Are Recessions Good for Your Health? A Macroeconomic Analysis

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Abstract

This paper first documents several important business cycle properties of health expenditures across countries. We then develop a stochastic dynamic general equilibrium model with endogenous health accumulation. The model has three 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. We calibrate the model to US economy. The results replicate the stylized facts of medical expenditure and health status over business cycles. We also investigate the relative importance of each feature in affecting the business cycle properties of health accumulation.

JEL classification: E22, E32, I12

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1 Introduction

The share of health expenditure in GDP has been increasing over the past 60 years. Take the United States as an example, the aggregate health expenditure as a share in GDP was approximately 4 % in 1952, 9 % in 1980, and jumped to 16% in 2008. There are many studies aiming at explaining this long-run trend in health expenditure-GDP ratio. Hall and Jones (2007) suggest that the increasing health expenditure-GDP ratio is due to the income effect and the fact that health is a luxury good. Suen (2006) argues that technological change in medical care is the major driving force behind the increase in aggregate health expenditure. Fonseca et al. (2009) estimate that technological change along

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with the increase in the generosity of health insurance explains major part of the rise in health spending while the income effect only explains less than 10%.

Although the literature on explaining long-run trend of health expenditure is already abundant, less research has been done on examining the short-run fluctuations of health expenditure. A series of influential papers by Ruhm (2000, 2003, 2005) show striking 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 as a proxy of health status and unemployment rate during the time period 1979 to 1991 as a proxy of the state of the economy and finds 1% increase in the unemployment rate is associated with a 0.54% reduction in mortality rate. Ruhm (2003) further examines the relation between health status and medical care utilization fluctuation with state macroeconomic conditions. He conjectures four channels that explain why good economic times might worsen individuals' health status. First, when economy is in boom, it makes individuals feel costly to maintain time-intensive health-producing activities such as exercise. Second, assuming health being an input into production of goods and services, long working hours and stressful environment caused by short-lasting economic expansions might have negative effects on health. Third, income growth might increase the propensity of taking risky activities such as smoking, drinking and dangerous entertaining exercise, which affects health negatively. (also see Freeman 1999; Ruhm and Black 2002).[1] Finally, large migration flows in repsonse to changes in local economic conditions might raise the death rate in destinations states via increasing crowding and traffic fatality.

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, 2003, 2005) 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) 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. Bhalotra (2010) investigates the impact of aggregate income shocks on infant mortality in India and finds that rural infant mortality is counter-cyclical. 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

[1] Xu and Kaestner (2010), however, find that people are more likely to involve in unhealthy behaviors such as smoking and drinking during temporary economic downturns.

in Ruhm 2000). 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 (second and fourth channel in Rhum 2000) play an important role in health changes.

All these researches, however, focus on microeconomic dimension and generally use approximation for macroeconomic condition. They do not directly document business cycle properties of health status and health expenditure. All these papers are also empirical and don't have theoretical model that can be used to quantify the relative importance of the channels that Ruhm (2000) conjectures.

Our paper attempts to fill the void. Our contribution is twofold. First, we document the business cycle properties of health expenditure across countries following the mainstream macroeconomic literature (e.g., Cooley and Prescott 1995). Second, we develop a stochastic dynamic general equilibrium model with endogenous health accumulation. The model has three 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. We calibrate the model to US economy. The results replicate the stylized facts of medical expenditure and health status over business cycles. We also investigate the relative importance of each feature in affecting the business cycle properties of health accumulation. As far as we know, this is the first paper to do so.

The paper is organized as following. Section II describes the data we use and empirical results. Section III presents our benchmark model. Section IV outlines the calibration of the model and demonstrates the benchmark results. Section V decomposes each feature of the model and evaluate its relative importance in driving the results. Section VI conducts sensitivity analysis. Section VII concludes.

