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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 the 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 distinct features: 1) Both medical expenditures and leisure time are used to produce health stock; 2) Health enters into production function; 3) Depreciation rate of health stock negatively depends on working hours; 4) Health enters into utility function. We calibrate the model to US economy. The results show that the model can jointly rationalize the counter-cyclicality of health status and pro-cyclicality of medical expenditure. We also investigate the relative importance of each feature in affecting the business cycle properties of health status. We find that the joint presence of

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the time channel (feature 1) and the production channel (features 2 and 3) is crucial in replicating counter-cyclicality of health status.

JEL classification: E22, E32, I12

Keywords: business cycles; health status; health expenditure

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 health expenditure.[1] According to recent poll numbers from Gallup and in recent headline news, the confluence between health care 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), Granados and Ionides (2008), and Miller, Page, Stevens, and Filipski (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 health 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.

In this paper, we first document the business cycle properties of health status

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

(proxied by national mortality rate) in US, following the mainstream macroeconomic literature (e.g., Cooley and Prescott 1995). We find that there is a strong positive correlation between the national mortality rate and GDP per member of working-age population. Health status indeed is counter-cyclical. We thus confirm Ruhm's finding even on the macroeconomic dimension. However, we also find that health expenditure is pro-cyclical. This pattern is very different from physical capital because both capital stock and capital investment are pro-cyclical. The sharp contrast in the cyclicality between health status and health expenditure poses a very interesting question to economists. The way how health status and health expenditure fluctuate over business cycles may also have dramatic welfare and policy implications.

The contrast in the cyclicality of health status and health expenditure shows that health capital is different from physical capital and it has some unique features. This difference lies in two dimensions. First, accumulation of capital stock is through investment. Accumulation of health stock, however, is through both medical care and leisure time.[2] As surveyed in He and Huang (2013a), there is enormous empirical evidence showing that leisure time is a critical input in health production. There is also abundant evidence finding that an increase in leisure time activity helps to reduce medical expenditures (e.g., Colditz 1999; Pratt, Macera, and Wang 2000; Wang and Brown 2004; Brown, Wang, and Safran 2005).[3] Second, although leisure time contributes to health production, the opposite side of leisure in the dimension of time use, namely working time, might hurt health. Working longer hours might increase the chance to exposure to hazardous working conditions and work-related injuries. In addition, longer working hours implies less time to maintain the health stock by exercising and sleeping well. Finally, as surveyed in Sparks et al. (1997), overwhelming evidence shows that longer working hours increase stress and hence lead to ill-health.

In order to capture the unique features of health stock as mentioned above, in this paper, we model health status carefully via two internally coherent channels which both are affected by the nature of multiple use of time, namely leisure vs. labor supply. The first channel is one has to use both medical expenditure and leisure time produce health stock. We call it *time* channel. The second one is health enters into the production function as an input. And working hours 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

[2] In this paper we use health stock, health status, and health capital interchangeably.

[3] He, Huang and Hung (2013b) provide a first empirical investigation of the elasticity of substitution between medical care and leisure time in health production. They find that the elasticity is the range of 0.66–1.35, average around 1.

rate of physical capital stock. In other words, working hours negatively affects the depreciation rate of health stock in the model. We call it *production* channel. Finally, to further differentiate health stock from physical capital (and human capital), health also enters into the utility function to provide consumption value to individuals à là Grossman (1972). We call it *utility* channel.

All these three channels distinguish health stock from physical capital. And they also have implications on the business cycle properties of health status from different perspectives. 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 have 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. In other words, counter-cyclicality of leisure time, via time channel, will contribute to the counter-cyclicality of health status. Since medical expenditure is also used in health production, pro-cyclicality of health expenditure however will counter the effect from leisure time. Second, economic recessions are associated with shorter working hours, which implies less utilization of health stock and hence better health. Production channel therefore will contribute to counter-cyclicality of health as well.[4] Finally, depending on the relationship among health status, consumption and leisure in the utility function, the utility channel could contribute to the cyclicality of health status in different ways.

The main purpose of the present paper is to develop a structural framework which includes the three channels mentioned above to provide a systematic assessment of various channels in jointly accounting for the cyclical properties of health status and health expenditure, together with key macroeconomic variables studied in the standard business cycles literature such as Kydland and Prescott (1982) and Cooley and Prescott (1995).[5] We calibrate the benchmark model to US economy. The results show that our benchmark model can jointly replicate the counter-cyclicality of health status and pro-cyclicality of health expenditures. We then investigate the relative importance of each feature in affecting the cyclicality of health status and health expenditure by running a series of counterfactual experiments. We find that isolatedly the time and production channel both generate counter-cyclicality of health

[4] As will be shown in details in the next section, we do find empirical evidence that confirms the intuition of both time and production channels mentioned above.

