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Health Care Inflation and Its Implications for Monetary Policy

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Abstract

Motivated by recent findings on the cyclical movement of both health and health spending, we construct a general equilibrium model that distinguishes health care demand from the demand for other goods. Using this model, we are able to generate inflation dynamics and cyclicality of health that match the US data. When the model is subjected to an expansionary monetary policy shock, it yields different output and inflation responses compared with a two-sector model with homogeneous demand. We show that the trade-off between leisure and health spending plays an important role in model dynamics. The model further predicts different degrees of inflation stabilization across sectors when a shift in the monetary policy occurs.

Keywords: monetary policy, health care inflation, DSGE models

JEL classification: E52, E31, E32, I10

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I Introduction

For over a decade, rising health spending in the US has been a major topic of debate. During 2000 - 2007, nominal health spending grew at an average of 7.5% per year compared with the nominal GDP growth rate of 5.1% per year, and much of the health spending growth was due to health care inflation.[1] In 2013, health spending in real terms comprises almost one-fifth of total real GDP and this share is predicted to exceed 30% by 2050 (Hall and Jones, 2007). Despite the growing presence of the health care sector in the economy and an aging population in the US and around the globe, there are few studies that look at the interaction between health care inflation and monetary policy. This is because in the monetary policy literature the goal of monetary policy is, in part, to stabilize the *aggregate* price level, instead of sector-level prices.

This paper aims to answer the following questions: (i) are inflation dynamics in the health care sector different from other sectors? (ii) If so, how is the effect of monetary policy different in models that separate the health care sector from other sectors?

To address the first question, we obtain some stylized facts about health care inflation in the US using principal component analysis and a factor-augmented vector autoregression. We find that during 1980 - 2013 the volatility of health care inflation is much lower, and the persistence is higher than other services in the personal consumption expenditure category. The response of health care prices to an innovation in the federal funds rate is found to be smaller than that of other services.

To address the second question, we introduce a dynamic stochastic general equilibrium

[1]Source: U.S. Department of Commerce, Bureau of Economic Analysis.

(DSGE) model with two novel features. On the household side, we include health status in the utility function and distinguish health care demand from the demand for other goods. In the model, health is a "quality of life" indicator. Households can improve their quality of life by combining health spending with leisure. On the supply side, we allow the frequency of price adjustment in health care goods to be lower than regular goods, reflecting an empirical regularity (Bils and Klenow, 2004). We show that the model can successfully replicate the low volatility and the high persistence of health care inflation as seen in the data.

The main findings are summarized as follows. First, when the model economy is subject to an expansionary monetary policy shock, it yields an amplified response of the equilibrium output and a muted response of the equilibrium inflation in the health care sector relative to the regular goods sector, consistent with our empirical finding. Second, to understand the implication for monetary policy, we compare the impulse responses of our model with those of a two-sector model that does not feature health care. When these models are subject to the same expansionary monetary policy shock, the response of aggregate output is stronger and the response of aggregate inflation is weaker under the health care model. The differences between the two models lie in how households balance health spending and leisure to achieve better health. When health spending increases, health improves, which lowers the marginal utility of health and allows households to work longer hours and produce more output. Third, when the monetary policymaker shifts its policy and assigns a higher priority to output stabilization relative to inflation stabilization, it results in a smaller increase in the standard deviation of inflation in the health care sector compared with the regular goods sector, whereas in the simpler two-sector model the changes in the standard deviation of inflation are of similar magnitude across sectors.

This paper contributes to the literature that examines the role of demand heterogeneity in monetary DSGE models. Existing studies have focused on how a sector with a relatively small size could have a disproportionately large effect on the aggregate economy. For example, Barsky *et al.* (2007) introduce the durable goods sector characterized by a relatively small output share and a low depreciation rate. They find that the aggregate inflation dynamics are mainly determined by the inflation dynamics of the durable goods sector, irrelevant of its size and price stickiness. One puzzle that they encountered is that output in different sectors are negatively correlated in response to a monetary policy shock, which is inconsistent with empirical findings. Our model can generate positively-correlated sectoral output in response to a monetary policy shock, yielding strong monetary non-neutrality in aggregate. This occurs because health status in our model weakens the inverse relationship between relative demand and relative price as seen in many two-sector models.

This paper also contributes to another strand of literature on the relationship between business cycle fluctuations and health. Our DSGE model allows us to explore conditions at which health becomes pro- or counter-cyclical. We show that the cyclicality of health depends on several structural parameters, such as how effective medical care is in improving health, whether health contributes to the productivity of labor, and how fast health depreciates.

The next section reports empirical facts of health spending, health care inflation, and health status. In the third section, we introduce our model economy with health care demand and a two-sector model with homogeneous demand. In the fourth section, we provide details on model parameters, and then study the effect of a monetary policy shock and a policy shift. In the fifth section, we conduct various robustness analysis. The last section concludes.

II Stylized Facts on Health

A Facts on Health Spending

We study health spending in the US using the Personal Consumption Expenditure (PCE) from the Bureau of Economic Analysis.[2] The PCE uses broad categories of durable goods, nondurable goods, and services. Health spending is under the category of nondurable goods (e.g., drugs) and services (e.g., physician services, net payment on health insurance). For this exercise, we focus on health care services that constitute much of the overall health spending. Table 1 presents the detailed series in health care services and their price index. In the second quarter of 2013, the PCE for health care services totaled $1,902.9 billion, the second largest category within service after housing and utilities.

Table 2 shows the average growth rate of major type of products during the last three decades (1980Q1-2013Q2). On the one hand, nominal spending on health care services grew at an annual rate of 7.8% and average health care inflation during this period was 5.0%, outpacing the growth of the aggregate PCE average of 5.9% and the aggregate inflation of 2.9%. On the other hand, health spending in real terms grew only by 2.7%, slightly below the aggregate PCE average of 3.0%.

The time series of health spending is shown in Figure 1. We observe that the growth rate of PCE for health care services in real terms remained in close proximity to that of the aggregate PCE (panel (1)). The spending share of the PCE for health care services in

[2]There are several advantages using the PCE. First, the PCE covers a comprehensive list of health care services, including those financed by third-parties such as health insurance companies and government agencies. Second, the PCE is used to prepare the National Income and Product Account (NIPA), which is used by many government agents including the Federal Reserve in its policymaking process. Finally, the PCE ensures that price indexes are internally consistent with real quantities of spending through cross-checking different data sources, such as Economic Census, Service Annual Survey, Quarterly Services Survey.

real terms had a mild decline from 1980 to 2000, but it reverted back towards the sample mean of 16.6% after 2000 (panel (2)). Lastly, health care inflation was visibly higher than the aggregate inflation from 1980 to late 1990s, and moved closer to the aggregate inflation after 2000 (panel (3)).

Based on these results, we conclude that health care inflation is accountable for much of the rise in *nominal* health spending during the last three decades and that the fluctuation of real health spending has its unique pattern, occasionally deviating from the aggregate PCE.

B Facts on Health Care Inflation

Volatility and persistence of inflation are of particular interest to the policymaker because they directly relate to the objective of price stabilization. In this section, we first present volatility and persistence of inflation in the health care and other sectors, and then examine whether health care prices respond differently to a monetary policy shock.

A few issues arise when comparing inflation dynamics across sectors. One is that the volatility of large sectors that cover many items tends to be smaller than the volatility of small sectors because aggregation averages out idiosyncratic components. Another issue is that unobserved macroeconomic factors, such as trend inflation, could affect volatility and persistence of sectoral inflation, making them incomparable.[3] To overcome these complications, we decompose the individual inflation series into common macroeconomic factors and sector-specific components, and report the moments of the sector-specific components only. We use principal component analysis to generate the common factors for decomposition (Boivin *et al.*, 2009). The details of this approach are included in Appendix A.

[3]Reis and Watson (2010) report that 20% of the sectoral inflation dynamics can be explained by macroeconomic factors.

Table 3 summarizes the moments of the (filtered) inflation series for major service categories. The standard deviation of health care inflation is 0.4%, much lower than that for the PCE with all items (= 1.1%). This implies that the relative volatility of health care services is 0.39 (=0.4%/1.1%). The persistence for health care inflation is 0.56, twice as high as that for other services (= 0.26) and all items (= 0.24). Thus, the health care sector can be characterized by low volatility and high persistence relative to other sectors. The only sector that shares the same characteristics is education.