2 Data

Annual data on health expenditure and GDP for 12 OECD countries over the 1970-2008 period (except for France: 1990-2008; Italy: 1988-2008; and South Korea: 1980-2008) are taken from the OECD Health Data 2010 (OECD, 2010).[2] To be consistent with our model, we apply CPI index in each country to obtain annual real GDP and annual real health expenditure for each country. We then take a natural log on these variables and use H-P filter to detrend them.[3] From data of these 12 countries, we observe a similar pattern on the positive correlation between health expenditure and GDP and a significant volatility on health expenditure. Table 1 provides summary results. Most countries in the

[2] including Australia, Canada, France, Germany, Italy, Japan, Norway, South Korea, Sweden, Switzerland, UK, and US.

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

table show a significantly positive correlation between GDP and health expenditure except Germany and France.[4] United Kingdom and Italy show a strong correlation between health expenditure and GDP which are 0.736 and 0.745, respectively, at 1% significant level followed by Sweden 0.713, South Korea 0.690, Switzerland 0.608, Norway 0.581, Japan 0.574, Australia 0.474. United States has a relatively weaker positive correlation between health expenditure and GDP. It is 0.301 at a 10% significant level. France and Germany show positive correlation between health expenditure and GDP but fail to be statistically significant. Canada demonstrates a slightly negative and insignificant correlation between health expenditure and GDP. In order to check robustness of our results, we also apply Band-Pass filter to examine the cyclical features of GDP and health expenditure. Countries which show significantly positive correlations via H-P filter are confirmed again in Band-Pass filter. For US, the positive correlation between GDP and health expenditure becomes more significant. It is 0.3951 at 5% significant level. Germany turns to a positive correlation 0.3663 at 5% significant level. The results are also robust to the price index we use. For most of countries, we still observe a positive correlation between GDP and health expenditure using GDP deflator.
Figure 1 to 6 show the cyclical features of health expenditure and GDP for United States, United Kingdom, Australia, Germany, Italy and Japan. Figure 1 shows the detrended health expenditure and GDP for U.S. We can see that the health expenditure co-moved with GDP before 1980. After 1980, the health expenditure diverged from GDP. Germany is another example of non-positive correlation between health expenditure and GDP as shown in Figure 4. United Kingdom, Japan, Italy and Australia, however, all show a strong pro-cyclicality of health expenditure over time.

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 model has three 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. The economy consists only one good which can be used for consumption, or medical care, or investment.

3.1 The Environment

The model economy consists of a representative agent with following preference

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

[4] Both countries show a slightly negative correlation between GDP and health expenditure (but not statistically significant) in H-P and Band-Pass filter as well. The latter might be resulted from relatively short observed years.

with period utility function motivated by Huang and Huffman (2010)

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

The agent maximizes her utility subject to the following constraints

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

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

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

$$1 = N_t + L_t \tag{5}$$

$$Z_{t+1} = \chi Z_t + \epsilon_{t+1} \tag{6}$$

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

where C is consumption, L is leisure, H is health stock. M denotes medical expenditure and N is working hours. Z represents the productivity shock and is the only source of uncertainty in the model economy. β denotes the subjective discount factor. Consumption and health is bundled in a CES function with the elasticity of substitution between C and H determined by $\frac{1}{\eta}$. λ determines the weight of consumption in the consumption-health bundle in the preference. ρ is the weight of leisure. Equation 2 is the resource constraint where α is the share of capital. Equation 3 and 4 are the law of motion for physical capital and the health stock, respectively. δ_k and δ_h are the depreciation rate for capital and health, respectively. Notice that the health investment technology is a Cobb-Douglas function with both medical expenditure and leisure as inputs. B measures the productivity of health investment technology. θ is the share of goods investment (medical expenditure) 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 among working hours and 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

$$MPK_t = \alpha A_t K_t^{\alpha-1}(N_t H_t)^{1-\alpha} \tag{7}$$

$$MPN_t = (1-\alpha) H_t A_t K_t^{\alpha}(N_t H_t)^{-\alpha} \tag{8}$$

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

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

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

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 expenditure in health production technology. We have the following first order conditions