[5] It is worth noting that Ruhm (2000) made some conjectures regarding what drives the counter-cyclicality of health status and he covered some parts of time and production channels. Due to lack of structural model, he cannot answer the quantitative question raised here.

stock as we expect. Each channel alone, however, is not important enough to drive the counter-cyclicality as close as to the data. The joint presence of both time and production channel is crucial in replicating this counter-cyclicality. The dynamic interaction between these two channels is a key mechanism to generate counter-cyclicality of health stock. The utility channel also generates counter-cyclicality 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. It also shows some empirical evidence supporting the time and production channels. 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 evaluates its relative importance in driving the results. Section 6 conducts sensitivity analysis. Section 7 concludes.

2 Data

2.1 Cyclicality of Health Status and Health Expenditures

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.[6]

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% drop in

[6] These 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 $\geqq$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-cyclicality though is weakened but still significant for most of diseases. Sustained one percentage point rise in unemployment rates decreases the total mortality rate by 0.4% by the end of four years. See Ruhm (2000) for more details.

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) 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 and health changes that are related to "externalities" associated with macroeconomic conditions. Decomposing the morality 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 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 with empirical work by Ruhm, we use the mortality rate to proxy health status. Higher mortality rate implies lower health status. The mortality rate here is the mortality rate that indicates the number of deaths per 1,000 mid-year working age (ages 15-60) adults, which is taken from World Bank for the time period from 1960 to 2007.[7] The data of annual real GDP per member of working-age population from 1960 to 2007 are taken from NIPA.[8] We then take a natural log on GDP per member of working-age population and use H-P filter to detrend both variables.[9] We find a positive correlation between the

[7] Since our model presented later focuses on working-age population, to be consistent with the model, all data presented here are in terms of per member of working-age population. In addition, Ruhm (2000) shows that the effect of state unemployment rate on the mortality rate is the most significant in the group for 20-44 year olds. Our H-P filter results, however, are also similar in terms of GDP per capita.

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

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

mortality rate and real GDP per member of working-age population, which is 0.3874 at 1% significant level.[10] This implies health status is negatively correlated to real GDP per member of working-age population. Health status is counter-cyclical. We thus confirm Ruhm's finding on the macroeconomic dimension as well. The standard deviation of health status is quite small at the level of 0.34%.

Next, we take a look at business cycle properties of health expenditures. Annual data on total real health expenditure over the 1960-2007 period in the US are taken from OECD Health Data 2010 (OECD, 2010). We divide it by the data of working-age population to obtain total real health expenditures per member of working-age population. We then follow the same procedure to take natural log and apply H-P filter to real medical expenditure and GDP per member of working-age population. The results show that the correlation between the cyclical part of real medical expenditures and GDP per member of working-age population for the time period is 0.3722, which is significant at 1% level. The standard deviation of health expenditures is 2.48%, which is very close to the one for real GDP per member of working-age population 2.55%. Health expenditures are pro-cyclical.[11] Figure 1 shows the cyclicality of mortality rate (proxy health status) and health expenditure, respectively.

The sharp contrast in the cyclicality of health status and health expenditure raises the question why health stock is different from physical capital in terms of the sign of the cyclicality of stock vs. flow variable. As mentioned in the introduction, enormous evidence suggests that the difference lies in two dimensions. First, one has to use both medical expenditure and leisure time as inputs to produce health (time channel); second, the opposite side of leisure time–labor supply can be viewed as the utilization rate of individuals' health stock in the production function. Longer working hours are associated with higher chance to be exposed to hazardous working conditions and hence lead to higher chance of work-related fatal injuries. Longer working hours also lead to more stress, which would hurt health (production channel).

[10] For the exactly same time period 1972-1991 as Ruhm (2000) covers, the correlation between mortality rate and GDP per working age population is 0.5322 and it is statistically significant at p-value=0.015. The substantial drop in mortality rate for the time period 1996-1997 significantly weakens the pro-cyclicality of mortality rate for the period after 1995. This drop is mainly due to the decrease in death rate caused by HIV infection and it is mostly significant for working ages 25-44 (CDC). The medical technological breakthrough known by "cocktail therapy" (Combination Anti-retroviral Therapy), which was discovered in 1996, is believed to attribute to the sharp decline of mortality rate due to HIV infection.

[11] We also run band pass filter to both health status and health expenditure using the same data. We find that the correlation between the mortality rate and real GDP per member of working-age population is 0.3252 and correlation between the health expenditure and real GDP per member of working-age population is 0.2861. Both are at 5% significance level.

Most of the evidence, however, is in the literature of biomedical science, public health, psychobiology, and biosociology and it does not focus on high frequency. We fill the void here to provide further empirical evidence of these two channels along the business cycle dimension.