Next, we examine how health care prices respond to a monetary policy shock using the factor-augmented vector autoregression (FAVAR, Bernanke *et al.*, 2005) in Figure 2. FAVAR takes into account unobserved macroeconomic factors by using the common factors obtained through the principal component analysis. Details are provided in Appendix B.

On the one hand, the price of health care services responds mildly to an expansionary monetary policy shock (=negative innovation to the federal funds rate). This is particularly evident in comparison with aggregate PCE and items excluding health care services (panel (1)), and slightly less so when comparing health care services with other services (panel (3)). On the other hand, the output response of the health care sector is larger than that of items excluding health care services (panel (2)). The same pattern is observed when comparing health care services with other services (panel (4)).

C Facts on Health Status

In the past decade, there are many micro studies that examine the cyclicality of health. Findings of these papers are mixed depending on the health measure and time span used. For example, studies using total mortality as the health indicator tend to find health is countercyclical (for example, Ruhm, 2000; Neumayer, 2004) whereas studies using body weight and mental illness as the health indicator show that health is procyclical (for example, Charles and DeCicca, 2011; Latif, 2014). Several studies further suggest that the relationship between health and macroeconomic conditions may have become less cyclical in recent years (for example, Tekin, McClellan and Minyard, 2013; Ruhm, 2013; Stevens *et al.* 2011)

In this section, we examine the correlation between health and several macroeconomic variables. The purpose of this exercise is to produce some empirical moments to check model performance, rather than to provide direct evidence on the empirical relationship between health and unemployment as some of the micro studies do. For our health measure, we use a survey question in the National Health Interview Survey (NHIS). Since 1972, annual household surveys of illness and disability have been conducted for a large sample of non-institutionalized population, in which respondents are asked to rate their health based on a five-point scale from excellent to poor. We define health status as the percentage of the sample that says their health is good, very good, or excellent in a given year.[4] This variable is adjusted for sample weight so that it represents the overall population. Self-reported health is known to be correlated with mortality and highly predictive of physical functions.[5] In addition, it provides an *overall* evaluation of health status for individuals who are alive at the time of the interview. Self-reported health is likely to represent qualify of life, which is how we model health later.

In Table 4, we present correlation coefficients of our health measure and three macroe-

[4]The survey question is “Would you say ...s health in general is excellent, very good, good, fair, or poor?” Results are grouped into five categories during 1982 - 2012 and four categories (excellent, good, fair, or poor) during 1972-1981. Individuals who report their health being good and excellent during 1972-1981 are included in our health measure. On average, 91% of the sample report their health being good, very good, and excellent between 1972 and 2012.

[5]See for example, Idler and Kasl (1995).

conomic variables relevant to our model. We find that health status is positively and significantly correlated with real GDP per capita, GDP gap, and weekly hours worked during 1980-2012.[6] These results apply equally to the annual frequency data and the quarterly frequency data for which linear interpolation of the health measure is conducted.[7] The correlation of health and hours worked is smaller than the correlation with the GDP measures, possibly because health deteriorates with work. We show in a later analysis that our model can produce both pro- and counter-cyclical health depending on certain parameter values.

III The Health Care Model ("HC Model")

We first introduce the HC model and then highlight the differences between the HC model and a simpler two-sector model.

A Household

Our household utility function closely follows the functional form in Hall and Jones (2007). Utility monotonically increases with both regular goods spending C and health status X. More specifically, households maximize their expected lifetime utility

$$\max E_t \sum_{j=0}^{\infty} \beta^j \exp(e_{X,t+j}) \left[\frac{{C_{t+j}}^{1-\gamma_C}}{1-\gamma_C} + \frac{\eta_X {X_{t+j}}^{1-\gamma_X}}{1-\gamma_X} \right], \tag{1}$$

[6]We also constructed a health measure based on the average of the five categories (excellent, very good...). The signs and magnitudes of the correlations are very similar.

[7]Our results are not directly comparable to the findings of microeconomic studies in the literature. Here are some of the differences: (1) micro studies often examine total mortality or a specific illness whereas our health measure is defined as the percentage population above a particular health threshold in a given year. Mortality is often caused by external reasons (such as traffic accidents) whereas self-reported health likely reflects both physical and mental health; (2) many of the micro studies focus on the unemployment rate whereas we use hours worked conditional on employment. Unemployment rate reflects the extensive margin of employment whereas hours worked reflects the intensive margin; (3) micro studies often use state-level data (such as, state unemployment rate) whereas we use national-level data. This could make a difference because people may migrate based on economic opportunities; (4) we simply look at correlations and our sample period is different as well.

where β is the subjective discount factor, η_X is the utility weight on health status, and $e_{X,t} \sim N(0, \sigma_X^2)$ is the exogenous health shock. γ_C and γ_X are the inverse of the intertemporal elasticities of substitution (IES) for regular goods spending and health status, respectively. Health status X is subject to the following accumulation equation,

$$X_t = I_t^X + (1 - \delta_X) X_{t-1}, \tag{2}$$

where I_t^X is health investment and δ_X is the depreciation rate of health. Health investment is conducted by combining health spending and leisure in the following manner

$$I_t^X = \exp(e_{X,t}) (H_t)^{\kappa_H} (1 - N_t)^{\kappa_L}, \tag{3}$$

where H is health spending and $1 - N$ is (normalized) leisure hours defined as total hours minus hours spent working. κ_H and κ_L represent the elasticity of health investment with respect to "health input" H and $1 - N$. Households face the following budget constraint,

$$\frac{P_{R,t}}{P_t} C_t + \frac{P_{H,t}}{P_t} H_t + \frac{D_t}{P_t} = \frac{W_t}{P_t} N_t + \frac{R_{t-1}^n}{P_t} D_{t-1} + profit_t, \tag{4}$$

where D_t is a one-period nominal coupon bond maturing at time $t + 1$ that pays a gross nominal interest rate of R_t^n, W_t is the nominal wage determined in a competitive factor market, and P_t is the economy-wide aggregate price index, $P_{R,t}$ and $P_{H,t}$ are the price of regular goods and health care goods, respectively, and $profit_t$ is the sum of real profits collected from firms.

Let λ_X be the Lagrange multiplier on the health accumulation equation (Equation (2)) and λ_D be the Lagrange multiplier on the budget constraint (Equation (4)). The first order necessary conditions for optimization yield the following expressions for marginal rates of substitution and intertemporal efficiency conditions,

$$\frac{MU_{H,t}}{MU_{C,t}} = \frac{\kappa_H \lambda_{X,t} \frac{I_t^X}{H_t}}{\exp(e_{X,t}) C_t^{-\gamma_C}} = \frac{P_{H,t}}{P_{R,t}}, \tag{5}$$

$$\frac{MU_{1-N,t}}{MU_{C,t}} = \frac{\kappa_L \lambda_{X,t} \frac{I_t^X}{1-N_t}}{\exp(e_{X,t}) C_t^{-\gamma_C}} = \frac{W_t}{P_{R,t}}, \tag{6}$$

$$\frac{MU_{1-N,t}}{MU_{H,t}} = \frac{\kappa_L}{\kappa_H} \frac{H_t}{1-N_t} = \frac{W_t}{P_{H,t}}, \tag{7}$$

$$\lambda_{D,t} = \beta R_t^n E_t \left[\frac{\lambda_{D,t+1}}{\Pi_{t+1}} \right], \tag{8}$$

$$\lambda_{X,t} = \eta_X \exp(e_{X,t}) X_t^{-\gamma_X} + \beta(1-\delta_X) E_t \left[\lambda_{X,t+1} \right], \tag{9}$$

where MU_i ($i = C, H, 1-N$) is the marginal utility of regular goods spending, health spending, and leisure, and $\Pi_{t+1} = P_{t+1}/P_t$ is the gross inflation. The optimality conditions imply that the marginal utility of health input $H, 1-N$ is a product of two terms, i.e. the marginal utility of health status ($MU_X \equiv \lambda_X$) and the marginal product of each input with respect to health investment ($MP_H \equiv \kappa_H \frac{I^X}{H}$ and $MP_L \equiv \kappa_L \frac{I^X}{1-N}$).