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

$$\frac{\partial U/\partial L_t}{\partial U/\partial C_t} = MPN_t - \frac{MPV_t}{MPM_t} \tag{13}$$

$$\frac{\partial U}{\partial C_t} = \beta MPM_t \left\{ \frac{\partial U}{\partial H_{t+1}} + \frac{\partial U}{\partial C_{t+1}} MPH_{t+1} + (1-\delta_h)\frac{\partial U/\partial C_{t+1}}{MPM_{t+1}} \right\} \tag{14}$$

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 real wage. The intra-temporal condition suggests that the 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 productivity. This is a gain which is embodied in MPV_t. The gain, however, is discounted 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 expenditure by MPM_t. The additional term in the right-hand-side of equation 13 $\frac{MPV_t}{MPM_t}$ 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 representative agent faces a choice between consumption and health expenditure. 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 expenditure. 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$(1-\delta_h)\frac{\partial U/\partial C_{t+1}}{MPM_{t+1}}$.

4 Calibration and Benchmark Results

4.1 Parameterization

In this section, we outline the parameters used in the benchmark model. In order to avoid artificial parameters issue, except for some parameters that we can find values used in relevant studies, we calibrate the 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 2. The capital-output ratio 3.32 and depreciation rate of capital 7.6% come from Cooley and Prescott (1995).[5] The depreciation rate of health is taken from Scholz and Seshadri (2010). The elasticity of substitution between consumption and health is taken from Halliday et al. (2010). With $\eta = 8.85$, the elasticity is 0.11 which shows that health and consumption are strongly complementary. The return to scale for health production technology $\xi = 1$ is suggested by Grossman (1972). For those calibrated parameters, β is used to match capital-output ratio 3.32; λ is pinned down to match consumption-output ratio 0.63;[6] ρ is calibrated by matching average working

[5] 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.

[6] 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 12% for period 1970-2008, non medical consumption-output ratio

hours ratio 0.31;[7] B is calibrated by matching health expenditure-output ratio 12% which is the average for the period 1970-2008; and finally θ is pinned down by matching health expenditure-total consumption ratio 17%.[8]

We construct Solow residuals z_t for this economy from annual NIPA data for period 1970-2008 following 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 0.0125.

4.2 Benchmark Results

Table 3 presents the standard deviations of the key variables and the correlation coefficient of each variable with output from the simulation of the benchmark economy. For purpose of comparison, we also report the data counterpart of the measurements in the first column of the table. 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 1.77%, which explains about 67% of the standard deviation of GDP in US data. The number comes surprisingly close to that found in Cooley and Prescott (1995). 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 2.28% in the data. It is about 85% of that of GDP. The standard deviation of medical expenditure in the model is 1.34%. It captures about 76% of the standard deviation of GDP in the model. The model also predicts a very strong positive correlation between medical expenditure and GDP, although the US data only shows a correlation 0.3. Probably the most important finding is that the benchmark model is able to generate a negative correlation between health stock and GDP as shown in Ruhm (2000). Ruhm (2000) uses proxies to approximate health stock and GDP in his estimation. Our results here confirm his finding based on a structural model and direct measured health stock and GDP.

For purpose of comparison, we also calibrate a version of the benchmark

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is thus 63%.

[7] OECD statistics show that average annual hours worked per worker in US for period 1970-2007 is 1832.7 hours. We divide it by 365×16 which we interpret as the total available discretionary hours per year. It ends up with 31%. This number is also the same as the one used in Cooley and Prescott (1995).

[8] Data is taken from Huang and Huffman 2010 for the period 1980-2008.

model without health (called it traditional RBC model).[9] Table 3 reports the results from that model as well. Our benchmark model seems doing a good job in replicating the measurements for all key variables compared to this traditional RBC model except on one dimension, the working hours. The benchmark model significantly reduces the volatility of working hours compared to the traditional RBC model. Given the latter already underpredicts the standard deviation of working hours compared to that in the data, the benchmark model makes it even worse.

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. Let's call it time channel. 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. 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 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.