2.2 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 are 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 data set 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 on caring for the elderly, and more time talking on the telephone. Sleeping, socializing, and traveling also rise on average. Table 1, which replicates Table 4 from Edwards (2011), reports marginal effects of the state-level unemployment rate on selected categories of time use from a Tobit estimation regression.[12] We see for each percentage increase in state unemployment rate, there is 1.776 minutes increase in sleeping time. And the increase is significant at 1% level. Not surprising, working time falls as unemployment rate increases. However, time spent eating and drinking, socializing and relaxing, and telephoning all increase significantly, with the largest increase associated with socializing and relaxing, which is an important part of leisure time that benefits health. 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 un-

[12] See Edwards (2011) for details of the regression. Each cell shows an estimate from a separate Tobit regression on pooled data observed at the monthly frequency. Asterisks denote statistical significance at the 1% (***), 5% (**), and 10% (*) levels.

employment 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 provides a direct micro-evidence to the time channel discussed above.[13]

2.3 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.[14] 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 the number of fatal work injuries for the period 1992-2010 from CFOI.[15] We divide them by the working-age population for the same period to obtain number of fatal work-related injuries per member of working-age population to be consistent to the model. We also take annual real GDP per member of working-age population data for the same period from NIPA. We then take natural log on both variables and run H-P filter. Our results show that fatal work injuries are strongly pro-cyclical. The correlation is 0.60 at 1% significance level. Panel a in Figure 2 reports the detrended fatal work injuries and GDP per member of working-age population. To investigate the strength of the production channel, we also run H-P filter for the log of working hours per member of working-age population for the same period. The results show that the correlation between fatal work injuries

[13] Dehejia 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 post-neonatal 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.

[14] We thank Bart Hobijn points this dataset to us.

[15] Data are downloaded from http://www.bls.gov/iif/oshwc/cfoi/cfch0009.pdf.

and working hours per member of working-age population is 0.48 at 5% significance level. We report the detrended fatal work injuries and working hours per member of working-age population in panel b in Figure 2. The CFOI data provide a strong support to the production channel which claims that when the economy is in boom, workers work longer hours and hence increase the exposure to work-related injuries and accidents.

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 distinct features: 1) Both medical expenditures and leisure time are used to produce health stock; 2) Health enters into production function; 3) Depreciation rate of health stock negatively depends on working hours; 4) Health enters into utility function. These features aim to capture the uniqueness of health stock compared to physical capital. We call feature 1 time channel. Features 2 and 3 consist of production channel. Finally, feature 4 is called utility channel. It models so-called "consumption value" of health stock as emphasized in Grossman (1972).

3.1 The Environment

The economy is populated with a large number of identical agents and a large number of perfectly competitive firms. A representative agent has one unit time endowment in each period, which she spends either in working (N_t) or enjoying leisure (L_t)

$$1 = N_t + L_t \tag{1}$$

A representative agent derives utility from consumption (C_t), leisure (L_t), and health stock (H_t) and maximizes the discounted present value of life time utility

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

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

$$u(C_t, L_t, H_t) = log \left[(\lambda C_t^{1-\eta} + (1-\lambda) H_t^{1-\eta})^{\frac{1}{1-\eta}} - \phi \frac{N_t^{1+\rho}}{1+\rho} \right]. \tag{2}$$

The reason why we want to take the form of GHH preference is because the intuition we 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.[16] 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 $1/\eta$. 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 is $1/\rho$ for this type of preference.

In the economy, firms use physical capital (K_t), labor input (N_t), and health stock (H_t) to produce output (Y_t). The production technology is described in the following production function

$$Y_t = e^{z_t} K_t^{\alpha} (N_t H_t)^{1-\alpha} \tag{3}$$

where Z_t represents the total factor productivity shock and is the only source of uncertainty in the model economy. 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.[17] The output is used for consumption, or medical care (M_t), or investment in physical capital (I_t). The resource constraint thus is defined as

$$C_t + M_t + I_t \leq e^{z_t} K_t^{\alpha} (N_t H_t)^{1-\alpha}. \tag{4}$$

Health stock is accumulated via a production technology which employs both medical expenditure and leisure time to produce new health stock

$$H_{t+1} = (1 - \delta_h - \frac{N_t^{\varpi}}{\varpi}) H_t + B(M_t^{\theta} L_t^{1-\theta})^{\xi} \tag{5}$$

B measures the productivity of health investment technology. θ is the share of goods investment (medical expenditures) in health production technology and ξ represents

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

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

the return to scale for the technology. Notice that similar to the utilization rate of physical capital in GHH, here working hours N_t act as the utilization rate of health stock. Another way to think about the NH bundle in the production function is that health stock is an essential input in the production process. Longer working hours imply that one utilizes her health capital more frequently. It therefore will increase output. However, more frequent utilization of health stock comes at a cost. Longer working hours are associated with higher chance to be exposed to hazardous working conditions and hence lead to higher chance of work-related fatal injuries. Longer working hours also implies one has less time for exercising and taking care of herself. Finally, longer working hours also lead to more stress, which would hurt health. The cost of utilization of health is thus captured in the term $\frac{N_t^{\varpi}}{\varpi}$ in equation (5). The depreciation of existing health stock therefore consists two parts: a constant natural depreciation rate δ_h, and a flexible part which depends on the length of working hours.