There are a few points worth noting. First, the adoption of additive separable utility in Equation (1) implies that regular goods and health care goods are substitutes in raising households' utility.[8] Second, in our model the role of health shock is *twofold*, one as an intertemporal preference shock that affects how households smooth consumption and health status over time (Equation (1)), and the other similar to the labor supply shock in a conventional model that affects how households value leisure relative to consumption in a given period (Equation (3)).[9] Third, the choice of the Cobb-Douglas function for health investment

[8]Hall and Jones (2007, p49) justify the use of additive separability by arguing that such preference is a natural intermediate case in which the marginal utility of consumption neither rises nor falls with the change in health status.

[9]For example, a positive health shock today increases the marginal utility of both consumption and health status, making households want more of *both*. The positive shock also makes households value health status relatively more because the marginal utility of health status rises further relative to consumption.

(Equation (3)) implies that H and $1-N$ have unit elasticity of substitution.[10] While these model assumptions can be relaxed, we do not further pursue them for the sake of clarity of the model structure.

B Producers

On the supply side, we introduce sector heterogeneity similar to Barsky *et al.* (2007) and Erceg and Levin (2006). There are two sectors in our model: the regular goods sector ($k = R$) and the health care sector ($k = H$).[11]

The final good producers in both sectors purchase differentiated goods $Y_k(z)$ from the corresponding intermediate goods producers who are indexed along the unit interval $z = [0, 1]$. The purchased goods are then aggregated into the sectoral good Y_k as in Dixit and Stiglitz (1977),

$$Y_{k,t} = \left(\int_0^1 Y_{k,t}(z)^{\frac{\epsilon_k - 1}{\epsilon_k}} dz \right)^{\frac{\epsilon_k}{\epsilon_k - 1}}, \tag{10}$$

where ϵ_k is the elasticity of substitution across varieties of intermediate goods. Taking prices $P_{k,t}(z)$ as given and solving the cost minimization problem subject to (10) yields the within-sector demand curve,

$$Y_{k,t}(z) = \left(\frac{P_{k,t}(z)}{P_{k,t}} \right)^{-\epsilon_k} Y_{k,t}, \tag{11}$$

and the sectoral price index of

$$P_{k,t} = \left(\int_0^1 P_{k,t}(z)^{1-\epsilon_k} dz \right)^{\frac{1}{1-\epsilon_k}}.$$

[10]There are opposing views as to whether time and health care are complements (as modeled in Grossman, 1972) or substitutes. Recent medical literature has shown that better night sleep, time spent on physical activities, cooking and eating meals at home (as opposed to fast food) enhance health, thus individuals may not need as much medical care. The Cobb-Douglas functional form provides both substitutability and complementarity between health input, allowing us not to take an extreme stance on this debated issue.

[11]In our model, health care "goods" covers both goods and services following the PCE categorization.

The sectoral final goods $Y_{R,t}$, $Y_{H,t}$ are absorbed as either private spending or government spending. Thus we have

$$Y_{R,t} = C_t + G_{C,t}, \tag{12}$$

$$Y_{H,t} = H_t + G_{H,t}. \tag{13}$$

The aggregate output in both nominal and real terms is defined following the GDP definition,

$$P_t Y_t = P_{R,t} Y_{R,t} + P_{H,t} Y_{H,t}, \tag{14}$$

$$Y_t = \frac{\overline{P_R}}{\overline{P}} Y_{R,t} + \frac{\overline{P_H}}{\overline{P}} Y_{H,t}, \tag{15}$$

where $\overline{P_R}/\overline{P}$, $\overline{P_H}/\overline{P}$ are steady-state relative prices for the two goods. The aggregate price index P_t is implicitly defined as the GDP deflator through (14) and (15).

Following the new Keynesian model of Gali (2008), we assume that the intermediate firm z in each sector hires labor N_t from the competitive nationwide labor market to produce intermediate goods. The firm's production constraint is given as

$$Y_{k,t}(z) = A^s_{k,t} \left(N_{k,t}(z)\right)^{\mu_N} \left(X_t\right)^{\mu_X}, \tag{16}$$

where μ_N measures how efficiently labor is used in producing output and μ_X measures how the (nationwide) health status contributes to labor productivity. The sectoral productivity shock $A^s_{k,t}$ is defined as

$$A^s_{k,t} = (A^s_{k,t-1})^{\rho^s_k} \exp\left(e^s_{k,t}\right), \text{ where } e^s_{k,t} \sim N\left(0, (\sigma^s_k)^2\right). \tag{17}$$

Labor demand can be obtained through solving the cost minimization problem subject to (16) while taking the nationwide real wage $w_t \equiv W_t/P_t$ and health status as given. This yields the following first order necessary condition,

$$MC_{k,t} = \frac{1}{\mu_N A^s_{k,t}} w_t \left(N_{k,t}\right)^{1-\mu_N} \left(X_t\right)^{-\mu_X}, \tag{18}$$

where $MC_{k,t}$ is the sector-specific real marginal cost. Total labor demand has to satisfy the following constraint,

$$N_t = N_{R,t} + N_{H,t}. \tag{19}$$

We assume that a randomly assigned fraction ρ_k of intermediate goods firms is prohibited from adjusting their prices in each period. Within each sector, price-adjusting firms' profit maximization problem can be written as

$$\max_{P_{k,t}} E_t \sum_{j=0}^{\infty} \rho_k^j \Delta_{k,j,t+j} \left[\frac{P_{k,t}}{P_t} - MC_{k,t+j} \right] Y_{k,t+j},$$

where $\Delta_{k,j,t+j}$ is the j-period ahead stochastic discount factor for the firm in sector k. The first order necessary condition for the optimal price is

$$P_{k,t}^* = \frac{\epsilon_k}{\epsilon_k - 1} \frac{E_t \sum_{j=0}^{\infty} \rho_k^j \Delta_{k,j,t+j} MC_{k,t+j} \left(P_{k,t+j}\right)^{\epsilon_k} Y_{k,t+j}}{E_t \sum_{j=0}^{\infty} \rho_k^j \Delta_{k,j,t+j} \left(P_{k,t+j}\right)^{\epsilon_k - 1} Y_{k,t+j}}, \tag{20}$$

where $P_{k,t}^*$ is the optimal price set by the adjusting firms. The sectoral price index can be rewritten in a fixed-distributed lag form,

$$\begin{aligned} P_{k,t} &= \left[\int_0^1 P_{k,t}(z)^{1-\epsilon_k} dz \right]^{\frac{1}{1-\epsilon_k}} \\ &= \left[(1-\rho_k) \left(P_{k,t}^*\right)^{1-\epsilon_k} + \rho_k \left(P_{k,t-1}\right)^{1-\epsilon_k} \right]^{\frac{1}{1-\epsilon_k}}. \end{aligned} \tag{21}$$

C Government

We assume that fiscal policy provides an additional disturbance to the economy,

$$G_{j,t} = \left(G_{j,t-1}\right)^{\rho_j^d} \exp\left(e_{G,t}\right), \text{ where } e_{G,t} \sim N(0, \sigma_G^2), \tag{22}$$

and $j = C, H$. Monetary policy follows the modified Taylor rule with partial adjustment

$$R_t^n = \left(R_{t-1}^n\right)^{\rho_n} \left[\left(\Pi_t\right)^{\rho_\Pi} \left(Y_t\right)^{\rho_Y} \right]^{1-\rho_n} S_{M,t}, \tag{23}$$

where today's interest rate is set according to the realized inflation, output gap, and the interest rate in the previous period, and $S_{M,t}$ is the monetary policy shock.[12] The monetary policy shock $S_{M,t}$ is defined as

$$S_{M,t} = (S_{M,t-1})^{\rho_M} \exp(e_{M,t}), \text{ where } e_{M,t} \sim N(0, \sigma_M^2). \tag{24}$$

D The Two-Sector Model

To compare the HC model and traditional models, we prepare a simpler model with two sectors ("TS model" hereafter). The basic structure of the TS model closely follows the conventional two-sector model in the new-Keynesian literature (Aoki, 2001; Erceg and Levin, 2006), and to save space, the details of the model are delegated to Appendix C. On the supply side, the TS model shares many model equations with the HC model.[13] On the demand side, demand for health care is modeled as part of the aggregate spending and the resulting first order necessary conditions imply

$$\frac{Y_{R,t}}{Y_{H,t}} = \frac{\omega}{1-\omega}\left(\frac{P_{R,t}}{P_{H,t}}\right)^{-1}, \tag{25}$$

where $0 < \omega < 1$ represents the (nominal) spending share of regular goods. This equation states that the demand for sectoral goods is inversely proportional to the relative price. The implied relationship between price and quantity is much simpler than the equivalent equation in the HC model (equation (5)).

