on working hours. We calibrate the model to US economy. The results replicate the stylized facts of health status and medical expenditure over business cycles. We also investigate the relative importance of each feature in affecting the business cycle properties of health accumulation.

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1 Introduction

Economists have paid an increasing attention to the relationship between health and macroeconomic conditions. Issues pertaining to health and healthcare expenditure are often of the first-order importance in macroeconomic analysis and policy forums nowadays. For example, the recent study by Jones and Klenow (2011) illustrates the importance of health for national welfare; the relationship between health and macroeconomic development also takes the center stage in the World Health Organization's Commission on Macroeconomics and Health (CMH); and health is a key measure of national macroeconomic development in the United Nations' Human Development Index (HDI). On the empirical ground, there is ample evidence on a positive correlation between health and long-run economic growth. There is also a growing literature on the macroeconomic causes and implications of the long-run trend in healthcare

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expenditure.¹ According to recent poll numbers from Gallup and in recent headline news, the confluence between healthcare and macroeconomy tops America’s “most important problem” list.

While the positive association of health with favorable macroeconomic performance holds in the long run, recent empirical studies provide overwhelming evidence that the association of the two in the short run is exactly the opposite in modern developed economies. See, among others, a series of empirical papers by Ruhm (2000, 2003, 2005, 2007), Neumayer (2004), Gerdtham and Johannesson (2005), Gerdtham and Ruhm (2006), Tapia Granados and Ionides (2008), and Miller, Page, Stevens, and Filipinski (2009) for the most conclusive evidence. These studies find that in the US and other OECD countries, national health status, which is usually proxied by the adult mortality rate, tends to improve during economic contractions but worsens during economic expansions, even though healthcare expenditure generally declines in recessions and rises in expansions. This finding is also not a recent phenomenon. Tapia Granados and Diez Roux (2009) find that the recessions of 1921, 1930–1933, and 1938 in the US coincided with declines in mortality and gains in life expectancy. The counter-cyclicality of health status, especially in the face of the pro-cyclicality of healthcare expenditure, may sound paradoxical even to many economists. The way how health status and healthcare expenditure fluctuate over business cycles may have dramatic welfare and policy implications.

Several heuristic arguments have been made by Ruhm and followed by others subsequently for why health might be counter-cyclical. First, since the opportunity cost of leisure is pro-cyclical, time tends to be shifted away from market work towards leisure time when the cost of leisure falls in economic recessions, allowing individuals more time to engage in health-enhancing activities, such as sleeping, exercising, socializing, preparing healthier meals at home, caring for family members, and visiting doctor’s office; and the opposite would occur in economic booms when the cost of leisure rises. Second, the production of goods and services may require not only physical capital and labor inputs, but also health capital input, and since contractions (expansions) can be associated with shorter (longer) working hours and/or less (more) intensive labor effort, hazardous working conditions, exertion from employment, work-related stress and injuries can be less (more) prevalent in recessions (booms). In this vein, the fraction of time spent on market labor can be viewed as the utilization rate of individuals’ health stock, in the spirit of Greenwood, Hercowitz, and Huffman (1988, hereafter GHH) in modeling the capacity utilization rate of physical capital stock. Third, rising income during economic expansions may lead individuals to take on more unhealthy activities, such as smoking, drinking, and engaging in dangerous entertainign activities, which would harm their health.²

The main purpose of the present paper is to develop a structural framework to provide a systematic assessment of various channels in accounting for the cyclical properties of health status and health expenditure, jointly with key macroeconomic variables studied in the standard busines scycle literature.....

We will start by first documenting the business cycle properties of health expenditures and health status (proxied by national mortality rate) in US, following the mainstream macroeconomic literature (e.g., Cooley and Prescott 1995). We find that although health expenditures are pro-cyclical, health status is exactly opposite. Therefore we confirm Ruhm’s finding even on the macroeconomic dimension. Second, we develop a stochastic dynamic general equilibrium model with endogenous health accumulation which focuses on the first two channels Ruhm emphasized. The model has four distinguished features: 1). Health enters into utility function; 2) Health enters into production function; 3). Both goods and time input are used to produce health stock; 4). Depreciation rate of health stock negatively depends on working hours. Our feature 3 captures the first channel as Ruhm mentioned in his paper (we can

¹See Suen (2006), Hall and Jones (2007), Fonseca et al. (2009), and Zhao (2010).

²See, also, Freeman (1999) and Ruhm and Black (2002). However, Xu and Kaestner (2010) argue that individuals are more likely to engage in unhealthy activities such as smoking and drinking during temporary economic downturns.

call it *time* channel). Our feature 2 and 4 model the different aspects of the second channel in Ruhm (2000), which we call it *production* channel. In addition, we call feature 1 *utility* channel.³ We calibrate the model to US economy. The benchmark results replicate the stylized facts of medical expenditure and health status over business cycles. We then investigate the relative importance of each feature in affecting the cyclicity of health status by running a series of counterfactual experiments. Since the model captures main mechanisms that Ruhm conjectured in his paper, this exercise is able to tell us which mechanism is the most important in generating counter-cyclicity of health status as observed in the data. As far as we know, this is the first paper to do so.

We find that isolatedly the time and production channel both generate counter-cyclicity of health stock as we expect. Each channel alone, however, is not important enough to drive the counter-cyclicity as close as to the data. The joint presence of both time and production channel is crucial in replicating this counter-cyclicity. The dynamic interaction between these two channels is a key mechanism to generate counter-cyclicity of health stock. The utility channel also generates counter-cyclicity of health stock. However, its effect is quantitatively very insignificant.

The paper is organized as following. Section 2 describes the data we use and empirical results. Section 3 presents our benchmark model. Section 4 outlines the calibration of the model and demonstrates the benchmark results. Section 5 decomposes each feature of the model and evaluate its relative importance in driving the results. Section 6 conducts sensitivity analysis. Section 7 concludes.

2 Data

A series of influential papers by Ruhm (2000, 2003, 2005, 2007) show striking empirical results that recessions might be good for health by demonstrating a counter-cyclical property of state-level mortality rate. In Ruhm (2000), he uses the mortality rate related to ten specific diseases for the time period 1972-1991 as a proxy of health status and unemployment rate for the same period as a proxy of the macroeconomic condition. He finds 1% increase in the unemployment rate is associated with a 0.54% reduction in total mortality rate.⁴

Ruhm's finding has been strengthened by subsequent researches. Neumayer (2004) finds the counter-cyclical property of physical health by applying similar methods as in Ruhm (2000) to German data. He estimates that a 1% point drop in unemployment predicts a 0.7% to 1.1% rise in total mortality. Gerdtham and Johannesson (2005) confirm Ruhm's finding by using a large scale individual data set in Sweden which covers time period of 10-16 years. Gerdtham and Ruhm (2006) extend Ruhm (2000)

³In an extension of the benchmark model, we also differentiate the consumption behavior which harms health, such as smoking and drinking from the normal consumption which does not affect health. We call the former "bad consumption" and the latter "good consumption." In other words, we explicitly capture the third channel Ruhm mentioned. Our results show that the bad consumption channel can generate either counter-cyclical or pro-cyclical health status, depending on the specification of bad consumption in the model. However, no matter what specification we have, the effect of bad consumption channel on cyclicity of health is quantitatively insignificant. See Appendix for more details.

⁴These ten specific sources of diseases account for around 80 percent of all fatalities. Among the ten sources, eight (including heart disease, pneumonia/influenza, liver disease, vehicle accidents and other accidents, homicide, infant and neonatal mortality) are shown to exhibit a procyclical fluctuation. Cancer is essentially acyclical. Suicides represent an important exception to be strongly counter-cyclical. Among the three age groups (20-44 year olds, 45-64 year olds and ≥ 65 year olds), the effect of state unemployment rate is the most significant in the group for 20-44 year olds. 1% increase in unemployment rate lowers death rate of this group by 2%. For group older than 65, this number is 0.3%. Unemployment rate has no effect on the death rate of persons aged 45-64. Including four-year lags of state unemployment rates into the estimation, the magnitude of counter-cyclicity though is weakened but still significant for most of diseases. Sustained one percentage point rise in unemployment rates still decreases the total mortality rate by 0.4% by the end of four years. See Ruhm (2000) for more details.

by using the aggregate data for time period from 1960 to 1997 and for 23 OECD countries. Their finding is consistent with Ruhm’s previous results that total mortality and death rise when labor market strengthens and the effects are particularly strong for countries with weak social support systems. On the other hand, Miller et al. (2009) not only replicate Ruhm’s estimations but also advance the understanding of the mechanisms that are likely to explain the counter-cyclical property of mortality. In particular, they aim to distinguish health changes resulting from changes in individuals’ own work and health related behaviors (i.e., the first and third channel in Ruhm 2000) and health changes that are related to “externalities” associated with macroeconomic conditions (i.e., the second and fourth channel in Ruhm 2000). Decomposing the mortality rate regression exercise in the spirit of Ruhm (2000) by age, sex, race, and causes of death, their results show that the primary causes of death contributing to cyclical mortality fluctuations among working-age population are not due to changes in individuals’ own employment status, work, or health behaviors. In contrast, the business cycle externalities (second and fourth channel in Ruhm 2000) play an important role in health changes.

All these researches, however, focus on microeconomic dimension and generally use approximation for macroeconomic condition. What we want to do here is to extend this research line and document business cycle properties of health status and health expenditure by following mainstream macroeconomic literature (e.g., Cooley and Prescott 1995).

First, we investigate the business cycle properties of health status. Following the health economics literature, and also to be consistent to empirical work by Ruhm, we use total mortality rate to proxy health status. Higher mortality rate implies lower health status. Total mortality rate here is the crude death rate that indicates the number of deaths per 1,000 mid-year population. The annual data are taken from World Bank for the time period from 1960 to 2007. Our annual GDP per capita data is taken from NIPA.⁵ To be consistent with our model, we apply CPI index in US for the same period to obtain real GDP per capita. We then take a natural log on GDP per capita and use H-P filter to detrend both variables.⁶ We find a positive correlation between the mortality rate and real GDP per capita, which is 0.3728 at 1% significant level. This implies health status is negatively correlated to real GDP per capita. Health status is counter-cyclical. We thus confirm Ruhm’s finding on the macroeconomic dimension as well. The standard deviation of health status is extremely small at the level of 0.014%.