In contrast to health stock, the accumulation of physical capital follows the law of motion

$$K_{t+1} = (1 - \delta_k)K_t + I_t \tag{6}$$

where δ_k is the depreciation rate for capital. Notice that the investment technology does not involve any time input, which is an essential difference between physical capital and health capital.

We conclude the model environment by introducing the law of motion of TFP shock z_t

$$Z_{t+1} = \chi Z_t + \epsilon_{t+1} \tag{7}$$

where the innovation ϵ is distributed normally with mean zero and standard deviation σ_ϵ.

3.2 First Order Conditions

Define

$$MPK_t = \alpha K(N_t H_t)^{1-\alpha} \tag{8}$$

$$MPN_t = (1 - \alpha)K(N_t H_t)^{-\alpha} H_t \tag{9}$$

$$MPH_t = (1-\alpha) N_t K_t^{\alpha} (N_t H_t)^{-\alpha} \tag{10}$$

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

$$MPM_t = B\theta\xi M_t^{\theta\xi - 1} L_t^{(1-\theta)\xi} \tag{12}$$

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

$$\frac{\partial u}{\partial C_t} = \beta \frac{\partial u}{\partial C_{t+1}} (MPK_{t+1} + 1 - \delta_k) \tag{13}$$

$$\frac{\partial u / \partial L_t}{\partial u / \partial C_t} = MPN_t - \frac{H_t N_t^{\varpi - 1} + MPV_t}{MPM_t} \tag{14}$$

$$\frac{\partial u}{\partial C_t} = \beta MPM_t \left\{ \frac{\partial u}{\partial H_{t+1}} + \frac{\partial u}{\partial C_{t+1}} MPH_{t+1} + (1 - \delta_h - \frac{N_{t+1}^{\varpi}}{\varpi}) \frac{\partial u / \partial C_{t+1}}{MPM_{t+1}} \right\} \tag{15}$$

Equation (13) represents the inter-temporal Euler equation for physical capital. Equation (14) 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 lowers 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 $\frac{MPV_t + H_t N_t^{\varpi-1}}{MPM_t}$ in the right-hand-side of equation (14) 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 (15) 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 through 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 it 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 be used 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 ratios in US economy. The summary of parameters and corresponding moment conditions is shown in Table 2.

The depreciation rate of capital 7.6% comes from Cooley and Prescott (1995).[18] A strand of literature in biology that studies natural aging of human body finds that as humans age we develop an increasing number of disorders, which the literature refers to as "deficits." The research shows the average individual accumulates

[18] More 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.

3-4% more deficits per year in four developed countries including US.[19] 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. (2011). 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;[20] ϕ is calibrated by matching average working hours ratio 0.318;[21] 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.[22] 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 of ϖ does not significantly change our results.

We construct Solow residuals z_t for US 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.

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[19] See Dalgaard and Strulik (2010).

[20] Given 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 the period 1960-2007, non-medical consumption-output ratio is thus 64.8%.

[21] OECD 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).

[22] We 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.

4.2 Benchmark Results

Table 3 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.[23] For comparison purpose, we also report the data counterpart of the measurements in the second column of the table.[24] 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 81% 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 2.48% 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 63% 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 0.3722 at 1% 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 jointly capture two distinct features of health status and health expenditures over the business cycle, namely counter-cyclicality of health status and pro-cyclicality of health expenditures.

For comparison purpose, we also calibrate a version of the benchmark model without health (called it RBC model).[25] Table 3 reports the results from that model

[23] We use Dynare to simulate the model and all following experiments.

[24] All the variables here are in terms of per member of working-age population. Medical expenditures are excluded from consumption. All the data are from NIPA for the period 1960-2007.

[25] The social planner's problem in the RBC model is following:

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

with period utility function

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

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 this 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 three 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. Second, if health is an input in the production function, then when economy expands, more directly hazardous working conditions, job-related stress, and the physical exertion of employment might have negative effects on health. Third, drinking and driving rise in good times, leading to higher motor vehicle fatality rates.[26] These three channels all lead to a negative correlation between business cycles and health stock. With four distinct features in

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subject to

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

We calibrate parameter ϕ and β to match the corresponding moment conditions in Table 2. All other parameters are set to the values in Table 2. 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.