[12] We also conducted analysis using a forward-looking Taylor rule specification (not shown). For the one-quarter forecast horizon, results are almost unchanged from the baseline specification in the paper. For the four-quarter forecast horizon, we encounter indeterminacy of the equilibrium.

[13] One notable difference is that in the TS model health status neither contributes to the production process nor affects sectoral marginal costs.

IV Model Analysis

In this section, we introduce model parameters and then examine model dynamics using stochastic simulation and impulse responses. The implication of the HC model under a monetary policy shift is provided at the end of the section. The linearized model equations used in the simulation are shown in Appendix D.

A Model Parameterization

The parameter values we choose reflect quarterly frequency, the same as the moments reported in Section II, and they are shown in Table 5.

1 Common Parameters

For the parameters that are common in both models, we largely follow the convention in the literature. The discount factor is set to imply a 2.5% annual real return. The income share of labor is two-thirds. The elasticity of demand is set to be the same across sectors, implying a steady-state markup of 10%. The IES parameter for consumption is 2, following Hall and Jones (2007). The steady state level of labor is set to 0.38.[14]

The price stickiness parameter for the regular goods sector is set to 0.5, which implies an average duration of six months between price changes. Based on the estimates in Bils and Klenow (2004), the price stickiness for the health care sector is set to 0.81, implying an average duration of 15.9 months between price changes.[15]

[14]This value does not include time associated with home production, such as, household chores and child care. According to Rupert *et al.* (2000), time used in home production (excluding sleeping time) accounts for 18% of total time.

[15]Specifically, we chose six health care services listed in their appendix and recalculated the weighted mean duration based on the reported expenditure weights. These six services are (a) hospital services, (b) physicians services, (c) dental services, (d) services by other medical professionals, (e) care of invalids, elderly, and convalescents in the home, (f) nursing and convalescent home care.

For the steady-state expenditure share of health spending in the HC model, we apply the value of 0.166 based on the average during our sample period. The same value is used to pin down ω in the production function in the TS model. The steady-state government spending share of output is set to 0.21 in the TS model, based on historical observations in the US. We apply the same government spending share for health care goods in the HC model so that simulation outcome is comparable across models.

We set the labor supply elasticity to unity following Ham and Reilly (2013).[16] For the TS model, labor supply elasticity can be implicitly calculated as

$$\varepsilon_w^{TS} = \frac{1}{\gamma_N} \frac{1 - \overline{N}}{\overline{N}},$$

which is determined by the curvature parameter on labor γ_N and the steady state level of labor $\overline{N}$. We set γ_N to 1.65 so that together with $\overline{N} = 0.38$, we have $\varepsilon_w^{TS} = 1$.

2 Parameters Specific to the Health Care Model

There are five parameters (μ_X, δ_X, γ_X, κ_L, κ_H) unique to the HC model. These health-related parameters are difficult to pin down because there are few studies estimating them. To simplify the model and highlight the role of health spending and leisure, we set the technology parameter μ_X to zero and the depreciation rate of health δ_X to one in the baseline specification. In the robustness analysis, we examine model performance under more reasonable parameter values.

The intertemporal elasticity of substitution with respect to health status ($1/\gamma_X$) captures how averse households are to the fluctuation in health status. The larger γ_X is, the quicker the marginal utility of health status falls in response to the rise in health status (equation

[16] Empirical estimates can vary by much depending on the data and methods used. See for example, Blundell *et al.* (1998), French (2004), and Ziliak and Kniesner (1999).

(9)). To prevent the marginal utility from falling too quickly, households may "smooth" their health status over time by cutting down either health spending or leisure. We prepare our own estimate of γ_X using the self-reported health status introduced in section II C and Euler equations (8) and (9). The method described in Appendix E yields a value of 5.46.

Once we assume $\delta_X = 1$, the labor supply elasticity in the HC model can be expressed as follows,

$$\varepsilon_w^{HC} = \frac{1}{1 - \kappa_L (1 - \gamma_X)} \frac{1 - \overline{N}}{\overline{N}}. \tag{26}$$

We set κ_L to 0.15 so that together with $\gamma_X = 5.46$ and $\overline{N} = 0.38$, we have $\varepsilon_w^{HC} = 1$ (unit elasticity).

Although there is no direct estimate of κ_H in aggregate, many studies in the medical literature show that medical treatment improves health. Hall and Jones (2007) provide their own estimates of the effectiveness of health care for different age cohorts. We adopt their estimate of 0.25 (for the middle aged group, 40-50 years old) as our baseline value.

3 Policy and Shock Parameters

The monetary policy parameters follow the estimates of English *et al.* (2003), which allows for the extrinsic inertia process. The persistence of the monetary policy shock takes the value of the autoregressive parameter for the serially correlated errors in their paper.[17] To simplify analysis, we set the persistence of the government policy shock the same in regular goods and health care goods spending. Likewise, we set the persistence of the sectoral productivity shocks the same. These values are uniformly set at 0.75.

[17] We also experimented with another set of policy parameters in English *et al.* (2003) that assume the autoregressive parameter for serially correlated errors to be zero. This set of parameters are ρ_π=1.70, ρ_y=0.26, ρ_n=0.72, and ρ_M=0. We find slightly lower correlation between health and labor and slightly lower volatility for health care inflation. The main findings using the alternative parameters are qualitatively similar as our baseline.

The standard deviations of the monetary and fiscal policy shocks are calibrated based on Smets and Wouters (2005). We apply the size of the aggregate productivity shock in their paper for our sectoral productivity shocks and apply the size of the preference shock for our health shock. To facilitate comparison, the size of the preference shock and the labor supply shock in the TS model is set to equal the size of the health shock in the HC model.

B Simulation Results

We first look at the unconditional moments generated using the HC model and then compare them with the empirical counterparts. For simulation, we generate artificial time series of one million periods while activating all stochastic shocks at once. Results are shown in Table 6.

We use output (y) and normalized labor hours (n) as business cycle measures.[18] The correlation coefficients between health status and output and between health status and labor hours are 0.68 and 0.71, respectively. The correlation between health status and output is close to the empirical counterparts reported in Table 4. The correlation between health status and labor hours is somewhat larger in the model than in the data. This number becomes smaller once we allow certain parameters to vary and these results are discussed in section V. The volatility of health care inflation relative to aggregate inflation is 0.44, consistent with the observed low volatility in Table 3. The HC model is also able to generate higher persistence of health care inflation relative to aggregate inflation (0.78 versus 0.48).[19]

The impulse responses of inflation and output after an unanticipated one standard de-

[18] Variables denoted in lower case letters or with a tilde are measured in deviations from the steady state.

[19] We do not attempt to exactly match the absolute level of relative volatility and persistence in the model with those in the data. This is because in obtaining these measures from data, we used the principal component analysis that removed the effect of the common macroeconomic factors, and obtained the average of the disaggregated series. Both procedures cannot be performed in simulation.

viation decline in the nominal interest rate are shown in Figure 3. We observe that the monetary policy shock increases both the aggregate inflation (π) and the sectoral inflation (π_R, π_H). The response of regular goods inflation closely resembles aggregate inflation, whereas the initial response of health care inflation is much more muted, reflecting the higher price stickiness in the health care sector. We also observe that the aggregate output (y) and sectoral output (y_R, y_H) respond positively to the expansionary monetary policy. Output in the health care sector responds stronger than output in the regular goods sector. These responses are consistent with our empirical finding in Figure 2.

C The Role of Health Care Demand

From Table 6, we see that the relative volatility and persistence of health care inflation generated using the HC model are closer to those in the data comparing with the moments generated using the TS model. We explore the mechanism below.

There are two key mechanisms that transmit the monetary policy shock in the HC model. The first mechanism, which also exists in the TS model, is the relative price channel. When the interest rate is lowered, demand for both regular and health care goods is stimulated (equation (8)), causing prices to rise in both sectors. Due to the higher price stickiness in the health care sector, the price of regular goods rises relatively more. This higher relative price of regular goods triggers a substitution from regular goods to health care goods. As a result, the equilibrium output of health care goods rises further.