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

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

with period utility function

$$u(C_t, L_t) = \frac{logC_t^{1-\eta}}{1-\eta} + \rho log L_t$$

subject to

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

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

$$1 = N_t + L_t$$

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

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

Due to the structure of our benchmark model, we cannot address the consumption and migration channel. However, with three distinguished features in the model as mentioned in Section 3, we cover the time channel and production channel as in Ruhm (2000). 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.[10] Finally, since medical expenditure is 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 procyclical. 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 is determined by the relative importance of each channel. In this section, in order to quantify relative importance of each channel and let us understand better the mechanisms behind the counter-cyclicality of health status as shown in Ruhm (2000), we conduct a series of counterfactual experiments to decompose the effect for each channel.[11]

5.1 Health in Preference Only (Model 1)

In this economy, an agent still derives her utility from consumption, health and leisure. However, health is not an input in production function. Our model thus changes to

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

with period utility function

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

subject to

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

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

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

$$1 = N_t + L_t$$

[10] To be more accurate, they are two layers of pro-cyclicality can be generated from the utility channel. One is through the complementarity. Another is health enters directly into the utility function as a normal good. See footnote 12 for the further decomposition of the effect of these two layers on the cyclicality of health stock.

[11] In order to decompose the goods channel, we have to only use time to produce 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.

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

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

We recalibrate this model and the results are reported in the fourth column of Table 3. Compared to the results of benchmark model, we see the correlation between health stock and GDP changes from -0.1152 in the benchmark to 0.2335 in model 1. The only difference between the benchmark model and model 1 is we shut down the production channel in the latter. Therefore, this exercise shows that the production channel indeed generates counter-cyclicality of health stock. The difference in $\rho(H, Y)$ is 0.35 between the two cases. That 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 1.3372 in the benchmark model to 3.1156 in model 1. This is because the substitution between labor supply N and health stock H in production function provides stablization to the economy. When the economy expands due to positive productivity shock, labor supply increases. But since N and H are bundled in production function, when N increases, H tends to decrease. That is the main mechanism why the production channel provides counter-cyclicality of health stock. The substitution between N and H can be seen clearly comparing the volatility of N and H between the benchmark model and model 1. From benchmark model to model 1, we lose the stability brought by the production channel, volatility of health stock increases from 0.0764 to 0.3031. Increasing volatility of health stock thus makes the investment in H, which is medical expenditure, more volatile.

5.2 Health in Production Only (Model 2)

In this economy, health does not enter into the utility function but remains as an input in production function. The social planner's problem changes to

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

with period utility function

$$u(C_t, L_t) = \frac{logC_t^{1-\eta}}{1-\eta} + \rho log L_t$$

subject to

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

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

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

$$1 = N_t + L_t$$

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

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

We recalibrate this model again and the results are reported in the fifth column of Table 3. Compared to the results of benchmark model, we see the correlation between health stock and GDP changes from -0.1152 in the benchmark to -0.7154 in model 2. The only difference between the benchmark model and model 2 is that the utility channel is completely shut down in model 2. The difference of cyclicality of health is about 0.60, which measures the magnitude of utility channel in driving pro-cyclicality of health stock. Another noticeable difference is, contrast to model 1, the volatility of medical expenditure decreases significantly from 1.3372 in benchmark model to 0.6216 in model 2. Utility channel amplifies the volatility of M. This is because the complementarity between consumption and health magnifies the effect of productivity shock to medical expenditure. When economy expands due to a positive productivity shock, GDP and consumption increase. The utility channel induces health increase, which requires higher health investment (i.e., M). In other words, the utility channel adds in another layer of volatility to medical expenditure. It not only makes M more volatile but also ties up the co-movement between consumption and medical expenditure. By shutting down the utility channel, $\rho(M, Y)$ decreases dramatically from 0.9496 in benchmark case to 0.1997 in model 2. Utility channel thus strengthens both volatility and pro-cyclicality of medical expenditure.

5.3 Goods Investment in Health Only (Model 3)

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

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

with period utility function

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

subject to

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

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

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

$$1 = N_t + L_t$$

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

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

We recalibrate the economy and report the results in the sixth 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 -0.1152 to 0.1743 in model 3. This tells us the magnitude of the time effect on cyclicality of health stock is about -0.29. Time channel does generate counter-cyclicality of health stock as predicted 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 Model 1 and 2. For example, adding time channel only reduces the volatility of medical expenditure from 1.5522 to 1.3372. Since leisure is counter-cyclical, it is not surprising that add time input in health production will help to reduce both volatility and pro-cyclicality of health expenditure. However, the magnitude of time channel is much less significant compared to the production and utility channel.