[26]Ruhm (2000) argues that 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 can call it migration channel. Due to the structure of our benchmark model, we are not able to address this channel and would like to leave the quantitative investigation of this channel to future research.

the benchmark model as mentioned in Section 3, our time and production channels in the benchmark model, which distinguish health stock from capital stock, also cover the first two conjectured mechanisms as in Ruhm (2000).[27] In addition, we add in two other channels that could potentially affect the cyclicality of health stock. 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-move 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-cyclicality 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.[28] Every time we shut down one feature, we recalibrate the model economy to match all the data targets as shown in Table 2 again. In addition, we 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

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

[27] See the appendix for an extension of the benchmark model which includes the bad consumption channel.

[28] In 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.

with period utility function

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

subject to

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

We recalibrate the economy and pick A to control the level effect.[29] The results are reported in the fifth column in Table 3. 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 cyclicality of health stock is about -0.12. Time channel does generate a significant amount of counter-cyclicality of health stock as conjectured by Ruhm (2000). Except for the effect on cyclicality 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 cyclicality of health stock. We shut down the production channel (model features 2 and 3) from the benchmark economy. Our model thus changes to

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

[29]The 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.

with period utility function

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

subject to

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

We recalibrate this model and pick A to control the level effect.[30] The results are reported in the sixth column of Table 3. 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

[30] The 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.

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 in the benchmark model we see 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 goods 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 disappears from the utility function.

We recalibrate this model again and pick A to control the level effect.[31] The results are reported in the seventh column of Table 3. 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 3 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, health is highly complimentary to consumption.

[31] Since 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.

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.[32]

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 cyclicality 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 channels still exist. Therefore the results we obtain in that exercise 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.[33]

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

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

with period utility function

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

subject to

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

[32] In 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 do observe that health turns to pro-cyclical, although it is still quantitatively insignificant.

[33] Of 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.

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 channels can identify the net effect of time channel 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 channels.

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.[34] The results are reported in the eighth column of Table 3. 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 channels generates -0.29 of counter-cyclicality of health. The joint presence of both channels is important in replicating the counter-cyclicality 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-cyclicality 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-cyclicality of health stock. The counter-cyclicality 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-cyclicality of health is just -0.003. In other words, almost the entire counter-cyclicality 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-cyclicality. The interaction between the time and production channels thus is crucial in bringing enough counter-cyclicality as observed in the data. Finally, compared to RBC model without health, the model here shows the effect of pure

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

consumption value of health (without interaction from both time and production channels) on counter-cyclicality 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 channels from the benchmark model. Only the production channel remains. The model changes to

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

with period utility function

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

subject to

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

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 channels (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 utility channels.

We recalibrate the economy and pick A to control the level effect.[35] The results are reported in the last column in Table 3. Shutting down the time and utility channels 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 from 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 turn 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 from the utility channel but with the interaction from the production 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 channels) 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 mainly 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 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,

[35] The 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.

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

Why is the joint presence of time and production channels so important in driving counter-cyclicality of health stock? Let's go back to the key first order equations that govern an individual's optimal choices in the model, which are equations (13)-(15). 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 (15) 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 (14). In contrast, the time channel only reflects in the term MPV_t in equation (14). 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 (14), but also the intertemporal condition in equation (15). When a negative TFP shock hits the economy, marginal product of labor MPN decreases. Individuals therefore optimally choose to work less since the opportunity cost of enjoying leisure goes down in recessions. Keeping other things equal, more leisure first helps to improve health stock of next period as seen in equation (5) via both time and production channels. And with more leisure time and less stress from working, it also contributes to better health the day after tomorrow, and so on (via the continuation term in equation 15). 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-cyclicality 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-cyclicality of health.

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

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 parameters are not calibrated. Some of them are not well backed up by empirical evidence (e.g. ϖ). That's the reason why 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:

$$u(C_t, L_t, H_t) = \frac{log[\lambda C_t^{1-\eta} + (1-\lambda) H_t^{1-\eta})}{1-\eta} - \phi \frac{N_t^{1+\rho}}{1+\rho} \tag{16}$$

In order to be consistent with the benchmark model, we again choose ρ to be 2 so that the labor elasticity is 0.5. All the parameters in Table 2 are unchanged. We recalibrate the economy again to match moment conditions in Table 2 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 4.