Next, we take a look at business cycle properties of health expenditures. Annual data on total health expenditure per capita over the 1960-2007 period in the U.S. are taken from OECD Health Data 2010 (OECD, 2010). we again apply CPI index in US for the same period to obtain real health expenditure per capita. We then follow the same procedure to take natural log and apply H-P filter to real medical expenditure and GDP per capita. The results show that the correlation between the cyclical part of real medical expenditures and GDP per capita for the time period is 0.3032, which is significant at 5% level. The standard deviation of health expenditures is 2.12%, which is lower than the one for real GDP per capita 2.61%. Health expenditures are pro-cyclical.⁷ For a robustness check, we also apply Band-Pass filter to examine the cyclical property of health expenditures. Under Band-Pass filter, the positive correlation between GDP and health expenditure becomes more significant. It is 0.3951 at 5% significant level. The results are also robust if we use GDP deflator instead of CPI as the price index.

Figure 1 shows the cyclicity of mortality rate (proxy health status) and health expenditure, respectively.⁸

⁵Since the model is a closed economy model, we take out net exports from GDP in data to be consistent with our model.

⁶We set parameter $\lambda = 400$ in the H-P filter to be consistent with the annual data we use.

⁷In fact, this data pattern is not only unique to the US, but also true for most OECD countries. Australia, Italy, Japan, Norway, South Korea, Sweden, Switzerland and UK all show a significantly positive correlation between health expenditures and real GDP at 1% level.

⁸For the purpose of illustration, we also take natural log of mortality rate here to put it in the same scale of GDP.

3 Model

In this section, we describe the benchmark model that we are going to use for the remaining parts of the paper. It is an infinite-horizon stochastic general equilibrium model with endogenous health accumulation. The economy consists only one good which can be used for consumption, or medical care, or investment. The model has four distinguished features: 1). Health enters into utility function; 2) Health enters into production function; 3). Both goods and time input are used to produce health stock; 4). Depreciation rate of health stock negatively depends on working hours. These features are included because first we want to follow Grossman (1972) who argues that the demand of health comes from the consumption value (individuals value health as a consumption good to provide utility, as in our feature 1) and the investment value (individuals value health as an investment good to enhance labor productivity, as in our feature 2 of of health stock). Second, we want to include some key channels as mentioned in Ruhm (2000). Our feature 3 captures the time channel in Ruhm (2000) by adding in time (more accurately leisure time) as an input to the health production function. Our feature 2 and 4 are motivated by the production channel as mentioned in Ruhm (2000). He argues that extended job hours during short-lasting economic boom might have negative effects on health since longer working hours may lead to both higher chance of work-related accidents and higher stress.

3.1 The Environment

The model economy consists of a representative agent with following preference

$$\max \sum_{t=0}^{\infty} \beta^t u(C_t, L_t, H_t)$$

The form of period utility function is taken from GHH and is defined as

$$u(C_t, L_t, H_t) = \log \left[(\lambda C_t^{1-\eta} + (1-\lambda)H_t^{1-\eta})^{\frac{1}{1-\eta}} - \phi \frac{n^{1+\rho}}{1+\rho} \right] \quad (1)$$

where C is consumption, L is leisure, H is health stock, and β denotes the subjective discount factor.⁹ The reason why we want to take the form of GHH is because the intuition Ruhm (2000) had for the time channel focuses on the substitution effect of cyclical wage. However, the income effect of cyclical wage tends to dampen this channel in economic downturn since lower wage will induce negative income effect and make individuals enjoy less leisure time. In order to strengthen the time channel, we would like to mute the income effect of cyclical wage. GHH utility function exactly provides a way to do so.¹⁰ In addition, as will be mentioned below, GHH also provides an ideal framework for modeling the production channel in this model economy. As a whole package, we would like to keep the preference as same as in GHH. Since it is less known about the relationship between consumption and health in the preference, we allow a flexible CES form between C and H . With this functional form, the elasticity of substitution between consumption and health is $\frac{1}{\eta}$. Parameter λ measures the relative importance of consumption in the consumption-health bundle. Parameter ϕ determines the weight of leisure in the utility function. ρ determines the labor elasticity which in this type of preference is $\frac{1}{\rho}$.

Taking log does not affect the cyclicity of mortality rate significantly. The correlation between log of mortality rate and log GDP per capita is 0.3674. It is significant at 1% level.

⁹In this paper we use health stock and health status interchangeably.

¹⁰In Section 6.1, we show that our quantitative results do not change significantly with CRRA preference.

The agent maximizes her utility subject to the following constraints

$$C_t + M_t + I_t \leq e^{z_t} K_t^\alpha (N_t H_t)^{1-\alpha} \quad (2)$$

$$I_t = K_{t+1} - (1 - \delta_k) K_t \quad (3)$$

$$H_{t+1} = (1 - \delta_h - \frac{N_t^\varpi}{\varpi}) H_t + B(M_t^\theta L_t^{1-\theta})^\xi \quad (4)$$

$$1 = N_t + L_t \quad (5)$$

$$Z_{t+1} = \chi Z_t + \epsilon_{t+1} \quad (6)$$

$$C_t \geq 0, K_0, H_0 > 0 \text{ given}$$

Equation 2 is the resource constraint. M denotes medical expenditures and I is the investment to physical capital K . Z represents the total factor productivity shock and is the only source of uncertainty in the model economy. N is working hours. α is the share of capital. Notice that N and H are bundled in the production function. When health stock increases, it enhances the labor productivity. Therefore even the working hours keep the same, with better health, the effective labor input NH increases.¹¹ Equation 3 is the law of motion for capital stock where δ_k is the depreciation rate for capital. Equation 4 is the law of motion for health stock. The existing health stock is subject to depreciation which consists two parts: a constant natural depreciation rate δ_h , and a flexible part which depends on the length of working hours. We think length of working hours can be a proxy for the utilization of health stock an individual accumulates. Longer working hours means higher utilization of the accumulated health stock and hence leads to a faster depreciation of health stock, either because longer working hours make one much more stressful as emphasized in Ruhm (2000), or because less time can be devoted to maintain your health.¹² In this sense, health capital is much like a physical capital with working hours N represents the degree of utilization of health capital. GHH thus provides a natural way to model the production channel for health. Motivated by GHH, we assume this flexible part of depreciation rate takes the form $\frac{N_t^\varpi}{\varpi}$ where $\varpi > 1$ denotes the elasticity of depreciation rate of health with respect to the length of working hours. Therefore, the term $N_t H_t$ in equation 2 and the term $\frac{N_t^\varpi}{\varpi}$ exactly capture the production channel in Ruhm (2000). When economy expands, working hours and hence the utilization of health stock increase. It first hurts health from the term $N_t H_t$ in production function since when N_t increases, H_t decreases because of the substitution between N_t and H_t in this term. In other words, this term captures the intuition that longer working hours tend to increase the chance of work-related accidents and injuries. Furthermore, longer working hours hurt health via the term $\frac{N_t^\varpi}{\varpi}$ in equation 4. This term as we mentioned above, captures the intuition that longer working hours make individuals more stressful. The depreciation of health thus is eventually determined by a natural health depreciation rate and a stress-related depreciation rate $d_h(N) = \delta_h + \frac{N^\varpi}{\varpi}$.

¹¹It is easy to show $\frac{\partial MPN}{\partial H} > 0$. Being healthy raises an individual's marginal product of labor.

¹²Overwhelming evidence on the positive correlation between longer working hours and ill-health is surveyed in Sparks et al. (1997).

Facing the depreciation of health stock, an individual can choose to invest either in goods or time in order to compensate her loss of health stock over time shown in equation 4. Notice that the health investment technology is a Cobb-Douglas function with both medical expenditure and leisure as inputs.¹³ B measures the productivity of health investment technology. θ is the share of goods investment (medical expenditures) in health production technology and ξ represents the return to scale for the technology. Equation 5 is the time constraint. The agent splits her time between working and enjoy leisure. Finally, equation 6 is the law of motion of z_t , where the innovation ϵ is distributed normally with mean zero and standard deviation σ_ϵ .

3.2 First Order Conditions

Define

$$MPK_t = \alpha K(N_t H_t)^{1-\alpha} \quad (7)$$

$$MPN_t = (1 - \alpha) K(N_t H_t)^{-\alpha} H_t \quad (8)$$

$$MPH_t = (1 - \alpha) N_t K_t^\alpha (N_t H_t)^{-\alpha} \quad (9)$$

$$MPV_t = B(1 - \theta) \xi M_t^{\theta \xi} L_t^{(1-\theta)\xi-1} \quad (10)$$

$$MPM_t = B\theta \xi M_t^{\theta \xi-1} L_t^{(1-\theta)\xi} \quad (11)$$

where MPK_t denotes the marginal product of capital, MPN_t is the marginal product of labor, MPH_t is the marginal product of health, MPV_t is the marginal product of leisure in health production technology, and MPM_t is the marginal product of medical expenditures in health production technology. Based on these definitions, we have the following first order conditions

$$\frac{\partial u}{\partial C_t} = \beta \frac{\partial u}{\partial C_{t+1}} (MPK_{t+1} + 1 - \delta_k) \quad (12)$$

¹³Empirical literature shows the evidence that time input is very important in producing good health. Kenkel (1995) and Contoyannis and Jones (2004) find that adequate sleep and exercise improves health. A series of evidence also show the effectiveness of regular physical activity in the primary and secondary prevention of major chronic diseases and premature death. See Haskell (1994), Sacker and Cable (2005) and Warburton et al. (2006). In addition, Wang and Brown (2004), Brown et al. (2005) all show the evidence that lack of physical activity induces higher medical expenditures among patients. Pratt, Macera, and Wang (2000) estimates that if all physically inactive Americans became active, we would save \$77 billion in annual medical costs in U.S. In other words, there is at least some degree of substitutability between time input and medical expenditure in health production function. This motivates the Cobb-Douglas functional form we choose for health production. See He and Huang (2011) for a comprehensive survey of empirical evidence.

$$\frac{\partial u / \partial L_t}{\partial u / \partial C_t} = MPN_t - \frac{H_t N_t^{\varpi-1} + MPV_t}{MPM_t} \quad (13)$$

$$\frac{\partial u}{\partial C_t} = \beta MPM_t \left\{ \frac{\partial u}{\partial H_{t+1}} + \frac{\partial u}{\partial C_{t+1}} MPH_{t+1} + \left(1 - \delta_h - \frac{N_{t+1}^{\varpi}}{\varpi}\right) \frac{\partial u / \partial C_{t+1}}{MPM_{t+1}} \right\} \quad (14)$$