5.4 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. For example, when compare model 1 with the benchmark model, we can see the magnitude of production channel is -0.35, the magnitude of time channel is -0.29, and the magnitude of utility channel is 0.60. Therefore among these three channels, we conclude that utility channel is the most important in affecting $\rho(H, Y)$. Production channel is the second. And the time channel is the least important. We do this evaluation to the key variables we are interested and summarize the findings in Table 4. We find that time and production channels, which generate counter-cyclicality of health stock, dominate the utility and goods channels, which drive pro-cyclicality of health stock. That's the reason why we replicate the main result in Ruhm (2000). However, interestingly, the simple sum of magnitude of counter-cyclicality from time and production channel is equal to or might be less than the sum of magnitude of pro-cyclicality from utility and goods channel (given goods channel will also generate $\rho(H, Y) > 0$). This indicates that there is a strong interaction between the time and production channel. We also find that the time channel, although highlighted by Ruhm (2000), plays the least important role in affecting the cyclicality and volatility of health stock and health expenditure. This finding confirms Miller et al. (2009)'s conclusion that individuals' own labor market involvement is not the key mechanism behind the counter-cyclicality of health. In addition, We find that the utility channel and the production channel switch its role in driving the cyclicality and volatility of health stock and health expenditure, respectively. The utility channel is the leading mechanism in affecting cyclicality of health and medical expenditure, while the production channel is the most important factor in driving the volatility of health and medical expenditure. Our intuition is that since the only source of shock comes from the production side in the model, it is not surprising that the production channel plays a more direct role in affecting the volatility. The utility channel, on the other hand, links consumption and health stock (and hence medical expenditure) tightly through complementarity between consumption and health stock. Therefore, it affects more directly the correlation of health stock and health expenditure.

6 Sensitivity analysis

In this section, we conduct a sensitivity analysis to investigate how our results are affected quantitatively by changing the model setting of time input in health production and changing elasticity of substitution between health and consumption in the preference.

As we show in Table 5, the complementarity between consumption and health is a crucial channel in affecting cyclically and volatility of health and medical expenditure. To test the sensitivity of our results to this elasticity, we take an extreme case to let η be equal to 1. In other words, we shut down the complementarity completely. We then recalibrate and compute the benchmark model. The results are shown in the third column of Table 5. $\rho(H,Y)$ changes from -0.1152 in the benchmark model to -0.3480. Shutting down the complementarity does weaken the importance of the utility channel as we expect.[12] However, it does not affect significantly the other dimension of business cycle properties of key variables compared to the benchmark model.

Grossman (1972) argues that health capital is different from other forms of human capital in the sense that human capital affects an individual's labor productivity, while health capital determines the total amount of time she can spend in working. In other words, if you are healthier, the sick time decreases so that you can spend more time in market and non-market activity. Our production channel captures the human capital feature of the health stock. But it does not really model the sick time mechanism mentioned in Grossman (1972). As a robustness check, we change the benchmark model to replace the original production channel with this sick time mechanism. The social planner's problem is as follows

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

with period utility function

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

subject to

[12]The magnitude of the utility channel in affecting $\rho(H,Y)$ decreases to 0.37 under $\eta = 1$. This shows that the complementarity effect alone captures 0.23 out of 0.60, i.e., around 38% of the counter-cyclicality of health stock, while the pure utility channel accounts for 62% of the counter-cyclicality.