The second mechanism is the health status channel. This channel is only present in the HC model. We illustrate the health status channel in the bottom two panels of Figure 3 with the following steps.

1. The expansionary monetary policy shock stimulates spending on both regular goods and health care goods through equation (8). The higher demand also increases the demand for labor, pushing up the equilibrium wage.

2. The higher health spending in Step 1 results in higher health status x and lower marginal utility of health status mu_x (panel (3)).

3. Households increase labor supply in response to the higher wage in Step 1. Marginal product of leisure with respect to health investment mp_l increases because leisure becomes scarce relative to health spending. Marginal utility of leisure mu_l falls on impact because the rise in marginal product of leisure (dash line, panel (4)) is dominated by the fall in marginal utility of health status (dash-dotted line, panel (3)).

4. In the subsequent periods, the fall in the marginal utility of health status in Step 2 applies downward pressure on the marginal utility of leisure (dash-dotted line, panel (4)).

5. The "reduced" marginal utility of leisure in Step 4 effectively enables households to spend less time on leisure and work longer hours (solid line, panel (4)). This amplifies the equilibrium response of the *aggregate* output.

In Figure 4, we compare the impulse responses of the HC and the TS model under the same monetary policy shock. First, we observe that the response of health care inflation in the HC model is smaller than that in the TS model (panel (3)). This is because the rise in health status in the HC model results in a subdued health care demand, which adds downward pressure onto the marginal cost of health care goods in equilibrium.

Second, the response of the aggregate output is stronger in the HC model (panel (4)). This is because the improved health status applies downward pressure on the marginal utility of leisure, inducing households to work longer hours (panel (7)). The rise in the relative price (panel (8)) further causes a substitution from regular goods to health care goods (panel (5)-(6)). This substitution is smaller in the HC model because health status mitigates the substitution mechanism (equation (5)). As a result, health care goods output increases less and regular goods output increases more in the HC model. Because the regular goods sector is larger than the health care sector, the response of the aggregate output is amplified.[20]

D The Monetary Policy Shift

The main purpose of monetary policy is to remove the distortionary effect of price changes, which is analogous to minimizing the volatility of aggregate inflation. However, once we assign unique roles to individual sectors, monetary policy may have an asymmetric effect on the volatility of sectoral inflation. In this subsection, we examine how the volatility of the aggregate and sectoral inflation changes under a monetary policy shift.

We consider a hypothetical policy shift in which the policymaker assigns a higher priority to output stabilization relative to inflation stabilization. This is modeled as a simultaneous change in the policy coefficient ρ_π from 1.83 to 1.50 and ρ_y from 0.21 to 0.25. This policy shift effectively sets the slope of the aggregate demand curve "steeper", i.e. demand shock of a given size would have a larger destabilizing effect on inflation relative to output.

The same stochastic simulation under the new monetary policy rule is conducted. Table 7 shows that after the policy shift the standard deviation of health care inflation rises by

[20] If we allow μ_X to take a positive value in the HC model, the output response becomes slightly larger and inflation smaller than those in Figure 4, but the change is almost invisible in the impulse response.

only 3.69% in the HC model versus 23.67% in the TS model. This is because in the HC model households can freely combine health spending with leisure to change health status (equation (5)). In addition, the change in the volatility of inflation is very different across sectors in the HC model: the volatility of health care inflation increases by 3.69% compared with 13.80% for regular goods inflation. Such asymmetry is non-existent in the TS model, implying that price stickiness alone does not produce much asymmetry across sectors.

V Robustness Check

In this section, we examine model outcome under alternative parameterization and study the cyclicality of health.

A Elasticity of Health Investment

The two parameters that may affect model outcome are the elasticity of health investment with respect to health spending κ_H and leisure κ_L.

Literature on the effectiveness of health spending generally agrees that medical treatment improves health (Cutler and McClellan, 2001; McClellan *et al.*, 1994), though there is disagreement about how effective medical care is as health spending increases (the so-called "flat-of-the curve" phenomenon).[21] In this exercise, we use the estimates in Hall and Jones (2007) for different age groups for κ_H. Their estimates range from 0.04 for elderly to 0.4 for infants. Literature on the effectiveness of leisure in improving health is mixed. Some studies

[21] Recent studies attribute as much as 50% of life expectancy increase to medical spending alone (Cutler *et al.*, 2006; Ford, 2007), while several studies note that the effectiveness of health spending has been diminishing in recent years. For example, Cutler *et al.* (2006) find that the cost of per year of life rose in the 1990s compared to earlier years. For more on the "flat-of-the curve" phenomenon, see for example, Garber and Skinner (2008).

show that working longer hours negatively impacts health (Bell *et al.*, 2012; Caruso, 2006; Shields, 1999), while others suggest that *too much* leisure (e.g., unemployment) can result in an increased probability of mortality (Catalano, 2009; Eliason and Storrie, 2009; Sullivan and von Wachter, 2009). Thus, it is reasonable to conjecture that leisure has a positive effect on health investment with diminishing returns, i.e. $0 < \kappa_L < 1$.

For robustness check, we use two sets of parameters: $[\kappa_H, \kappa_L]$= $[0.04, 0.99]$ and $[0.40, 0.01]$. This first set assumes that health spending is not very effective in improving health and health investment is mainly through leisure, and the second set assumes the opposite. The impulse responses from the same monetary policy shock are shown in Figure 5. The alternative parameterization has almost no effect on aggregate inflation, and the responses of aggregate output, health care inflation and output are also qualitatively similar to the baseline. These parameters mainly alter the response of health status and marginal utility of leisure (bottom two panels of Figure 5). For example, under $[\kappa_H,\ \kappa_L] = [0.04, 0.99]$, health status responds *negatively* to the expansionary monetary policy shock, contrary to the baseline result. This occurs because the negative health effect of having less leisure is so large that it cannot be offset by the increase in health spending (which is assumed to be less effective than the baseline).

B "Health Smoothing"

As we mentioned earlier, a higher γ_X (or lower IES) implies that households are more willing to smooth health status over time. There is no direct estimate of this parameter in the literature. Hall and Jones (2007) uses the non-accidental mortality rate as the health measure and estimate this parameter to be 1.05. Although their health status is different from the quality of life aspect stressed in our model, we nevertheless use their estimate as the lower bound value in our robustness analysis. For the upper bound, we pick the value of 10, which is within the range of estimates for the (implied) IES for consumption in the literature.

Figure 6 shows the impulse response of selected variables to the expansionary monetary policy shock. When $\gamma_X = 10$, health care inflation and output both rise by a little less than in the baseline. A larger γ_X "magnifies" the negative response of marginal utility of health status, further inducing households to work longer hours, which enhances the positive response of aggregate output. Overall the impact of this parameter on inflation measures is quantitatively small.

C Cyclicality of Health and Moments for Inflation Revisited

In this subsection, we examine how alternative parameterization affects the cyclicality of health using stochastic simulation. We also examine whether our model outcome changes if we allow health to depreciate slowly ($0 < \delta_X < 1$) and to increase productivity ($\mu_X > 0$). We set $\delta_X = 0.0015$ based on Cutler and Richardson (1997), implying an annual depreciation rate of 0.6%.[22] We set $\mu_X = 0.04$ based on Bloom *et al.* (2004)'s estimates of how life expectancy affects labor productivity.[23] Table 8 shows the moments obtained using the HC model under alternative parameterization. We alter parameters one at a time while keeping the baseline value fixed for other parameters. We also provide another scenario in which

[22]Cutler and Richardson (1997) calculated QALYs for various diseases, such as diabetes, hypertension, heart disease, arthritis, etc, and obtained age-specific QALYs for men and women separately (see Figure 7 in their paper). They assume the QALY is 1 for newborn. Their estimates of QALYs for men at age 16 and 64 are 0.96 and 0.72, respectively. Using these numbers, we calculated the implied depreciation rate of health is 0.597% annually. For women, the annual depreciation rate is 0.561%, which corresponds to the QALYs of 0.93 and 0.71 at age 16 and 64.