Equation 12 represents the inter-temporal Euler equation for physical capital. Equation 13 is the intra-temporal condition which governs the choice between working hours and leisure. It says that the marginal rate of substitution between leisure and consumption is equal to the effective opportunity cost of leisure. This intra-temporal condition suggests that the opportunity cost of enjoying one unit of leisure is actually lower in our model compared to the one in the standard RBC model which has the FOC $\frac{\partial u / \partial L_t}{\partial u / \partial C_t} = MPN_t$. With health in the model, leisure does not only enter into the utility function but also helps improving health stock to enhance labor productivity. This is a gain which is embodied in the term $H_t N_t^{w-1} + MPV_t$. Leisure not only improves health stock directly via health production technology by MPV_t , but also lowering down the depreciation rate by N_t^{w-1} and hence indirectly improves health stock by $H_t N_t^{w-1}$. The gain, however, is offset by the fact that if the agent chooses to enjoy one more unit of leisure, she also loses one unit of labor supply and hence the labor income decreases. This will reduce her medical expenditures by MPM_t which can be used to improve health stock too. The additional term in the right-hand-side of equation 13 $\frac{MPV_t + H_t N_t^{\varpi-1}}{MPM_t}$ thus captures the marginal benefit of increasing leisure to health stock, which should be deducted from the opportunity cost of leisure MPN_t . Finally, equation 14 is the Euler equation regarding the accumulation of health stock. An agent faces a choice between consumption and health expenditures. If she chooses to spend one additional unit on health expenditure, she loses utility by $\frac{\partial u}{\partial C_t}$, but she gains by increasing health stock for tomorrow by the amount of MPM_t . Higher health stock for tomorrow will first bring her higher utility by $\frac{\partial u}{\partial H_{t+1}}$ since health directly enters into the utility function (Grossman 1972 calls it the consumption motive). Second, with better health, the effective labor supply increases and in turn transforms into higher labor income and higher consumption, which brings higher utility. The term $\frac{\partial u}{\partial C_{t+1}} MPH_{t+1}$ thus captures so-called investment motive for health expenditures as in Grossman (1972). Finally, with better health tomorrow, she also has a better starting point of health stock brought to the future. This saves medical expenditure and can hence use for higher consumption in the long run. This continuation effect is captured by the last term $(1 - \delta_h - \frac{N_{t+1}^{\varpi}}{\varpi}) \frac{\partial u / \partial C_{t+1}}{MPM_{t+1}}$.

4 Calibration and Benchmark Results

4.1 Parameterization

In this section, we outline the parameters used in the benchmark model. Except for some parameters that we can find values used in relevant studies, we calibrate the model-specific parameters by matching corresponding moment conditions that represent the long-run average ratio in US economy. The summary of parameters and corresponding moment conditions is shown in Table 1.

The depreciation rate of capital 7.6% come from Cooley and Prescott (1995).¹⁴ A strand of literature

¹⁴More accurately, the depreciation rate of capital 7.6% is an annualized version of the number used in Cooley and Prescott (1995) without population growth and technological change to be consistent with the current model.

in biology that studies natural aging of human body finds that as humans age we develop an increasing number of disorders, which they refer to as “deficits.” Their research shows the average individual accumulates 3-4% more deficits per year in four developed countries including US.¹⁵ We use this measurement as a proxy for the natural depreciation rate of health in our model and set $\delta_h = 4\%$. The parameter of elasticity of substitution between consumption and health is taken from Halliday et al. (2010). With $\eta = 8.85$, the elasticity between consumption and health is 0.11, which shows that health and consumption are strongly complementary. In other words, marginal utility of consumption increases as health status increases, which is confirmed by several empirical studies (Viscusi and Evans 1990; Finkelstein, Luttmer, and Notowidigdo 2010). The return to scale for health production technology $\xi = 1$ is suggested by Grossman (1972). Finally, we pick $\rho = 2$ to set labor elasticity to be 0.5, which is standard in the literature.

For those calibrated parameters, β is used to match long-run US capital-output ratio 3.32 (Cooley and Prescott 1995); λ is pinned down to match non-medical consumption-output ratio 0.648;¹⁶ ϕ is calibrated by matching average working hours ratio 0.318;¹⁷ B is calibrated by matching health expenditure-GDP ratio 10.2% which is the average for the period 1960-2007 (OECD Health Data 2010); and finally θ is pinned down by matching the average health expenditure-total consumption ratio 12.4% for the same period.¹⁸ ϖ is unable to be calibrated due to lacking of empirical data. We take $\varpi = 5$ as our benchmark value. With the working hours ratio being 0.318 in the steady state, this implies health stock depreciates at a rate of 0.065% per year due to this amount of working hours. In Section 6.2, we show that different values does not significantly change our results.

We construct Solow residuals z_t for this economy from annual NIPA data for the period 1960-2007 following the standard approach. We set the autocorrelation coefficient χ to be 0.95 by following Cooley and Prescott (1995). We estimate the standard deviation of innovations σ_ϵ to be 0.0151.

4.2 Benchmark Results

Table 2 presents the standard deviations of the key variables ($\sigma(X)$ is the standard deviation of variable X) and the correlation coefficient of each variable with output ($\rho(X, Y)$ is the correlation of variable X with GDP Y) from the simulation of the benchmark economy in the fourth column. For purpose of comparison, we also report the data counterpart of the measurements in the second column of the table.¹⁹ Cooley and Prescott (1995) show that the real business cycle model is able to explain 66% of business cycle fluctuation from a single TFP shock for time period 1954-1991. Their measurement on key variables is quarterly data. In our benchmark model, the only source of uncertainty is the TFP shock as well. Our measurement on key variables however is annual data. Our benchmark model reports the standard deviation of GDP being 2.06%, which explains about 79% of the standard deviation of real GDP in US data. Meanwhile, we are able to capture the cyclical features of health expenditure which have not been considered and documented in the RBC literature. Medical expenditure exhibits a standard deviation of

¹⁵See Dalgaard and Strulik (2010).

¹⁶Given the depreciation rate of capital and capital-output ratio, investment-output ratio in US economy is about 25% and hence consumption-output ratio is 75%. Since medical expenditure-output ratio is 10.2% for period 1960-2007, non-medical consumption-output ratio is thus 64.8%.

¹⁷OECD statistics show that average annual hours worked per worker in US for period 1960-2007 is 1859 hours. We divide it by 365×16 which we interpret as the total available discretionary hours per year. It ends up with 31.8%. This number is also very close the one used in Cooley and Prescott (1995).

¹⁸We construct total private consumption-GDP ratio from NIPA for time period 1960-2007. We then use the health expenditure-GDP ratio taken from OECD for the same period to obtain health expenditure-total consumption ratio.

¹⁹All the variables here are in terms of per capita. The consumption takes away the medical expenditure. All the data are from NIPA for the period 1960-2007.

2.12% in the data. It is about 81% of that of GDP. The standard deviation of medical expenditures in the model is 1.57%. It captures about 74% of the standard deviation of medical expenditures in the data as well. The model also predicts a very strong positive correlation between medical expenditure and GDP, although the US data only shows a correlation 0.3032 at 5% significant level. Probably most surprisingly, the benchmark model is able to replicate a negative correlation between health stock and GDP as shown in data. The model generates a correlation -0.3320 between health stock and output. It is quite close to the one shown in the data. Therefore, the benchmark model is able to capture two distinguished features of health status and health expenditures over the business cycle, namely counter-cyclicality of health status and pro-cyclicality of health expenditures.

For purpose of comparison, we also calibrate a version of the benchmark model without health (called it RBC model).²⁰ Table 3 reports the results from that model in the third column. Our benchmark model seems doing a good job in replicating the measurements for all key variables compared to this RBC model. Notice that due to structure of GHH preference, in RBC model there is a one-to-one correspondence between working hours N and real wage w . Shutting down income effect thus strengthens the correlation between labor supply N and GDP Y . In the special case of RBC model, we have $\rho(N, Y) = 1$ as implied in the theory.

5 Decomposition Experiments

Why are recessions good for health? Ruhm (2000) makes a conjecture by bringing four mechanisms that macroeconomic conditions might affect health status (or to be more specific mortality rate). First, when economy expands, wage increases and hence the opportunity cost of leisure also increases. Leisure time decreases, making it more costly to undertake health-producing activities that are time-intensive (such as exercise) or schedule medical appointments. We can call it time channel. Second, if health is an input in the production function, then when economy expands, more directly hazardous working

²⁰The social planner's problem in the RBC model is following:

$$\max \sum \beta^t u(C_t, L_t)$$

with period utility function

$$u(C_t, L_t) = \log \left[C_t - \phi \frac{n^{1+\rho}}{1+\rho} \right]$$

subject to

$$C_t + I_t \leq Ae^{z_t} K_t^\alpha N_t^{1-\alpha}$$

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

$$1 = N_t + L_t$$

$$Z_{t+1} = \chi Z_t + \epsilon_{t+1}$$

$$C_t \geq 0, K_0 > 0 \text{ given}$$

We calibrate parameter ϕ and β to match the corresponding moment conditions in Table 1. All other parameters are set to the values in Table 1. We pick parameter A to make sure this economy ends up with the same level of GDP in the model as that number in the benchmark model, which is 0.1610. In other words, we pick A to control the possible level effect of comparing two different economies.

conditions, job-related stress, and the physical exertion of employment might have negative effects on health. We can call it production channel. Third, drinking and driving rise in good times, leading to higher motor vehicle fatality rates. We can call it bad consumption channel. Finally, migration flows are sensitive to changes in local economic conditions. This mobility might have the potential to raise death rates in destination states through increasing crowding and the import of disease from new migrants. We call it migration channel. These four channels all lead to a negative correlation between business cycles and health stock. Due to the structure of our benchmark model, we are not able to address the bad consumption and migration channel. However, with four distinguished features in the benchmark model as mentioned in Section 3, we cover the time channel and production channel as in Ruhm (2000). Therefore, in this paper we are able to address two major channels mentioned in Ruhm (2000). In addition, we also add in two other channels that link health stock with business cycles. Since in the utility function health is complementary to consumption, when economy expands due to a positive productivity shock, consumption increases and hence will also raise health stock through this complementarity. Therefore, this channel (we call it utility channel) tends to make health stock positively co-moves with GDP. Finally, since medical expenditures are used in producing health, health expenditure increases along with economic upturns and consequentially improves health stock. This channel (we call it goods channel) again reinforces the utility channel to make health stock pro-cyclical. Therefore in our benchmark model, two channels make health stock counter-cyclical, and the other two channels make it pro-cyclical. The equilibrium effects of business cycles on health thus are determined by the relative importance of each channel. In this section, in order to quantify relative importance of each channel and help us understand better the mechanisms behind the counter-cyclical of health status as shown in data, we conduct a series of counterfactual experiments to decompose the effect for each channel by shutting down one feature each time.²¹ Every time we shut down one feature, we also recalibrate the model economy to match all the data targets as shown in Table 1 again. We also make sure the model economy not only matches all the ratios, but also reaches the same level of GDP as in the benchmark model. In other words, every model economy stands at the same starting line as the benchmark economy.