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

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

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

$$1 = N_t + L_t + S_t$$

$$S_t = QH_t^{-\gamma}$$

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

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

where S_t denotes sick time. Q is the scale factor of sick time and γ measures the sensitivity of sick time to health status. Grossman (1972) suggests that $\gamma = 1$. We take that value for γ. However, we still need to calibrate the additional parameter Q. Following Halliday et al. (2010), we use average ratio of sick time out of total discretionary time 2.1% as an additional moment condition to pin down Q. This ends up with $Q = 0.013$.[13] Given these parameters, we compute the benchmark model and report the results in the fourth column of Table 5. We find that the results of the sick time model are quite close to those in model 1 (no health in production). Our take is that since sick time only accounts for a small fraction of time endowment and hence does not affect labor supply significantly, this model is essentially much like the model without health in production function.[14]

7 Conclusion

Are recessions good for your health? And why? This paper first documents several important business cycle properties of health expenditures across countries. We then develop a stochastic dynamic general equilibrium model with endogenous health accumulation. The model has three 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. We calibrate the model to US economy. The results confirms the finding in Ruhm (2000) showing health stock is counter-cyclical. The model is also able to replicate some important business cycle features of medical expenditure. We investigate the relative importance of each model feature in affecting the business cycle properties of health accumulation. We find that the utility channel (feature 1) is the leading mechanism in affecting cyclicality of health and medical expenditure, while the production channel (feature 2) is the most important factor in driving the volatility of health and medical expenditure. The time channel

[13] The other five calibrated parameters are $\beta = 0.9574, \lambda = 0.1410$, $\rho = 1.2920$, $B = 0.1765$, and $\theta = 0.6142$.

[14] In an unreported experiment, we also increase the sick time ratio from 2.1% to 5%, it does not change our results significantly.

(leisure as an input in producing health), although highlighted by Ruhm (2000), plays the least important role in affecting the cyclicality and volatility of health stock and health expenditure.

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	GDP/Health Exp. corr.	Y-std[a]	M-std[b]
Australia	.474***	.0372	.0477
Canada	-0.151	.0305	.0237
France	.129	.0248	.0221
Germany	.139	.0283	.0341
Italy	.745***[c]	.0252	.0436
Japan	.574***	.0524	.0425
Norway	.581***	.0458	.0596
S. Korea	.690***	.0491	.0644
Sweden	.713***	.0400	.0559
Switzerland	.608***	.0440	.0290
UK	.736***	.0508	.0444
US	.301*[d]	.0267	.0228

Table 1: Cyclical behavior of 12 OECD economies on health expenditure

[a]Y-std is the annual real log GDP
[b] M-std is the annaul total real log health expenditure
[c]significant at 1% confidence inverval
[d]significant at 10% confidence interval

Parameter	Description	Value	Source
η	elasticity b/w consumption and health	8.85	Halliday et al. (2010)
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	0.056	Scholz and Seshadri (2010)
ξ	return to scale for health production	1.00	Grossman (1972)
χ	autocorr coefficient	0.95	
σ_ϵ	std. of Solow residuals	0.0125	
Calibrated			**Target**
β	subjective discount factor	0.9574	Capital-output ratio =3.32
λ	share of cons in $C-H$ combo	0.6409	Consumption-output ratio=0.63
ρ	weight for leisure	1.7966	working hours=0.31
B	productivity of health technology	0.2437	Health expenditure-output ratio=0.12
θ	share of H. exp. in H. production	0.3668	H. Exp.-total consumption ratio=0.17

Table 2: Model parameters

(%)	Data	Traditional RBC	Benchmark	Model 1	Model 2	Model 3
Y-std	2.67	1.7576	1.7692	1.5984	1.8034	1.8139
C-std	2.06	0.9134	0.9534	0.4426	1.0903	0.9705
I-std	9.28	4.8290	4.3583	4.1402	4.7024	4.3612
N-std	1.69	0.7410	0.2804	0.1678	0.3143	0.3030
M-std	2.28		1.3372	3.1156	0.6216	1.5522
H-std			0.0764	0.3031	0.0558	0.0964
$\rho(C,Y)$	0.9022	0.8627	0.9232	0.7275	0.9382	0.9236
$\rho(M,Y)$	0.3006		0.9496	0.9887	0.1997	0.9809
$\rho(N,Y)$	0.8615	0.9028	0.9096	0.7589	0.9126	0.9225
$\rho(I,Y)$	0.8485	0.9590	0.9670	0.9755	0.9653	0.9696
$\rho(H,Y)$	- (Ruhm,2000)		-0.1154	0.2335	-0.7154	0.1743