[23]The economic growth literature has noted that a higher life expectancy increases output growth, especially in developing countries. Estimates of the elasticity of output with respect to life expectancy range from 0.02 to 0.07. Bloom *et al.* (2004)'s estimate falls within that range.

changes occur for all parameters at the same time.

There are several findings. First, health status becomes less procyclical (particularly with labor) when health spending is less effective and leisure is more effective in health investment (when $[\kappa_H, \kappa_L] = [0.04, 0.99]$). This is because labor becomes more "costly" for health under new parameterization. Second, health status becomes less procyclical when households are less willing to smooth their health status over time (when γ_X=1.05). A smaller γ_X mitigates the positive effect of health status on output by making marginal utility of health status less responsive, leading to weaker co-movement of health and output. Third, introducing health depreciation in our model reduces the cyclicality of health significantly (when δ_X=0.0015). The sluggish dynamics of health status effectively breaks the contemporaneous link between health input and health status, making health status weakly linked to the business cycle. Lastly, when health status is allowed to contribute to production (when $\mu_X = 0.04$), the correlation between health status and output increases and the correlation between health status and labor decreases. The former occurs because health status adds to the productivity of labor while the latter occurs because improved health status allows firms to reduce labor as an input for production. Lastly, when we apply alternative values for all the parameters at once, the correlation between health and labor becomes negative. This scenario is consistent with the studies that find health to be countercyclical (for example, Ruhm, 2000, 2003).

The moments of inflation under alternative parameterization are shown in the last two columns of Table 8. The relative volatility of health care inflation varies between 0.43 and 0.63 whereas the persistence of health care inflation varies between 0.78 and 0.86. In several cases, the relative volatility and persistence are larger than those in the data, but they are within a reasonable range.

VI Concluding Remarks

This paper studies the role of monetary policy in relation to health care inflation, which is increasingly becoming an important policy topic in today's aging society. We show that health care inflation is accountable for much of the increase in nominal health spending in the past 30 years, and it is less volatile and more persistent than aggregate inflation and inflation in other service sectors. Under an expansionary monetary policy shock, health care inflation does not increase as much compared with aggregate inflation and other service items.

Based on the empirical findings, we construct a DSGE model that distinguishes the health care sector from the regular goods sector. This model includes health in the utility function and allows health spending and leisure to play a role in improving health status. Comparing with a traditional two-sector model that does not feature health care demand, the health care model can better replicate the empirical facts of health care inflation. It also yields a larger response in aggregate output and a notably smaller response in health care inflation under an expansionary monetary policy shock. We show that the main mechanism that drives the difference between the two models is the response of health status and labor supply. Another implication of our model is that a hypothetical policy shift would cause asymmetric stabilization in the volatility of inflation across sectors. This would necessarily complicate the policymaker's goal of minimizing the distortional effect of inflation on the economy.

There are several ways to extend our paper. First, in the simulation we assume zero steady state level of inflation for both the health care sector and the regular goods sector.

Wolman (2011) and others have worked on models in which average sectoral inflation is allowed to differ in the long run. It may be helpful to explicitly incorporate non-zero steady state inflation in future work. Second, our model assumes separability between health status and consumption. As Finkelstein *et al.* (2013) point out, marginal utility of consumption may depend on health status. Allowing dependency between consumption and health status may be a meaningful step forward.

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Table 1: List of Health Care Services

Category	Type of service	Price index
Outpatient Services	Physicians	PPI for offices of physicians
	Dentists	CPI for dental services
	Home health care	PPI for home health care
	Specialty outpatient care facilities, and health allied services	PPI for medical laboratories, diagnostic imaging centers
	All other professional medical services	CPI for services by other medical professionals
Hospitals	Nonprofit hospitals	PPI for hospitals
	Proprietary hospitals	
	Government hospitals	
Nursing homes	Nonprofit nursing homes	PPI for nursing care facilities
	Proprietary nursing homes	
	Government nursing homes	

Note: type of service corresponds to the Personal Consumption Expenditures series from the Bureau of Economic Analysis. The corresponding price index is obtained from the Bureau of Labor Statistics.

Table 2: Summary Statistics by Major Type of Products

	Nom. spending growth rate	Real spending growth rate	Inflation	Share in real PCE
PCE, aggregate	5.9%	3.0%	2.9%	100%
Goods	5.0%	3.3%	1.7%	34.0%
Services	6.6%	2.8%	3.7%	66.0%
Health care services	7.8%	2.7%	5.0%	16.6%
Excl. health care services	6.3%	2.9%	3.3%	49.4%

Note: the numbers in columns 2-4 are the mean growth rate for each category. Growth rates are annualized using quarterly data. All statistics are based on NIPA Tables 2.4.4 and 2.4.5. The sample period is 1980Q1-2013Q2 and the share in real PCE is calculated based on 2013Q2.

Table 3: Volatility and Persistence of Inflation Measures

	Standard deviation	Relative volatility	Persistence	Share in real PCE
PCE, all items (342)	1.1	1	0.24	100.0%
Goods (143)	1.3	1.23	0.19	34.0%
Services (157)	1.0	0.93	0.28	66.0%
Health care services (13)	0.4	0.39	0.56	16.6%
Excl. health care services (144)	1.1	0.97	0.26	49.4%
Housing and utilities (17)	0.8	0.78	0.56	18.4%
Financial / insurance (20)	2.8	2.63	0.19	7.1%
Food / accommodations (15)	0.4	0.39	0.24	6.3%
Recreation services (22)	0.6	0.54	0.22	3.7%
Transportation (17)	1.4	1.28	0.06	2.8%
Communication (7)	1.6	1.49	0.19	2.4%
Education services (7)	0.4	0.41	0.54	2.2%
Professional (9)	0.7	0.60	0.22	1.4%

Note: the numbers in the parentheses are the number of series in each category. We report the average of the individual series within each categories. For example, for health care services, the standard deviation is the average of the thirteen individual series. The sample period is 1980Q1 - 2013Q2 and the share in real PCE is calculated based on 2013Q2.

Table 4: Correlation of Health Status and Macroeconomic Conditions

Macroeconomic Variables	Correlation (annual freq.)	Correlation (quarterly freq.)
Real GDP per capita	0.69	0.68
(p-value)	(0.00)	(0.00)
GDP Gap	0.56	0.55
(p-value)	(0.00)	(0.00)
Weekly hours worked	0.55	0.48
(p-value)	(0.00)	(0.00)

Note: the health measure is based on a question from the National Health Interview Survey, which asks the respondent to rate their own health in one of the five categories. We construct health status as the percentage of the sample reporting good, very good, and excellent health in a given year. The quarterly frequency health measure is constructed using linear interpolation from the annual data. Real GDP per capita is real GDP divided by total population. Real GDP per capita is detrended using the residuals from regressing the log of real GDP per capita on a linear trend. GDP gap is calculated using logged real GDP minus logged potential GDP. All macroeconomic variables are seasonally adjusted except for potential GDP. They are obtained from the FRED website. Sample period is 1980 - 2012.

Table 5: Baseline Parameters

Parameters	HC model	TS model
Discount factor $\beta = 1/\overline{R}$	0.994	0.994
Labor share μ_N	0.67	0.67
Elasticity of demand $\epsilon_R = \epsilon_H$	11	11
(Inverse of) IES for consumption γ_C	2	2
Steady state labor $\overline{N}$	0.38	0.38
Price stickiness ρ_R	0.5	0.5
Price stickiness ρ_H	0.81	0.81
Policy parameter ρ_π	1.83	1.83
Policy parameter ρ_y	0.21	0.21
Policy parameter ρ_n	0.58	0.58
Shock persistence ρ_M	0.75	0.75
Shock persistence $\rho_H^s = \rho_R^s$	0.75	0.75
Shock size σ_M	0.0013	0.0013
Shock size $\sigma_H^s = \sigma_R^s$	0.0036	0.0036
Shock size σ_G	0.0043	0.0043
Elasticity of health investment κ_L	0.15	
Elasticity of health investment κ_H	0.25	
(Inverse of) IES for health γ_X	5.46	
Depreciation rate for health δ_X	1	
Health share μ_X	0	
Health spending share of output $\frac{\overline{H}+\overline{G}_H}{\overline{Y}}$	0.166	
Government spending share of output $\frac{\overline{G}_C}{\overline{Y}_R} = \frac{\overline{G}_H}{\overline{Y}_H}$	0.21	
Shock persistence $\rho_H^d = \rho_C^d$	0.75	
Shock size σ_X	0.0040	
Curvature parameter on labor γ_N		1.65
Health spending share of output $1-\omega$		0.166
Government spending share of output $\frac{\overline{G}}{\overline{Y}}$		0.21
Shock persistence ρ_G		0.75
Shock size $\sigma_I = \sigma_L$		0.0040