5.1 No Time Channel (Model 1)

First, we shut down the time channel from the benchmark model. Health still enters into preference and production function. However, only goods input (medical expenditures) is used to produce health. The model changes to

$$\max \sum \beta^t u(C_t, L_t, H_t)$$

with period utility function

$$u(C_t, L_t, H_t) = \log \left[(\lambda C_t^{1-\eta} + (1-\lambda)H_t^{1-\eta})^{\frac{1}{1-\eta}} - \phi \frac{n^{1+\rho}}{1+\rho} \right]$$

subject to

$$C_t + M_t + I_t \leq A e^{z_t} K_t^\alpha (N_t H_t)^{1-\alpha}$$

²¹In order to evaluate the goods channel, we have to shut down medical expenditure in producing health in equation 4. But this will lead to zero health expenditure and hence cannot evaluate any business cycle feature of this key variable. Therefore, we cannot isolate the goods channel from others.

$$\begin{aligned}
I_t &= K_{t+1} - (1 - \delta_k)K_t \\
H_{t+1} &= (1 - \delta_h - \frac{N_t^\varpi}{\varpi})H_t + BM_t^\xi \\
1 &= N_t + L_t \\
Z_{t+1} &= \chi Z_t + \epsilon_{t+1} \\
C_t &\geq 0, K_0, H_0 > 0 \text{ given}
\end{aligned}$$

We recalibrate the economy and pick A to control the level effect.²² The results are reported in the fifth column in Table 2. By shutting down the time channel, compared to the benchmark case, we see the correlation between health stock and GDP changes from -0.3320 in the benchmark case to -0.2093 in model 1. This tells us the magnitude of the time effect in generating cyclical of health stock is about -0.12. Time channel does generate a significant amount of counter-cyclical of health stock as predicted by Ruhm (2000). Except for the effect on cyclical of health stock, the impact of time channel on the business cycle features of other key variables are quite small compared to the benchmark model.

5.2 No Production Channel (Model 2)

Next, we want to investigate the effect of production channel on the cyclical of health stock. We shut down the production channel (model feature 2 and 4) from the benchmark economy. Our model thus changes to

$$\max \sum \beta^t u(C_t, L_t, H_t)$$

with period utility function

$$u(C_t, L_t, H_t) = \log \left[(\lambda C_t^{1-\eta} + (1-\lambda)H_t^{1-\eta})^{\frac{1}{1-\eta}} - \phi \frac{n^{1+\rho}}{1+\rho} \right]$$

subject to

$$\begin{aligned}
C_t + M_t + I_t &\leq Ae^{z_t} K_t^\alpha (N_t)^{1-\alpha} \\
I_t &= K_{t+1} - (1 - \delta_k)K_t \\
H_{t+1} &= (1 - \delta_h)H_t + B(M_t^\theta L_t^{1-\theta})^\xi \\
1 &= N_t + L_t \\
Z_{t+1} &= \chi Z_t + \epsilon_{t+1} \\
C_t &\geq 0, K_0, H_0 > 0 \text{ given}
\end{aligned}$$

²²The calibration ends up with $\beta = 0.9574$, $\lambda = 0.5300$, $\phi = 3.1266$, $B = 0.0363$, and $\xi = 0.3376$. $A = 1.023$ is set to make sure Y in this economy is equal to 0.1610, same value as in the benchmark economy.

We recalibrate this model and pick A to control the level effect.²³ The results are reported in the sixth column of Table 2. Compared to the results of benchmark model, we see the correlation between health stock and GDP changes from -0.3320 in the benchmark to -0.0435 in model 2. The only difference between the benchmark model and model 2 is we shut down the production channel in the latter. Therefore, this exercise shows that the production channel indeed generates significant counter-cyclicality of health stock. The difference in $\rho(H, Y)$ is -0.29 between the two cases. This measures the magnitude of counter-cyclicality provided by the production channel.

Shutting down production channel also has significant impact on business cycle properties of medical expenditure. The standard deviation of medical expenditure dramatically increases from 1.5674 in the benchmark model to 4.4358 in model 2. This is because the substitution between labor supply N and health stock H in production function provides stabilization to the economy. When the economy expands due to a positive productivity shock, labor supply increases. But since N and H are bundled in production function in a way that two are quite substitutable to each other, when N increases, H tends to decrease. This is the main mechanism why the production channel provides counter-cyclicality of health stock. In addition, increasing working hours also further increases the depreciation rate of health and hence decreases the health stock even more. Since medical expenditure is always strongly pro-cyclical, as an important determinant of health, one would expect that health stock is also pro-cyclical. The production channel provides an counter force and hence stabilizes the health stock. That is the reason why the benchmark model sees a very low volatility of health stock. Once we remove the production channel from the benchmark case, we lose the stability brought by the production channel. Volatility of health stock increases from 0.0438 to 0.2939. Increasing volatility of health stock thus makes the investment in H , which is medical expenditure, more volatile.

5.3 No Health in Utility (Model 3)

In this section, we want to detect the role of consumption value of health (i.e., health in utility function) in generating business cycle properties of health stock and health expenditure. We do so by setting $\lambda = 1$ in the benchmark model so that health disappear from the utility function.

We recalibrate this model again and pick A to control the level effect.²⁴ The results are reported in the seventh column of Table 2. Compared to the results of benchmark model, we see the correlation between health stock and GDP changes from -0.3320 in the benchmark to -0.3283 in model 2. The only difference between the benchmark model and model 2 is that the utility channel is completely shut down in model 3. The difference of cyclicality of health is about -0.0037, which measures the magnitude of utility channel in driving counter-cyclicality of health stock. Although qualitatively utility channel seems to be quite important in offsetting the counter-cyclicality of health stock, quantitatively its impact is very small and it goes into an opposite direction. In fact, all the properties of key variables in model 3 are very similar to those in the benchmark model. That said, the utility channel, or the consumption value of health as termed in Grossman (1972) is not quantitatively important in driving business cycle properties of both health stock and health expenditure.

The reason why the utility channel is quantitatively unimportant is because there are two forces in the utility function that affect cyclicality of health. The first is the one mentioned above. In our model,

²³The calibration ends up with $\beta = 0.9574$, $\lambda = 0.4748$, $\phi = 1.8288$, $B = 0.0465$, and $\theta = 0.5309$. $A = 0.412$ is set to make sure Y in this economy is equal to 0.1610, same value as in the benchmark economy.

²⁴Since we do not need calibrate λ , we only calibrate four parameters to match four ratios which are capital-output ratio $\frac{K}{Y}$, medical expenditure-output ratio $\frac{M}{Y}$, non-medical consumption-output ratio $\frac{C}{Y}$, and average working hours ratio N . The calibration ends up with $\beta = 0.9574$, $\phi = 2.4525$, $B = 0.0602$, and $\theta = 0.3520$. We also pick $A = 0.9$ to match the level of Y in the benchmark economy.

health is highly complimentary to consumption. Since consumption is highly pro-cyclical, this channel will generate the pro-cyclicality of health. However, leisure is also in the utility function. And leisure is highly counter-cyclical. Therefore leisure in the utility will drive the counter-cyclicality of health. These two forces offset each other in the current model.²⁵

5.4 No Time and Production Channel (Model 4)

The exercises we did in the three cases above, although help us to understand the role that each channel plays in affecting the cyclicity of health stock, it is still unclear for isolating the effect of each individual channel. For example, Model 1 shuts down the time channel. However, the production and utility channel still exist. Therefore the results we obtain in that exercise still cannot get rid of interaction of the time channel with the other two channels. To identify the *pure* effect of each channel (i.e., the effect without interaction with other channels), we have to do further decomposition.²⁶

In this section, we shut down both time and production channel. In other words, health only enters into utility function. The social planner problem thus changes to

$$\max \sum \beta^t u(C_t, L_t, H_t)$$

with period utility function

$$u(C_t, L_t, H_t) = \log \left[(\lambda C_t^{1-\eta} + (1-\lambda)H_t^{1-\eta})^{\frac{1}{1-\eta}} - \phi \frac{n^{1+\rho}}{1+\rho} \right]$$

subject to

$$C_t + M_t + I_t \leq A e^{z_t} K_t^\alpha (N_t)^{1-\alpha}$$

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

$$H_{t+1} = (1 - \delta_h)H_t + B M_t^\xi$$

$$1 = N_t + L_t$$

$$Z_{t+1} = \chi Z_t + \epsilon_{t+1}$$

$$C_t \geq 0, K_0, H_0 > 0 \text{ given}$$

Depending on what is the benchmark for the comparison, this model can work as different ways to identify the pure effect of different channels. First, compared to our benchmark model in Section 3, this model can help to identify the joint effect of both time and production channel (with the interaction from the utility channel). Second, compared to model in Section 5.1 (no time channel), this exercise can tell us what is the magnitude of counter-cyclicality of health the production channel can generate without the interaction from the time channel. Third, compared to the model in Section 5.2 (no production channel), shutting down both time and production channel can identify the net effect of time channel

²⁵In Section 5.5, when we further shut down the time channel from the current model and hence dampen the effect from leisure in the utility function, we did observe that health turns to pro-cyclical, although it is still quantitatively insignificant.

²⁶Of course we can only shut down at most two channels together. Because if we shut down the time, production and utility channel, we go back to the RBC model without health. Also, we cannot shut down both utility and production channel simultaneously because in that case one does not need to invest in health. Medical expenditures will go zero.

without the interaction from the production channel. Finally, compared to RBC model without health, this model can show us the net effect of the utility channel without any interaction from both time and production channel.

We recalibrate this model and pick A to control the level effect and make sure this model economy is identical to the benchmark economy in terms of not only key macro ratios but also level of GDP.²⁷ The results are reported in the eighth column of Table 2. Compared to the benchmark model, we see $\rho(H, Y)$ changes from -0.3320 in the benchmark to -0.0405 in model 4. This shows that the joint presence of time and production channel generates -0.29 of counter-cyclicity of health. The joint presence of both channels is important in replicating the counter-cyclicity of health stock. Compared to the model only without time channel (Model 1), $\rho(H, Y)$ changes from -0.2093 in Model 1 to -0.0405 in Model 4. That implies the magnitude of counter-cyclicity of health generated by the production channel without any interaction from the time channel is -0.17. Compared to -0.29 generated by the model only without production channel (Model 2), this exercise shows the interaction with the time channel generates additional -0.12 of counter-cyclicity of health stock. The counter-cyclicity of health is -0.0435 in Model 2, while it is -0.0405 in the current model. The only difference between these two models is the time channel which is further shut down in Model 4. Therefore, comparing these two models, we can conclude the pure effect of the time channel (without interaction with the production channel) on generating counter-cyclicity of health is just -0.003. In other words, almost the entire counter-cyclicity of health generated by the time channel comes from the interaction with the production channel. On the other hand, without interaction with the time channel, pure production channel only generates -0.17 of counter-cyclicity. The interaction between the time and production channel thus is crucial in bringing enough counter-cyclicity as observed in the data. Finally, compared to RBC model without health, the model here shows the effect of pure consumption value of health (without interaction from both time and production channel) on counter-cyclicity of health is -0.04.