We find that overall the results are quite close to those in the GHH preference. However, compared to GHH preference, CRRA has both substitution and income effects on leisure, and hence both pro-cyclicality and volatility of labor supply are much lower in CRRA case. Compared benchmark case in Table 4 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 channels) 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 channels) 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 channels) generates a negligible counter-cyclicality of health of -0.0001.[36] Compared Model 1 to Model 4 (no time and production channels), we can tell the production channel (without interaction from the time channels) 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 channels) generates the counter-cyclicality of -0.027. Both comparisons indicate that the interaction between the time and production channels generates counter-cyclicality of health of around -0.07. Compared to Model 3 and Model 5 (no utility and time channels), 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 5 shows the benchmark model results with different values of ϖ. In Table 5, 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 ϖ=3, this number decreases to 1.07%. The numbers for $\varpi = 4$, 5, and 6 are 0.26%, 0.065% and 0.017%, respectively. We find that with a higher variable depreciation rate due to endogenous utilization of health, health

[36] 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.

stock becomes more counter-cylical 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, 0.04 (which is the value we use in the benchmark case in Section 4), 0.05, and 0.06. Table 6 shows the benchmark model simulations under different value of δ_h. We find that the natural depreciation rate of 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 7. $\rho(H, Y)$ changes from -0.3320 in the benchmark model to -0.5411. It does not affect significantly the other dimensions 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 result 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. Motivated by the sharp contrast in the cyclicality of health status and health expenditure and the enormous empirical evidence regarding the uniqueness of health stock, the model has four distinct features to differentiate health stock from physical capital: 1) Both medical expenditures and leisure time are used to produce health stock; 2) Health enters into production function; 3) Depreciation rate of health stock negatively depends on working hours; 4) Health enters into utility function. With these features, the model is able to quantify the impact of three channels that are unique to health stock, namely the time channel (feature 1), production channel (features 2 and 3), and utility channel (feature 4) on the cyclicality of health status and health expenditure. We find that with the TFP shock estimated from the data, the benchmark model can replicate jointly the counter-cyclicality of health status and pro-cyclicality of health expenditures. 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 status. We find that the joint presence of both time and production channels is crucial in driving the counter-cyclicality of health stock as observed in the data. While the utility channel is quantitatively insignificant in affecting this counter-cyclicality. The dynamic interaction between the time and the production channels via work-leisure decision 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 imply you have more leisure time that can be used to enhance your health. Less working hours also imply the decrease in the degree of utilization of your health. You are less stressful and less exposed to work-related accidents and injuries. All these channels lead to better health status during recessions.

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 might affect 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: health-neutral vs. bad consumption. Health-neutral consumption (such as eating nutritional food) provides utility and it does not hurt your health. In fact, health is complimentary to health-neutral consumption. In contrast, bad consumption (such as smoking and drinking) although provides utility, but negatively affects health stock. 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 health-neutral and bad consumption. The preference changes to

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

with the period utility function

$$u(C_{gt}, C_{bt}, L_t, H_t) = log \left[(\lambda C_{g,t} + (1-\lambda) H_t^{1-\eta})^{\frac{1}{1-\eta}} + \nu C_{b,t} - \phi \frac{N_t^{1+\rho}}{1+\rho} \right]. \quad (17)$$

The agent maximizes her utility subject to the following constraints

$$C_{g,t} + C_{b,t} + M_t + I_t \leq A e^{z_t} K_t^{\alpha} (N_t H_t)^{1-\alpha} \quad (18)$$

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

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

$$1 = N_t + L_t$$

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

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

where C_g stands for health-neutral consumption and C_b represents bad consumption. υ 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 equations (8)-(12), we can have the following first order conditions for this economy:

$$\frac{\partial u}{\partial C_{g,t}} = \beta \frac{\partial u}{\partial C_{g,t+1}} (MPK_{t+1} + 1 - \delta_k) \quad (19)$$

$$\frac{\partial u/\partial L_t}{\partial u/\partial C_{g,t}} = MPN_t - \frac{H_t N_t^{\varpi-1} + MPV_t}{MPM_t} \tag{20}$$

$$\frac{\partial u}{\partial C_{g,t}} = \beta MPM_t \left\{ \frac{\partial u}{\partial H_{t+1}} + \frac{\partial u}{\partial C_{g,t+1}} MPH_{t+1} + (1 - \delta_h - \frac{N_{t+1}^{\varpi}}{\varpi} - \frac{C_{b,t+1}^{\kappa}}{\kappa}) \frac{\partial u/\partial C_{g,t+1}}{MPM_{t+1}} \right\} \tag{21}$$

$$\frac{\partial u/\partial C_{b,t}}{\partial u/\partial C_{g,t}} = 1 + \frac{H_t C_{b,t}^{\kappa-1}}{MPM_t} \tag{22}$$

Equation (22) is a new FOC generated by including bad consumption into the benchmark model. It governs the choice between bad and health-neutral 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 (18) (that's why we have 1 in the right hand side in equation 22), she will obtain some additional gain in health. Since she consumes 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 can be used for health-neutral consumption to improve her utility.

Besides the five clibrated parameters in Table 2, this model adds two new parameters that need to be calibrated: υ 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 2, we calibrate κ to match the average share of alcohol and tobacco consumption in total non-durable 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.[37] 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

[37] The calibration ends up with $\lambda = 0.0022$, $\upsilon = 1.3028$, $\phi = 2.6033$, $B = 0.0299$, $\theta = 0.2155$, 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 hurts health.