Table 6: Relative Volatility and Persistence of Inflation Series

	HC model	TS model
Correlation:		
Health status and output, $corr(x, y)$	0.68	n.a.
Health status and labor, $corr(x, n)$	0.71	n.a.
Relative volatility of inflation:		
HC goods to Aggregate, $std(\pi_H)/std(\pi)$	0.44	0.58
Regular goods to Aggregate, $std(\pi_R)/std(\pi)$	1.16	1.12
HC goods to Regular goods, $std(\pi_H)/std(\pi_R)$	0.38	0.51
Persistence of inflation:		
Aggregate, $corr(\pi_t, \pi_{t-1})$	0.48	0.49
HC goods, $corr(\pi_{H,t}, \pi_{H,t-1})$	0.78	0.85
Regular goods, $corr(\pi_{R,t}, \pi_{R,t-1})$	0.47	0.45

Note: moments are calculated from artificial time series of one million periods. Variables are expressed in terms of deviation from the steady state. Relative volatility is calculated as the ratio of standard deviations and persistence is calculated as the one-period autocorrelation coefficient. All model variables are in quarterly frequency.

Table 7: Change in Volatility Before and After a Policy Shift

	HC model			TS model		
	Before shift	After shift	$\Delta\%$	Before shift	After shift	$\Delta\%$
Volatility of inflation:						
Aggregate, $std(\pi)$	0.419	0.476	13.73%	0.463	0.582	25.75%
HC goods, $std(\pi_H)$	0.183	0.190	3.69%	0.267	0.330	23.67%
Regular goods, $std(\pi_R)$	0.486	0.553	13.80%	0.518	0.650	25.39%

Note: moments are calculated from artificial time series of one million periods. Variables are expressed in terms of deviation from the steady state. Volatility is calculated as standard deviations expressed in percent. Policy shift is modeled as a simultaneous change in the policy coefficient ρ_π from 1.83 to 1.5 and ρ_Y from 0.21 to 0.25. $\Delta\%$ denotes percentage change in standard deviation before and after the policy shift. All model variables are in quarterly frequency.

Table 8: Robustness Analysis

	Correlation: with output $corr(x,y)$	with labor $corr(x,n)$	Rel.volatility of HC inflation $std(\pi_H)/std(\pi)$	Persistence of HC inflation $corr(\pi_{H,t},\pi_{H,t-1})$
Baseline	0.68	0.71	0.44	0.78
κ_H=0.04, κ_L=0.99	0.54	0.22	0.54	0.84
γ_X= 1.05	0.51	0.30	0.58	0.85
δ_X = 0.0015	0.16	0.13	0.63	0.86
μ_X = 0.04	0.69	0.70	0.43	0.78
Change all parameters	0.05	-0.06	0.62	0.85

Note: moments in the model are calculated from artificial time series of one million periods. Variables are expressed in terms of deviations from the steady state. All model variables are in quarterly frequency.

Figure 1: Personal Consumption Expenditure of Health Care Services: Growth Rate, Share, and Inflation
Note: panel (1) presents the time series plot of the growth rates of the aggregate real personal consumption expenditure (solid line) and real personal consumption expenditure for health care services (dash-dotted line). Panel (2) presents the share of real personal consumption expenditure for health care services (solid line) and its average for the entire sample period (dash-dotted line). Panel (3) presents the aggregate inflation (solid line) against health care inflation (dash-dotted line).

Figure 2: Impulse Responses of Prices and Output to a Monetary Policy Shock using Factor-augmented Vector Autoregression
Note: panel (1) and (2) present the impulse responses of aggregate prices and outputs (solid line), items excluding health care services ("Items excl.HCS", dashed line), and health care services ("HCS", dash-dotted line) to a negative innovation to the federal funds rate (="m shock"). Panel (3) and (4) present the impulse responses of prices and outputs for services (solid line), services excluding health care services (dashed line), and health care services (dash-dotted line), to the same negative innovation.

Figure 3: Impulse Responses of Inflation, Output, Health Status, and Leisure using the Health Care Model
Note: panel (1) and (2) present the impulse responses of inflation and output series to a negative innovation to the nominal interest rate. The solid line represents responses at the aggregate level, the dashed line represents those for regular goods, and the dash-dotted line represents those for health care goods. Panel (3) present the impulse responses of health status ("x, solid line") and marginal utility of health status ("mu_x, dash-dotted line). Panel (4) present the impulse responses of leisure ("l, solid line"), marginal utility of leisure ("mu_l, dash-dotted line), and marginal product of leisure ("mp_l, dashed line).

Figure 4: Impulse Responses of Selected Variables: Health Care Model vs. Two-sector Model
Note: the panels show the impulse responses of selected variables to a negative innovation to the nominal interest rate. The solid line represents responses using the HC model and the dash-dotted line represents responses using the TS model.

Figure 5: Impulse Responses of Selected Variables with Alternative Parameterization, Elasticity of Health Input
Note: the panels show the impulse responses of selected variables to a negative innovation to the nominal interest rate. The solid line represents responses using the baseline parameterization ($\kappa_H = 0.25$, $\kappa_L = 0.15$), the dash-dotted line represents those using lower efficiency of health spending and higher efficiency of leisure ($\kappa_H = 0.04$, $\kappa_L = 0.99$), and the dashed line represents those using higher efficiency of health spending and lower efficiency of leisure ($\kappa_H = 0.4$, $\kappa_L = 0.01$).

Figure 6: Impulse Responses of Selected Variables with Alternative Parameterization, IES for Health
Note: the panels show the impulse responses of selected variables to a negative innovation to the nominal interest rate. The solid line represents responses using the baseline parameterization ($\gamma_X = 5.46$), the dash-dotted line represents responses using the larger IES (i.e. $\gamma_X = 1.05$), and the dashed line represents responses using the smaller IES (i.e. $\gamma_X = 10$). Recall that γ_X is the inverse of the IES.

Appendix A: Estimating Volatility and Persistence of Health Care Inflation Using Principal Component Analysis

We use the underlying detailed tables of the NIPA account (Table 2.4.4U) to construct a large balanced panel of disaggregated inflation series. Starting from 1980Q1, $N = 342$ series are obtained at different levels of aggregation over $T = 134$ quarters. Following Boivin *et al.* (2009), we decompose individual inflation series as follows,

$$\pi_{i,t} = \lambda_i C_t + \pi^e_{i,t}, \tag{A.1}$$

where $\pi_{i,t}$ is the rate of inflation for sector i, C_t is a vector of K unobserved factors, λ_i is a vector of factor loadings that relate the factors to the observed inflation rates, and $\pi^e_{i,t}$ is the sector-specific component for sector i.

Equation (A.1) can be further written as

$$\Pi = \ C\Lambda' + \Pi^e, \tag{A.2}$$

where Π is a T by N matrix of original inflation series, C is a T by K matrix of unobserved factors, Λ is a N by K matrix of factor loadings, and Π^e is a T by N matrix of "filtered" inflation series net of unobserved factors. In Equation (A.2), C and Λ are not separately identifiable, unless restrictions are applied. To solve this problem, we apply the restriction $\frac{1}{T}C'C = I_K$ on the factors, following the convention in the literature. The estimation procedure takes two steps. First, we estimate the factor $\widehat{C}$ by minimizing the squared residuals in equation (A.2) while treating the unknown loading as given. Next, we estimate the loading by using a principal component analysis (PCA). Under certain regularity conditions on the error structures (Stock and Watson, 2005), the factor loading can be consistently estimated as the first K eigenvectors of the variance-covariance matrix of Π. We choose three factors ($K = 3$), based on a scree plot observation (not shown here).

For the sector-specific volatility, we calculate the simple average of the standard deviations of $\pi^e_{i,t}$ for a certain category (e.g. health care services). For the sector-specific persistence, we first calculate the the sum of the four-lag autocorrelation coefficients of $\pi^e_{i,t}$ and then calculate the simple average of these summed autocorrelation coefficients for a given category.