Table 3: Cyclical behavior of the model economy

	$\rho(H,Y)$[a]	$\rho(M,Y)$	$\sigma(M)$[b]	$\sigma(H)$
Time channel	$-$*	$-$*	$-$*[c]	$-$*
Production channel	$-$**	$-$**[d]	$-$***	$-$***
Utility channel	$+$***[e]	$+$***	$+$**	$+$**
Goods channel	$+$	$+$	$+$	$+$

Table 4: The quantitative impact of four channels

[a] ρ denotes the correlation between objects
[b] σ denotes the volatility of objects
[c] least important
[d] secondly important
[e] denotes the most important effect

%	Data	Benchmark: Eta=8.85	Benchmark: Eta=1.00	Sick time
Y-std	2.67	1.7692	1.7773	1.5313
C-std	2.06	0.9534	0.9647	0.4413
I-std	9.28	4.3583	4.4707	3.9031
N-std	1.69	0.2804	0.2888	0.1495
M-std	2.28	1.3372	1.1629	2.8858
H-std		0.0764	0.0513	0.2565
$\rho(C,Y)$	0.9022	0.9232	0.9220	0.7908
$\rho(M,Y)$	0.3006	0.9496	0.9197	0.9893
$\rho(N,Y)$	0.8615	0.9096	0.9065	0.5593
$\rho(I,Y)$	0.8485	0.9670	0.9666	0.9777
$\rho(H,Y)$	- (Ruhm,2000)	-0.1154	-0.3480	0.2189

Table 5: Sensitivity analysis

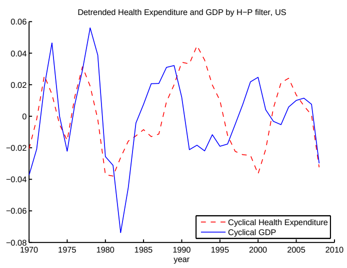

Figure 1: De-trend health expenditure and GDP, US

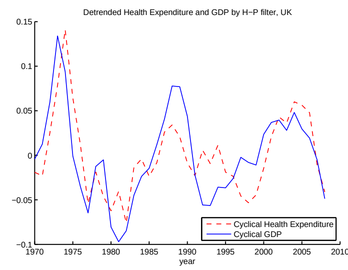

Figure 2: De-trend health expenditure and GDP, UK

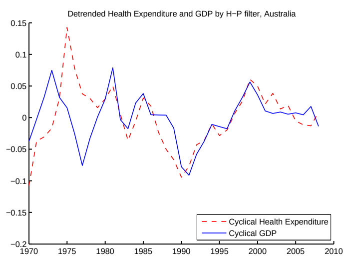

Figure 3: De-trend health expenditure and GDP, AU

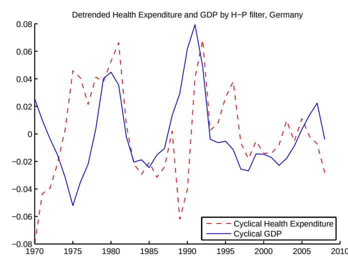

Figure 4: De-trend health expenditure and GDP, DE

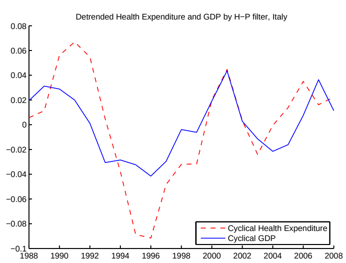

Figure 5: De-trend health expenditure and GDP, IT

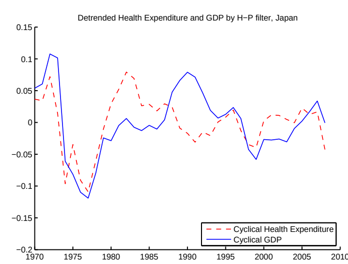

Figure 6: De-trend health expenditure and GDP, JP