-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 health-neutral consumption. Health-neutral consumption is surprisingly much alike health stock, both in terms of correlation with GDP and the volatility. This could be due to the fact that health-neutral consumption is highly complementary to health stock in the utility function. 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

$$u(C_{gt}, C_{bt}, L_t, H_t) = log\left[(\lambda C_{g,t} + (1-\lambda)H_t^{1-\eta})^{\frac{1}{1-\eta}} - \phi\frac{N_t^{1+\rho}}{1+\rho}\right] + \upsilon log C_{b,t} \tag{23}$$

In other words, bad consumption does not bundle with health-neutral 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.[38]

[38] In 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

$$u(C_{gt}, C_{bt}, L_t, H_t) = \frac{log[\lambda C_{gt}^{1-\eta} + (1-\lambda)H_t^{1-\eta})}{1-\eta} + \upsilon log C_{b,t} - \phi\frac{N_t^{1+\rho}}{1+\rho} \tag{24}$$

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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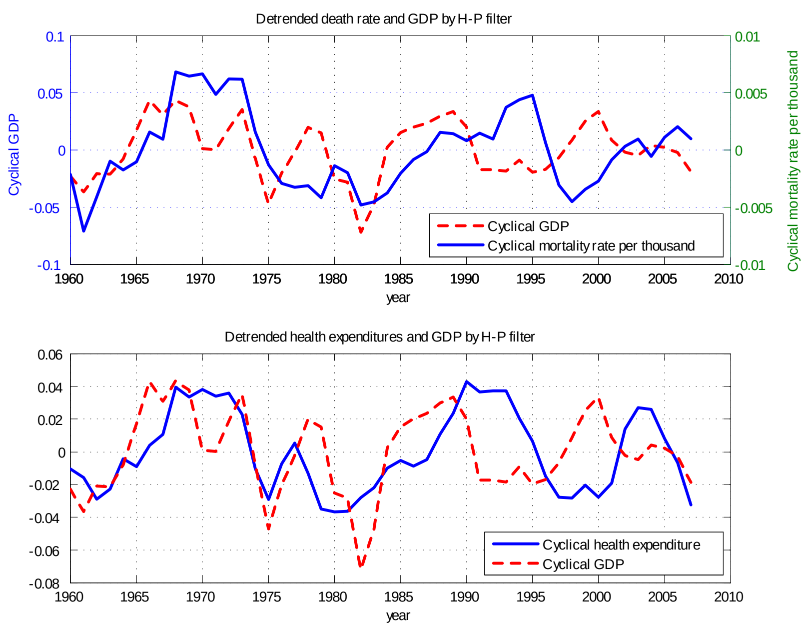

Figure 1: Cyclicality of health status and health expenditure: 1960-2007

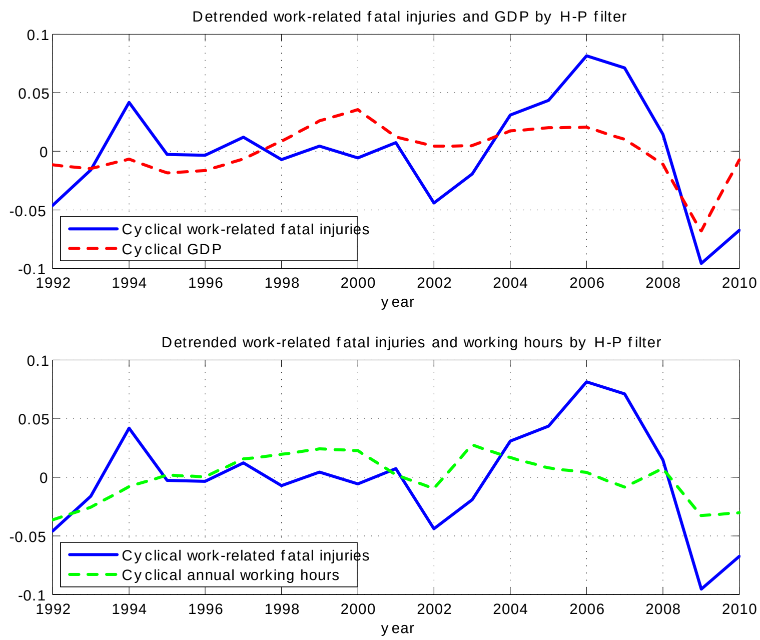

Figure 2: Cyclicality of work-related fatal injuries: 1992-2010

Table 1: Tobit marginal effects on time use, ATUS 2003-2009

Dependent Variable: US time use in	**Tobit marginal effect of State unemployment rate**
Sleeping	1.776***
Home food prep	0.449**
Working & related	-5.798***
Eating and drinking	0.499**
Socializing & relaxing	2.874***
Telephoning	0.311***

Source: Replication from Table 4 in Edwards (2011). Each cell in the table is the marginal effect on the type of observed time use in the ATUS shown in that row that is associated with the state-level unemployment rate. Asterisks denote statistical significance at the 1 percent (***), 5 percent (**) and 10 percent (*).