5.5 No Time and Utility Channel (Model 5)

Finally, in this section, we shut down both time and utility channel from the benchmark model. Only the production channel remains. The model changes to

$$\max \sum \beta^t u(C_t, L_t)$$

with period utility function

$$u(C_t, L_t) = \log \left[C_t - \phi \frac{L_t^{1+\rho}}{1+\rho} \right]$$

subject to

$$C_t + M_t + I_t \leq A e^{z_t} K_t^\alpha (N_t)^{1-\alpha}$$

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

$$H_{t+1} = \left(1 - \delta_h - \frac{N_t^\varpi}{\varpi}\right) H_t + B M_t^\xi$$

$$1 = N_t + L_t$$

$$Z_{t+1} = \chi Z_t + \epsilon_{t+1}$$

²⁷The calibration ends up with $\beta = 0.9574$, $\lambda = 0.4809$, $\phi = 1.9444$, $B = 0.0407$, $\xi = 0.5284$ and $A = 0.411$.

$$C_t \geq 0, K_0, H_0 > 0 \text{ given}$$

Again depending on what is the benchmark for the comparison, this model can work as different ways to identify the pure effect of different channels. First, compared to our benchmark model in Section 3, this model can help us to identify the joint effect of both time and utility channel (with the interaction from the production channel). Second, compared to model in Section 5.1 (no time channel), this exercise can tell us what is the magnitude of counter-cyclicality of health the utility channel can generate without the interaction from the time channel. Third, compared to the model in Section 5.3 (no utility channel), shutting down both time and utility channel can identify the net effect of time channel without the interaction from the utility channel. Finally, compared to RBC model without health, this model can show us the net effect of the production channel without any interaction from both time and production channel, in other words, the net effect on the counter-cyclicality of so-called investment value of health.

We recalibrate the economy and pick A to control the level effect.²⁸ The results are reported in the last column in Table 2. Shutting down the time and utility channel significantly reduces the counter-cyclicality of health stock. It decreases from -0.3320 in the benchmark case to -0.2119. However, the prediction of this model looks quite similar to that of the model only without the time channel (Model 1). The only difference between Model 1 and Model 5 is the utility channel is shut down in the latter. $\rho(H, Y)$ changes from -0.2093 to -0.2119. In other words, the utility channel alone (without the interaction with the time channel via leisure) generates 0.0026 of pro-cyclicality of health stock. Utility channel is still quantitatively unimportant. However, the sign is consistent with the theoretical prediction since the only force in the utility channel now is the complementarity between consumption and health. Given the pro-cyclicality of consumption, we expect to see pro-cyclicality of health. It is the interaction with the time channel (via leisure) that makes the utility channel turns to generate counter-cyclicality of health stock. Compared to Model 3 (no utility channel), the current model decreases the counter-cyclicality of health stock from -0.3283 in Model 3 to -0.2119. This implies the magnitude of counter-cyclicality of health generated by the time channel alone (without the interaction with the utility channel) is also -0.12. It is about the same number as in Section 5.1. This again confirms that the utility channel is quantitatively negligible in interacting with other channels to drive the cyclicality of health. Finally, compared to RBC model without health, the current model shows the production channel alone (without any interaction from both time and utility channel) can generate significant counter-cyclicality of health stock, which is -0.2119. Using the term from Grossman (1972), the effect of pure investment value of health on counter-cyclicality of health is much bigger than that of pure consumption value. Recessions are good for health is because health works as an investment good.

5.6 Summary and Intuition

By doing decomposition exercises as mentioned above, we can isolate the impact of each channel and evaluate relative importance of each mechanism in generating cyclicality of health stock and health expenditure. In terms of its impact on the absolute magnitude of cyclicality of health stock, we find that the production channel affects the counter-cyclicality of health stock the most, and then is the time channel. The utility channel is quantitatively insignificant. So the ranking is production channel > time channel > utility channel. In terms of the sign of cyclicality of health stock, time channel and production channel contribute to counter-cyclicality, while the pure utility channel (i.e., complementarity between health and consumption) generates pro-cyclicality of health stock. We also find that the counter-cyclicality of health stock generated by the time channel is almost entirely driven by the interaction

²⁸The calibration ends up with $\beta = 0.9574$, $\phi = 2.8787$, $B = 0.0542$, and $\xi = 0.3520$. We also pick $A = 0.8254$ to match the level of Y in the benchmark economy.

between the time and production channel. We identify that the interaction is able to generate -0.12 of counter-cyclicity of health. The time channel alone (without the interaction with production channel) only generates -0.003 of counter-cyclicity of health. With the interaction, this number changes to -0.12. On the other hand, the production channel alone (without interaction with time channel) generates around -0.17 of counter-cyclicity of health stock. With the interaction, this number changes to -0.29. Therefore, the joint presence and the interaction between the time and production channel is crucial in replicating the counter-cyclicity of health stock as observed in the data.

Why is the joint presence of time and production channel so important in driving counter-cyclicity of health stock? Let's go back to the key first order equations that govern an individual's optimal choices in this economy, which are equation 12-14. The role that the production channel plays reflects in three terms. The first is the term $\frac{\partial U}{\partial C_{t+1}} MPH_{t+1}$ in the Euler equation 14 of health accumulation because health enters into the production function. The second is the term $(1 - \delta_h - \frac{N_{t+1}^\varpi}{\varpi}) \frac{\partial U / \partial C_{t+1}}{MPM_{t+1}}$ in the same equation. And the third is in the term $H_t N_t^{\varpi-1}$ in the intratemporal condition equation 13. In contrast, the time channel only reflects in the term MPV_t in equation 13. Since it only enters in the intratemporal condition, it is not surprising that the pure effect of time channel without the interaction with the production channel is quite small. However, the work-leisure choice not only affects the intratemporal condition in equation 13, but also the intertemporal condition in equation 14. When a negative TFP shock hits the economy, marginal product of labor MPN decreases, individuals optimally choose to work less since the opportunity cost of enjoying leisure goes down in recession. Keeping other things equal, higher leisure first helps to improve health stock of next period as seen in equation 4 via both time and stress channel (the term $H_t N_t^{\varpi-1}$). And with more leisure time and less stress from working, it also contributes to better health the day after tomorrow, and so on (see equation 14). The work-leisure choice thus is the key to link the time channel and production channel dynamically. That's the reason why it is only with the interaction from the production channel that the time channel can generate a significant counter-cyclicity of health stock. On the other hand, since the production channel affects both intratemporal and intertemporal equations, it is not surprising that it is more significant than the time channel is generating counter-cyclicity of health.

Speaking about the pro-cyclicity of health expenditure, we find that all models predict very similar numbers. This implies that the time, production and utility channel are not important in driving the pro-cyclicity of health expenditure. Since health expenditure works as a normal good, similar to consumption in our model, it is the goods channel that drives this pro-cyclicity.

5.7 Empirical Evidence from American Time Use Survey

American Time Use Survey (ATUS) is a repeated cross-section survey of individuals in U.S. households conducted by Bureau of Labor Statistics (BLS) every year since 2003. The ATUS sample is drawn from the Current Population Survey (CPS). Time use data is collected via a telephone interview. During the interview, interviewers ask respondents to characterize their activities in minutes during a 24-hour period called the "diary" day. ATUS represents the state of the art of time use surveys for the US and reports over 400 detailed time use categories. Fortunately we now have data from 2003 to 2010, which covers the period of Great Recession. It thus provides an ideal dataset for documenting time allocation decisions over probably the largest business cycle after WWII.

Several papers already study the time allocation over business cycles by using ATUS. Among them, Edwards (2011) shows that all consumers report less sleeplessness when unemployment is high, more time spent caring for the elderly, and more time talking on the telephone. Sleeping, socializing, and traveling also rise on average, but the channel through which aggregate unemployment exerts these

effects appears to be individual-level job loss. Aguiar, Hurst, and Karabarbounis (2011) find that roughly 30% of the foregone market work hours due to the recession are allocated to increased home production. Additionally, around 50% of the foregone hours are allocated to increased leisure (including increased sleep time, exercise, and increased television watching). About 5% of foregone market work hours are allocated to increased time in own medical care. Coleman and Dave (2011) use within-state variation in employment and unemployment in ATUS and also find that recreational exercise tends to increase as employment decreases. In addition, individuals substitute into television watching, sleeping, childcare, and housework when the market hours decrease. All these works seem to reach the consensus that individuals tend to increase health-enhanced leisure activities during recessions, which provide a direct microevidence to the time channel discussed above.²⁹

5.8 Empirical Evidence from Census of Fatal Occupational Injuries

The Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI) produces comprehensive counts of fatal work injuries. CFOI is a Federal-State cooperative program that has been implemented in all 50 States and DC since 1992. To compile counts that are as complete as possible, the census uses multiple sources to identify, verify, and profile fatal worker injuries. To ensure that fatal injuries are work-related, cases are substantiated with two or more independent source documents such as death certificates, workers' compensation reports, and Federal and State agency administrative reports, or a source document and a follow-up questionnaire.

We take annual data of number of fatal work injuries for the period 1992-2010 from CFOI.³⁰ We divide them by the population for the same period to obtain number of fatal work-related injuries per capita. We also take annual real GDP per capita data for the same period from NIPA. We then take log on both variables and run H-P filter as in Section 2. Our results show that fatal work injuries are strongly pro-cyclical. The correlation is 0.74 at 1% significance level. Panel a in Figure 2 reports the detrended fatal work injuries and GDP per capita. To investigate the strength of the production channel, we also run H-P filter for the log of working hours per capita for the same period. The results show that the correlation between fatal work injuries and working hours per capita is 0.72 at 1% significance level. We report the detrended fatal work injuries and working hours per capita in panel b in Figure 2. The CFOI data provides a strong support to the production channel which claims that when economy is in boom, workers work more hours and hence increase the exposure to work-related injuries and accidents.

6 Sensitivity analysis

In this section, we conduct a sensitivity analysis to investigate how our results are affected quantitatively by changing the utility function to a common CRRA preference. We also show how the results are sensitive to three key parameters: ϖ that determines the magnitude of stress channel which affects depreciation rate of health, δ_h that pins down the natural depreciation rate of health, and η which governs the elasticity of substitution between health and consumption in the preference. All these three

²⁹Dehejia and Lleras-Muney (2004) study the relationship between the unemployment rate at the time of a baby's conception and health outcome at the birth. They find that babies conceived in times of high unemployment rate have a reduced incidence of low and very low birth weight, fewer congenital malformations, and lower postneonatal mortality, in other words, a better health outcome. Their results suggest that the opportunity cost of women's time may be an important determinant of health behavior during pregnancy, and consequently suggest a possible mechanism for improving child health outcomes.

³⁰Data are downloaded from <http://www.bls.gov/iif/oshwc/cfoi/cfch0009.pdf>.

parameters are not calibrated. And they are not well backed up by empirical evidence (except for η). That's the reason we would like to test the robustness of our results to these parameters. For each sensitivity analysis, we recalibrate the economy and pick the scale factor A to match not only the ratios but also absolute value of GDP in the benchmark economy in Section 4.

6.1 CRRA Preference

We choose GHH preference in the benchmark model for strengthening the time channel and also following GHH as a whole package. Will our results change if we use a normal CRRA preference in the literature? For this analysis, we take the following period utility function and keep all other features of the model unchanged.

$$u(C_t, L_t, H_t) = \frac{\log[\lambda C_t^{1-\eta} + (1-\lambda)H_t^{1-\eta}]}{1-\eta} - \phi \frac{n^{1+\rho}}{1+\rho} \quad (15)$$

In order to be consistent with the benchmark model, we also choose ρ to be 2 so that the labor elasticity is 0.5. All the parameters in Table 1 are unchanged. We recalibrate the economy again to match moment conditions in Table 1 and redo all the decomposition exercises in Section 5. We pick the scale factor A to match the level of the GDP in the benchmark model in Section 4 for all the cases. The results are reported in Table 3.

We find that over all the results are quite close to those in the GHH preference. However, compared to GHH preference, CRRA has both substitution effect and income effect on leisure, and hence both pro-cyclicality and volatility of labor supply is much lower in CRRA case. Compared benchmark case in Table 3 to Model 1 (no time channel) in the same table, we see the magnitude of counter-cyclicality of health generated by the time channel (with interaction from both production and utility channel) is -0.10. Compared the benchmark model to Model 2 (no production channel), we find that the production channel (with interaction from both time and utility channel) generates the counter-cyclicality of -0.204. Compared benchmark model to Model 3 (no health in utility function), the utility channel (with interaction from both time and production channel) generates a negligible counter-cyclicality of health of -0.0001 (recall in the GHH case, this number is -0.0037. This is because the CRRA preference keeps the income effect of leisure which weakens the effect of the time channel. So the interaction from the time channel does not generate enough counter force to offset the effect from the complementarity channel between consumption and health, which brings pro-cyclicality of health. Compared Model 1 to Model 4 (no time and production channel), we can tell the production channel (without interaction from the time channel) generates counter-cyclicality of health of -0.13. Compared Model 2 to Model 4, we find that the time channel (without interaction from the production channel) generates the counter-cyclicality of -0.027. Both comparison indicates that the interaction between the time and production channel generates counter-cyclicality of health of around -0.07. Compared to Model 3 and Model 5 (no utility and time channel), we confirm that the magnitude of counter-cyclicality of health generated by the time channel (without the interaction from the utility channel but with the one from production channel) is -0.10. This again shows the interaction with the utility channel is almost negligible. Finally, compared Model 4 to Model 5, we confirm that the counter-cyclicality of health is mainly driven by the investment value rather than consumption value of health.

6.2 Stress Parameter ϖ

Next, we try different values of ϖ to see how variable depreciation rate on health affects the counter-cyclicality of health in the benchmark model. Table 4 shows the benchmark model results and the decomposition exercises with different values of ϖ . In Table 4, with $\varpi = 2$ and length of working hours in the steady state is 0.318, the variable depreciation rate on health is up to 5.06%. With $\varpi=3$, this number decreases to 1.07%. The number for $\varpi = 4, 5, \text{ and } 6$ is 0.26%, 0.065% and 0.017%, respectively. We find that with a higher variable depreciation rate due to endogenous utilization of health, health stock becomes more counter-cyclical in all cases (except the case with $\varpi = 2$) since it strengthens the effect of production channel as ϖ increases and the production channel is the dominating mechanism to generate this counter-cyclicality.

6.3 Natural Depreciation Rate of Health δ_h

The fourth experiment is to see how natural depreciation rate affects cyclical features. Dalgaard and Strulik (2010) claim that the natural depreciation rate on health is in between 3% and 4% per year. Scholz and Seshadri (2010) calibrate the natural depreciation rate to be around 5.6%. Based on these findings, we run the sensitivity analysis on δ_h for four different values: 0.03, 0.05, 0.04 (which is the value we use in the benchmark case in Section 4) and 0.06. Table 5 shows the benchmark model simulations under different value of δ_h . We find that the natural depreciation rate on health does not significantly change our quantitative results.

6.4 Elasticity of Substitution between Consumption and Health

To test the sensitivity of our results to this elasticity of substitution parameter η , we take an extreme case to let η be equal to 1. In other words, we shut down the complementarity between consumption and health in the preference completely. The results for the benchmark model are shown in the second column of Table 8. $\rho(H, Y)$ changes from -0.3320 in the benchmark model to -0.5411. It does not affect significantly the other dimension of business cycle properties of key variables compared to the benchmark model.

In summary, our quantitative results are not significantly affected by these three parameters we choose rather than calibrate.

7 Conclusion

Are recessions good for your health? The answer is yes. We document that health status is counter-cyclical while the health expenditures are pro-cyclical in US. The striking results of counter-cyclicality of health status found by Ruhm (2000) thus is confirmed on a macroeconomic level.

Why are recessions good for your health? In order to answer this question, we develop a stochastic dynamic general equilibrium model with endogenous health accumulation. The model has four distinguished features: 1). Health enters into utility function; 2) Health enters into production function; 3). Both goods and time input are used to produce health stock; 4). Depreciation rate of health stock negatively depends on working hours. With these features, the model is able to address two major channels that might affect cyclicity of health as conjectured in Ruhm (2000). We find that with only the TFP shock estimated from the data, the benchmark model can replicate the counter-cyclicality of health status and pro-cyclicality of health expenditures quite well. Based on this success, we run several

decomposition exercises to investigate the relative importance of each model feature in affecting the business cycle properties of health accumulation. We find that the joint presence of both time channel (feature 3) and production channel (feature 2 and 4) is crucial in driving the counter-cyclicity of health stock as observed in the data. While the utility channel (feature 1) is quantitatively and considerably insignificant in affecting this counter-cyclicity. The dynamic interaction between the time and the production channel is a key mechanism to make your health better in recessions. In summary, the reason why recessions are good for your health is because during recessions, you work less. Less working hours implies you have more leisure time that can be used to enhance your health. Less working hours also means the degree of utilization of your health decreases. You are less stressful and less exposed to work-related accidents and injuries.

8 Appendix: Extension of Including Bad Consumption

Ruhm (2000) conjectures that income growth due to economic expansion might increase the propensity of taking risky activities such as smoking, drinking and dangerous entertaining exercise, which affects health negatively. However, apparently not all consumption behavior will hurt health. In this appendix, we take Ruhm's conjecture seriously and try to include this channel into the benchmark model in Section 3. In order to model this channel, we have to distinguish two types of consumption: good vs. bad consumption. Good consumption (such as eating nutritional food) provides utility and it does not harm health status. In fact, health is complimentary to good consumption. Bad consumption (such as smoking and drinking) although provides utility, but negatively affects health stock as well. Put in this way, smoking and drinking accelerate the depreciation of the health stock. We thus have a following model which extends the benchmark model to address the difference between good and bad consumption. The model changes to

$$\max \sum_{t=0}^{\infty} \beta^t u(C_{gt}, C_{bt}, L_t, H_t)$$

with the period utility function

$$u(C_{gt}, C_{bt}, L_t, H_t) = \log \left[(\lambda C_{g,t} + (1 - \lambda) H_t^{1-\eta})^{\frac{1}{1-\eta}} + \nu C_{b,t} - \phi \frac{n^{1+\rho}}{1+\rho} \right] \quad (16)$$

The agent maximizes her utility subject to the following constraints

$$C_{g,t} + C_{b,t} + M_t + I_t \leq A e^{z_t} K_t^\alpha (N_t H_t)^{1-\alpha} \quad (17)$$

$$I_t = K_{t+1} - (1 - \delta_k) K_t \quad (18)$$

$$H_{t+1} = (1 - \delta_h - \frac{N_t^\varpi}{\varpi} - \frac{C_{b,t}^\kappa}{\kappa}) H_t + B (M_t^\theta L_t^{1-\theta})^\xi \quad (19)$$

$$1 = N_t + L_t \quad (20)$$

$$Z_{t+1} = \chi Z_t + \epsilon_{t+1} \quad (21)$$

$$C_{gt}, C_{bt} \geq 0, K_0, H_0 > 0 \text{ given}$$

where C_g stands for good consumption and C_b represents bad consumption. v represents the weight of bad consumption in the preference. $\kappa > 1$ denotes the elasticity of depreciation rate of health with respect to the amount of bad consumption.

Using the definitions in equation 7-11, we can have the following first order conditions for this economy:

$$\frac{\partial u}{\partial C_{g,t}} = \beta \frac{\partial u}{\partial C_{g,t+1}} (MPK_{t+1} + 1 - \delta_k) \quad (22)$$

$$\frac{\partial u / \partial L_t}{\partial u / \partial C_{g,t}} = MPN_t - \frac{H_t N_t^{\varpi-1} + MPV_t}{MPM_t} \quad (23)$$

$$\frac{\partial u}{\partial C_{g,t}} = \beta MPM_t \left\{ \frac{\partial u}{\partial H_{t+1}} + \frac{\partial u}{\partial C_{g,t+1}} MPH_{t+1} + (1 - \delta_h - \frac{N_{t+1}^{\varpi}}{\varpi} - \frac{C_{b,t+1}^{\kappa}}{\kappa}) \frac{\partial u / \partial C_{g,t+1}}{MPM_{t+1}} \right\} \quad (24)$$

$$\frac{\partial u / \partial C_{b,t}}{\partial u / \partial C_{g,t}} = 1 + \frac{H_t C_{b,t}^{\kappa-1}}{MPM_t} \quad (25)$$

Equation 25 is a new FOC by including bad consumption into the benchmark model. It governs the choice between bad and good consumption. If an individual chooses to give up one unit of bad consumption but rather consume one unit of good consumption, besides the one-to-one correspondence embodied in the budget constraint equation 17 (that's why we have 1 in the right hand side), she will have some additional gain in health. Since she consume less bad consumption, her health will improve by the amount $H_t C_{b,t}^{\kappa-1}$. This improvement will save her the amount of medical expenditure $\frac{H_t C_{b,t}^{\kappa-1}}{MPM_t}$, which again can be used for good consumption.