Parameter	**Description**	**Value**	**Source**
η	elasticity b/w consumption and health	8.85	Halliday et al. (2011)
ρ	coeff. of labor elasticity	2	labor elas. = 0.5
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 dep. of health w.r.t work. 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 of leisure	2.6470	working hours=0.318
B	productivity of health technology	0.0486	H. expenditure-output ratio=0.102
θ	share of H. exp. in H. production	0.3378	H. Exp.-total consum. ratio=0.124

Table 2: Model parameters

(%)	Data	RBC	Benchmark	Model 1	Model 2	Model 3	Model 4	Model 5
$\sigma(Y)$	2.55	2.0177	2.0576	2.0680	1.7203	2.0639	1.7624	2.0757
$\sigma(C)$	1.99	1.1323	1.2926	1.3095	0.4802	1.2982	0.4966	1.3156
$\sigma(I)$	5.98	5.1557	4.4208	4.3337	4.0246	4.4349	5.3543	4.3571
$\sigma(N)$	1.73	0.6726	0.6210	0.6485	0.0675	0.6317	0.1324	0.6612
$\sigma(M)$	2.48		1.5674	1.7545	4.8358	1.5559	4.9758	1.7332
$\sigma(H)$	0.34		0.0438	0.0692	0.2939	0.0463	0.3014	0.0716
$\rho(C,Y)$	0.9270	0.9062	0.9734	0.9749	0.8091	0.9729	0.8149	0.9741
$\rho(M,Y)$	0.3722		0.9702	0.9808	0.9984	0.9690	0.9985	0.9796
$\rho(N,Y)$	0.8031	1.0000	0.9992	1.0000	0.8446	0.9993	0.9698	1.0000
$\rho(I,Y)$	0.8704	0.9614	0.9786	0.9790	0.9843	0.9781	0.9848	0.9784
$\rho(H,Y)$	-0.3874		-0.3320	-0.2093	-0.0435	-0.3283	-0.0405	-0.2119

Table 3: Cyclical behavior of the model economy

(%)	Data	RBC	Benchmark	Model 1	Model 2	Model 3	Model 4	Model 5
$\sigma(Y)$	2.55	1.8278	1.8746	1.8839	1.6572	1.8824	1.7268	1.8840
$\sigma(C)$	1.99	0.9779	1.0260	1.0337	0.4182	1.0307	0.4439	1.0305
$\sigma(I)$	5.98	4.8918	4.5298	4.5238	4.1308	4.5635	4.2691	4.5165
$\sigma(N)$	1.73	0.3576	0.1469	0.1508	0.0650	0.1518	0.0610	0.1513
$\sigma(M)$	2.48		1.5432	1.6029	4.2050	1.5213	4.4602	1.6207
$\sigma(H)$	0.34		0.0607	0.0667	0.2133	0.0625	0.2367	0.0702
$\rho(C,Y)$	0.9270	0.8801	0.9318	0.9296	0.8222	0.9289	0.8107	0.9292
$\rho(M,Y)$	0.3722		0.9666	0.9788	0.9961	0.9649	0.9974	0.9788
$\rho(N,Y)$	0.8031	0.9015	0.9068	0.9255	-0.4740	0.9130	0.3706	0.9261
$\rho(I,Y)$	0.8704	0.9596	0.9694	0.9695	0.9851	0.9684	0.9849	0.9694
$\rho(H,Y)$	-0.3874		-0.3177	-0.2172	-0.1134	-0.3176	-0.0867	-0.2159

Table 4: Cyclical behavior of the model economy with CRRA preference

(%)	$\boldsymbol{\varpi = 2}$	$\boldsymbol{\varpi = 3}$	$\boldsymbol{\varpi = 4}$	$\boldsymbol{\varpi = 5}$	$\boldsymbol{\varpi = 6}$
$\sigma(Y)$	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 5: Cyclical behavior of the benchmark economy: different ϖ

(%)	$\delta_h = \mathbf{0.03}$	$\delta_h = \mathbf{0.04}$	$\delta_h = \mathbf{0.05}$	$\delta_h = \mathbf{0.06}$
$\sigma(Y)$	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	0.9791
$\rho(H,Y)$	-0.3424	-0.3320	-0.3179	-0.3016

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

(%)	$\boldsymbol{\eta = 8.85}$	$\boldsymbol{\eta = 1.00}$
$\sigma(Y)$	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 7: 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 8: Cyclical behavior of the benchmark economy: including bad consumption