This model adds two new parameters that need to be calibrated: v and κ . Since discount rate β is very stable in all the cases, we fix $\beta = 0.9574$. We then need to calibrate six parameters. In addition to the five moment conditions used to calibrate five parameters in the benchmark case as shown in Table 1, we pin down κ to match the average share of alcohol and tobacco consumption in total nondurable goods consumption in the NIPA data for the period 1995-2007, which is 9.1%. Now we have six parameters to match six moment conditions.³¹ We also pick scale factor A to match the absolute level of GDP 0.1610 as in the benchmark model. We report the results in Table 8 in the column titled "Bad consumption 1." For the purpose of comparison, we also list the results for the benchmark model in the same table.

By adding in the bad consumption channel into the benchmark framework, the counter-cyclicality of health stock increases from -0.3320 in the benchmark case to -0.3691. That said, bad consumption channel indeed generates counter-cyclicality of health stock in the model as Ruhm conjectured, although it is not quantitatively significant. Notice that bad consumption acts quite different from good consumption. Good consumption is surprisingly much alike health stock, both in terms of correlation with GDP and

³¹The calibration ends up with $\lambda = 0.0022$, $v = 1.3028$, $\phi = 2.6033$, $B = 0.0299$, $\theta = 0.2155$, and $\kappa = 4.2038$. With the steady state level of bad consumption, this implies the health stock depreciates at a rate of 0.000000075% per year due to bad consumption that harms health.

the volatility. On the other hand, bad consumption is extremely volatile and pro-cyclical as predicted by Ruhm (2000).

However, the quantitative results of bad consumption model might depend on the way we model bad consumption in the preference. In a following exercise, we change the preference to

$$u(C_{gt}, C_{bt}, L_t, H_t) = \log \left[(\lambda C_{g,t} + (1 - \lambda) H_t^{1-\eta})^{\frac{1}{1-\eta}} - \phi \frac{n^{1+\rho}}{1+\rho} \right] + \nu \log C_{b,t} \quad (26)$$

In other words, bad consumption does not bundle with good consumption, health and leisure in the form of GHH, and it is rather separable from other elements. We again recalibrate this economy and pick A to control level effect. The results are reported in the column titled “Bad consumption 2” in Table 8. In this model, bad consumption is much alike good consumption. The results are similar to those in the original benchmark model. However, in contrast to the first specification, now counter-cyclicality of health decreases from -0.3320 in the benchmark case to -0.3168. Including bad consumption channel surprisingly brings pro-cyclicality, although again it is not quantitatively significant.³²

³²In order to check the robustness of our results, we also run an experiment to include bad consumption into the benchmark model CRRA preference as in Section 6.1. Our preference changes to

$$u(C_{gt}, C_{bt}, L_t, H_t) = \frac{\log[\lambda C_t^{1-\eta} + (1 - \lambda) H_t^{1-\eta}]}{1 - \eta} + \nu \log C_{b,t} - \phi \frac{n^{1+\rho}}{1 + \rho} \quad (27)$$

We recalibrate the economy and control the level effect. We find that the results are quantitatively similar to the case of “Bad consumption 2.” Compared to the benchmark case with that preference (i.e., column “Benchmark” in Table 3), counter-cyclicality of health decreases from -0.3177 in the benchmark case to -0.3246. It shows again that the bad consumption channel brings counter-cyclicality of health stock, but not quantitatively significant.

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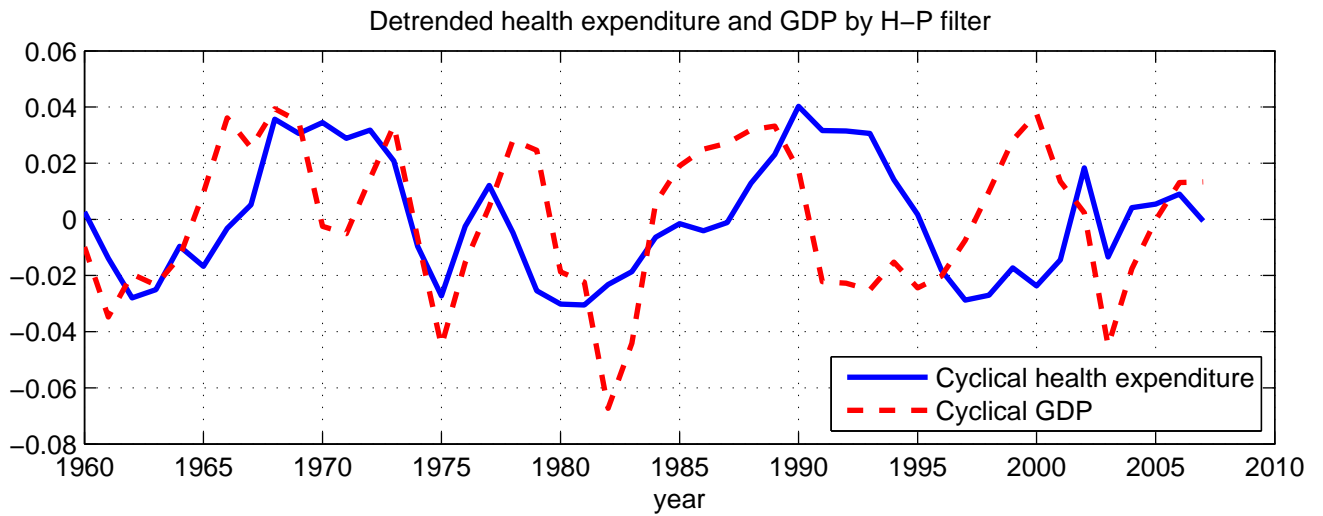
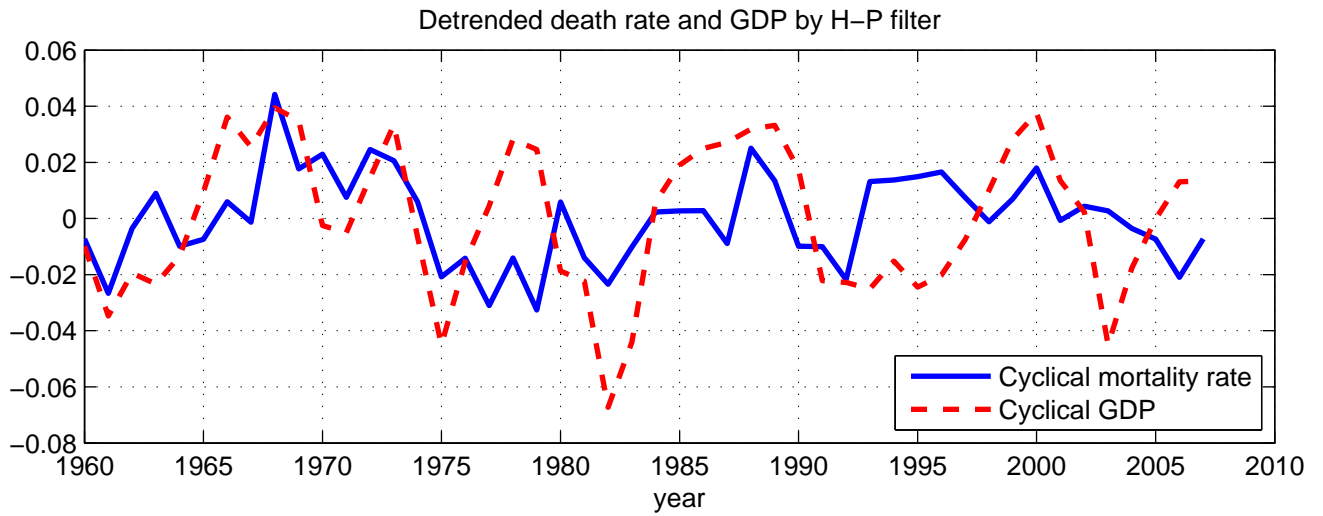


Figure 1: Cyclicity of health status and health expenditure: 1960-2007

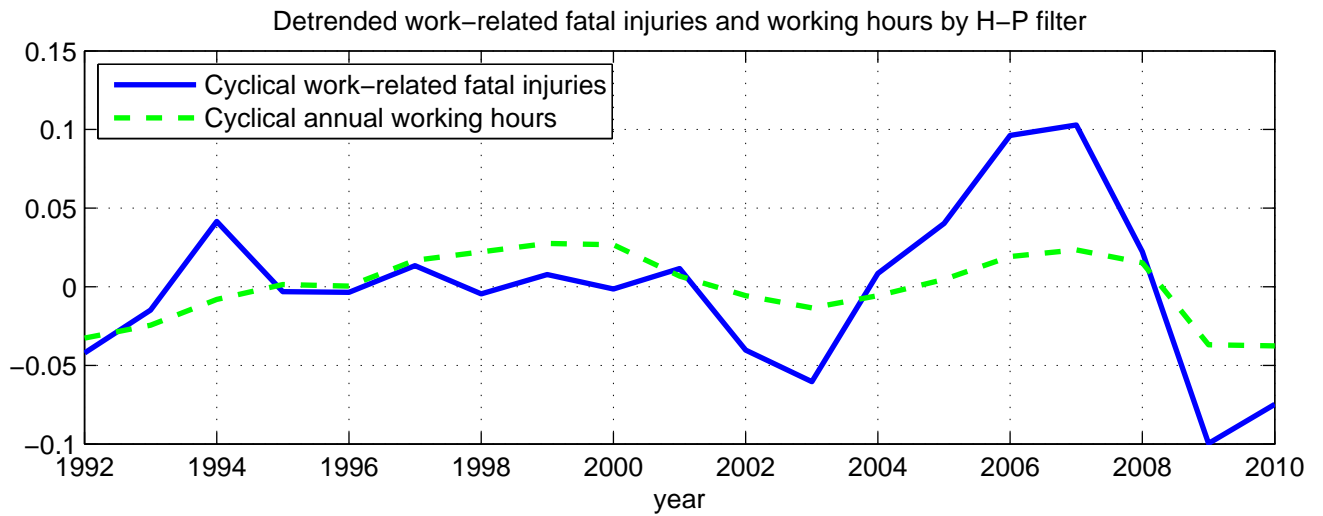
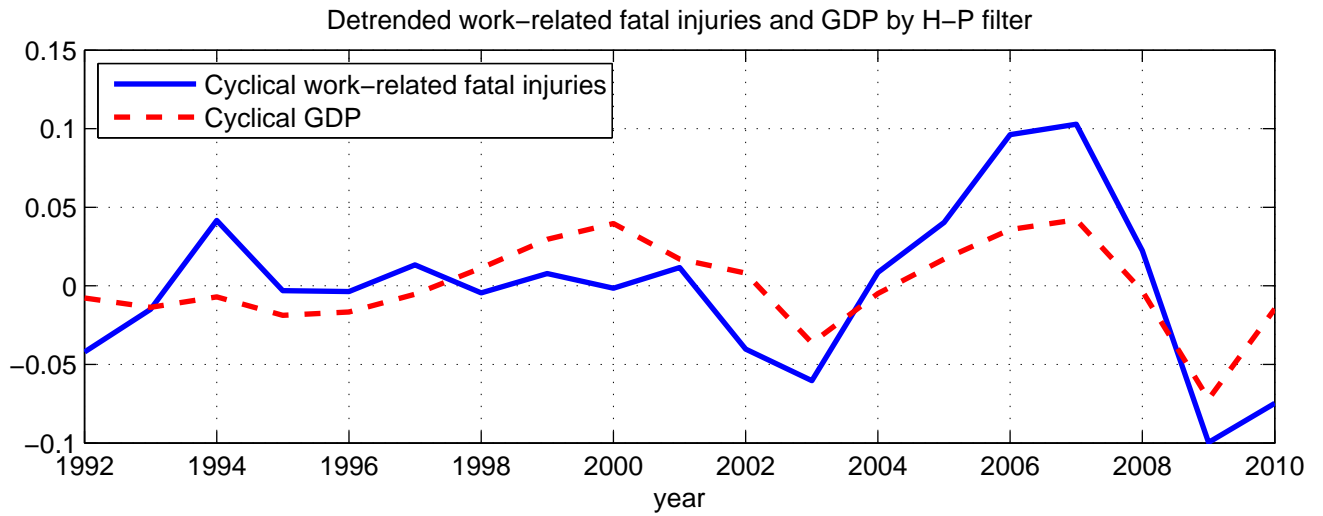


Figure 2: Cyclicity of work-related fatal injuries: 1992-2010

Parameter	Description	Value	Source
η	elasticity b/w consumption and health	8.85	Halliday et al. (2011)
ρ	labor elasticity	2	
α	capital share	0.4	Cooley and Prescott (1995)
δ_k	depreciation rate of capital	0.076	Cooley and Prescott (1995)
δ_h	depreciation rate of health	0.04	Dalgaard and Strulik (2010)
ξ	return to scale for health production	1.00	Grossman (1972)
χ	autocorr coefficient	0.95	Cooley and Prescott (1995)
σ_ϵ	std. of Solow residuals	0.0151	Data (NIPA 1960-2007)
ϖ	elas. of deprec.of health w.r.t working hours	5.00	Chosen
Calibrated		Target	
β	subjective discount factor	0.9574	Capital-output ratio =3.32
λ	share of cons in $C - H$ combo	0.5256	Consumption-output ratio=0.648
ϕ	weight for leisure	2.6470	working hours=0.318
B	productivity of health technology	0.0486	Health expenditure-output ratio=0.102
θ	share of H. exp. in H. production	0.3378	H. Exp.-total consumption ratio=0.124

Table 1: Model parameters

(%)	Data	RBC	Benchmark	Model 1	Model 2	Model 3	Model 4	Model 5
$\sigma(Y)$	2.61	2.0177	2.0576	2.0680	1.7203	2.0639	1.7624	2.0757
$\sigma(C)$	2.11	1.1323	1.2926	1.3095	0.4802	1.2982	0.4966	1.3156
$\sigma(I)$	6.08	5.1557	4.4208	4.3337	4.0246	4.4349	5.3543	4.3571
$\sigma(N)$	2.05	0.6726	0.6210	0.6485	0.0675	0.6317	0.1324	0.6612
$\sigma(M)$	2.12		1.5674	1.7545	4.8358	1.5559	4.9758	1.7332
$\sigma(H)$	0.0144		0.0438	0.0692	0.2939	0.0463	0.3014	0.0716
$\rho(C, Y)$	0.9264	0.9062	0.9734	0.9749	0.8091	0.9729	0.8149	0.9741
$\rho(M, Y)$	0.3032		0.9702	0.9808	0.9984	0.9690	0.9985	0.9796
$\rho(N, Y)$	0.8027	1.0000	0.9992	1.0000	0.8446	0.9993	0.9698	1.0000
$\rho(I, Y)$	0.8854	0.9614	0.9786	0.9790	0.9843	0.9781	0.9848	0.9784
$\rho(H, Y)$	-0.3728		-0.3320	-0.2093	-0.0435	-0.3283	-0.0405	-0.2119

Table 2: Cyclical behavior of the model economy

(%)	Data	RBC	Benchmark	Model 1	Model 2	Model 3	Model 4	Model 5
$\sigma(Y)$	2.61	1.8278	1.8746	1.8839	1.6572	1.8824	1.7268	1.8840
$\sigma(C)$	2.11	0.9779	1.0260	1.0337	0.4182	1.0307	0.4439	1.0305
$\sigma(I)$	6.08	4.8918	4.5298	4.5238	4.1308	4.5635	4.2691	4.5165
$\sigma(N)$	2.05	0.3576	0.1469	0.1508	0.0650	0.1518	0.0610	0.1513
$\sigma(M)$	2.12		1.5432	1.6029	4.2050	1.5213	4.4602	1.6207
$\sigma(H)$	0.0144		0.0607	0.0667	0.2133	0.0625	0.2367	0.0702
$\rho(C, Y)$	0.9264	0.8801	0.9318	0.9296	0.8222	0.9289	0.8107	0.9292
$\rho(M, Y)$	0.3032		0.9666	0.9788	0.9961	0.9649	0.9974	0.9788
$\rho(N, Y)$	0.8027	0.9015	0.9068	0.9255	-0.4740	0.9130	0.3706	0.9261
$\rho(I, Y)$	0.8854	0.9596	0.9694	0.9695	0.9851	0.9684	0.9849	0.9694
$\rho(H, Y)$	-0.3728		-0.3177	-0.2172	-0.1134	-0.3176	-0.0867	-0.2159

Table 3: Cyclical behavior of the model economy with CRRA preference

(%)	$\varpi = 2$	$\varpi = 3$	$\varpi = 4$	$\varpi = 5$	$\varpi = 6$
$\sigma(Y)$	1.9269	1.9872	2.0314	2.0576	2.0482
$\sigma(C)$	1.0580	1.1841	1.2586	1.2926	1.2842
$\sigma(I)$	4.7243	4.4919	4.4248	4.4208	4.3483
$\sigma(N)$	0.4155	0.4939	0.5737	0.6210	0.6101
$\sigma(M)$	1.4399	1.4826	1.5339	1.5674	1.6707
$\sigma(H)$	0.0896	0.0318	0.0367	0.0438	0.0504
$\rho(C, Y)$	0.9266	0.9632	0.9713	0.9734	0.9757
$\rho(M, Y)$	0.9630	0.9639	0.9677	0.9702	0.9745
$\rho(N, Y)$	0.9494	0.9931	0.9984	0.9992	0.9991
$\rho(I, Y)$	0.9686	0.9763	0.9781	0.9786	0.9798
$\rho(H, Y)$	-0.5890	-0.5991	-0.4096	-0.3320	-0.2920

Table 4: Cyclical behavior of the benchmark economy: different ϖ

(%)	$\delta_h = 0.03$	$\delta_h = 0.04$	$\delta_h = 0.05$	$\delta_h = 0.06$
$\sigma(Y)$	2.0584	2.0576	2.0569	2.0559
$\sigma(C)$	1.2832	1.2926	1.2951	1.2948
$\sigma(I)$	4.4277	4.4208	4.4171	4.4145
$\sigma(N)$	0.6223	0.6210	0.6198	0.6180
$\sigma(M)$	1.6372	1.5674	1.5438	1.5383
$\sigma(H)$	0.0455	0.0438	0.0436	0.0439
$\rho(C, Y)$	0.9734	0.9734	0.9730	0.9726
$\rho(M, Y)$	0.9642	0.9702	0.9748	0.9785
$\rho(N, Y)$	0.9993	0.9992	0.9991	0.9991
$\rho(I, Y)$	0.9780	0.9786	0.9789	0.97891
$\rho(H, Y)$	-0.3424	-0.3320	-0.3179	-0.3016

Table 5: Cyclical behavior of the benchmark economy: different δ_h

%	$\eta=8.85$	$\eta=1.00$
$\sigma(Y)$	2.0576	2.0003
$\sigma(C)$	1.2926	1.1999
$\sigma(I)$	4.4208	4.6157
$\sigma(N)$	0.6210	0.5032
$\sigma(M)$	1.5674	1.2781
$\sigma(H)$	0.0438	0.0216
$\rho(C, Y)$	0.9734	0.9588
$\rho(M, Y)$	0.9702	0.9447
$\rho(N, Y)$	0.9992	0.9883
$\rho(I, Y)$	0.9786	0.9743
$\rho(H, Y)$	-0.3320	-0.5411

Table 6: Cyclical behavior of the benchmark economy: different η

$\%$	Benchmark	Bad consumption 1	Bad consumption 2
$\sigma(Y)$	2.0576	2.1723	2.0425
$\sigma(C_g)$	1.2926	0.0232	1.2866
$\sigma(C_b)$	n.a.	14.8933	1.1940
$\sigma(I)$	4.4208	5.5450	4.3704
$\sigma(N)$	0.6210	0.3419	0.2786
$\sigma(M)$	1.5674	0.6979	1.6223
$\sigma(H)$	0.0438	0.0232	0.0464
$\rho(C_g, Y)$	0.9734	-0.3689	0.9771
$\rho(C_b, Y)$	n.a.	0.8992	0.9363
$\rho(M, Y)$	0.9702	0.8066	0.9725
$\rho(N, Y)$	0.9992	0.9978	0.9990
$\rho(I, Y)$	0.9786	0.9562	0.9793
$\rho(H, Y)$	-0.3320	-0.3691	-0.3168

Table 7: Cyclical behavior of the benchmark economy: including bad consumption