In addition to the individual service categories, volatility and persistence measures for the PCE: all items, goods, services, and other services are provided in the Table 6 of the main text.

Appendix B: Estimating the Response of Health Care Inflation to a Monetary Policy Shock

To obtain the impulse responses of health care inflation to an expansionary monetary policy shock, we use the Factor-augmented Vector Autoregression (FAVAR). Specifically, we modify equation (A.1) as follows

$$\begin{bmatrix} \Pi_t \\ X_t \end{bmatrix} = \psi \begin{bmatrix} C_t \\ FFR_t \end{bmatrix} + \begin{bmatrix} \Pi_t^e \\ X_t^e \end{bmatrix}, \tag{B.1}$$

where Π_t, Π_t^e are the vectors of N original and filtered inflation series, X_t, X_t^e are the vectors of M original and filtered macroeconomic variables that we add into this exercise, C_t is the vector of K extracted factors, and FFR_t is the federal funds rate which we treat as an additional factor. We add $M = 429$ additional macroeconomic variables so that the broad information available to the monetary policymaker is incorporated in our analysis (Bernanke *et al.*, 2005). These variables consist of 342 quantity variables in the PCE that are obtained through deflating the nominal series with the corresponding price indexes, plus 87 macroeconomic variables obtained from the FRED website. The latter variables are reported in Table A.1.

We further assume that $F_t \equiv [C_t, FFR_t]'$ has a recursive structure

$$F_t = \Phi_p F_t + \zeta_t,$$

where Φ_p is a conformable lag polynomial matrix with p number of lags and ζ_t is a vector of reduced form residuals.

Equation (B.1) can be further written as

$$\Upsilon = F\Psi' + e, \tag{B.2}$$

where $\Upsilon \equiv [\Pi \; X]$ is a T by $N+M$ matrix of observed variables, F is a T by $K+1$ matrix of unobserved factors with $F_t = [C_t, \; FFR_t]'$, Ψ is a $N+M$ by $K+1$ matrix of factor loadings that relates factors to the observed variables, and e is a T by $N+M$ matrix of "residuals".

Next, we run the vector autoregression using the factors F. To recover the structural shock from the reduced form residuals in equation (B.2), we apply the standard recursiveness assumption that the factors affect the federal funds rate within the same period, i.e. the variable FFR is ordered the last.

To examine the effect of the orthogonal shock to the FFR on the remaining factors (and eventually on variables), we need to remove the effect that FFR has on $C_1, ...C_K$. Following Bernanke *et al.* (2005), we define a set of "slow-moving" variables that cannot contemporaneously respond to the shocks to FFR. All price and quantity variables in the PCE and the variables marked with asterisk in Table A.1 are regarded as slow-moving variables. We then filter out the effect that the FFR has on the remaining factors by using the above slow-moving variables. For more details on this procedure, see Bernanke *et al.* (2005).

We choose three factors ($K = 3$) and lag length of two quarters ($p = 2$). When drawing the impulse response, the size of the shock is adjusted to be equivalent of a 25 basis point drop in the federal funds rate.

Appendix C: The Two-Sector Model

The basic structure of the two-sector model (TS model) is similar to the models in Aoki (2001) and Erceg and Levin (2006).[24] In the TS model, health care demand no longer plays a distinctive role and health spending is included as part of the aggregate consumption index. This means that utility derived from health status X in the health care model (HC model) is replaced by a term representing utility derived from leisure in the TS model and the health accumulation equation (2) and the health investment equation (3) no longer exist. Below we present the model equations that are different from the HC model.

We start with the supply side that shares many model equations with the HC model. Final goods producer purchase differentiated goods $Y_k(z)$ from the corresponding intermediate goods producers and aggregate them as in equation (10). The intermediate goods producer's

[24]Using this type of model, Aoki (2001) and Carvalho (2006) have studied how the asymmetry in the price stickiness across sectors affects the optimal conduct of monetary policy. They find that monetary policymakers should focus primarily on stabilizing inflation in the sector with higher price stickiness.

production constraint is given as

$$Y_{k,t}(z) = A_{k,t}^{s}\left(N_{k,t}(z)\right)^{\mu_N},$$

where the sectoral productivity shock follows the dynamics as in equation (17). Note that the contribution of health status is suppressed in the TS model. Consequently, the sectoral marginal cost is expressed as

$$MC_{k,t} = \frac{1}{\mu_N A_{k,t}^{s}} w_t \left(N_{k,t}\right)^{1-\mu_N}.$$

Total labor demand satisfies the constraint in Equation (19). Intermediate goods producer faces the random opportunity of price adjustment, same as in the HC model. Solving the profit maximization yields the new-Keynesian Phillips curve in equation (20).

On the demand side, households maximize their expected lifetime utility expressed as

$$\max E_t \sum_{j=0}^{\infty} \beta^j \exp(e_{I,t+j}) \left[\frac{1}{1-\gamma_C} C_{t+j}^{1-\gamma_C} + \frac{\eta_N}{1-\gamma_N} \exp(e_{N,t+j}) \left(1 - N_{t+j}\right)^{1-\gamma_N}\right],$$

where C represents the aggregate consumption index that constitutes of regular goods consumption and health care consumption (described below). The second term in the bracket represents the utility derived from leisure (or disutility of labor), which replaces the utility derived from health status in the HC model. $e_{I,t} \sim N(0, \sigma_I^2), e_{N,t} \sim N(0, \sigma_N^2)$ are the intertemporal preference shock and the labor supply shock, respectively. They replace the health shock in the HC model. The budget constraint is

$$C_t + \frac{D_t}{P_t} = \frac{W_t}{P_t} N_t + \frac{R_{t-1}^n}{P_t} D_{t-1} + profit_t.$$

Solving the utility maximization problem yields the intertemporal efficiency condition

$$\exp(e_{I,t}) C_t^{-\gamma_C} = \beta R_t^n E_t \left[\frac{\exp(e_{I,t+1}) C_{t+1}^{-\gamma_C}}{\Pi_{t+1}}\right],$$

and the labor-leisure choice

$$\frac{\eta_N \exp(e_{N,t}) \left(1 - N_t\right)^{-\gamma_N}}{C_t^{-\gamma_C}} = \frac{W_t}{P_t}.$$

In the TS model, households and government purchase sectoral outputs and produce a composite good defined as

$$C_t = \frac{C_{R,t}^{\omega} C_{H,t}^{1-\omega}}{\omega^{\omega}\left(1-\omega\right)^{1-\omega}},$$

$$G_t = \frac{G_{R,t}^{\omega} G_{H,t}^{1-\omega}}{\omega^{\omega} (1-\omega)^{1-\omega}},$$

where $C_{k,t}, G_{k,t}$ are the sectoral goods spent by households and the government, respectively, and $0 < \omega < 1$. Minimizing the total cost on the composite good while taking sectoral prices $P_{k,t}$ as given yields the following relative goods demand,

$$\frac{C_{R,t}}{C_{H,t}} = \frac{\omega}{1-\omega} \left(\frac{P_{R,t}}{P_{H,t}} \right)^{-1},$$

$$\frac{G_{R,t}}{G_{H,t}} = \frac{\omega}{1-\omega} \left(\frac{P_{R,t}}{P_{H,t}} \right)^{-1},$$

which in aggregate yields the expression (25) in the text.

The aggregate price index can be derived from the above cost minimization problem. It is expressed as the geometrical average of the sectoral prices

$$P_t = P_{R,t}^{\omega} P_{H,t}^{1-\omega}.$$

The resource constraint in the TS model follows the GDP definition

$$Y_t = C_t + G_t,$$

where aggregate government spending G_t follows the exogenous process

$$G_t = G_{t-1}^{\rho_G} \exp(e_{G,t}).$$

Finally, monetary policy follows the same modified Taylor rule with partial adjustment in equation (23).

Appendix D: Linearized Model Equations in the Health Care Model

All variables are expressed in deviation terms.

Nominal variables

$$r_t^n = \rho_n r_{t-1}^n + (1-\rho_n) [\rho_{\Pi} \pi_t + \rho_Y y_t] + s_{M,t}$$

$$rp_{R,t} - rp_{R,t-1} = \pi_{R,t} - \pi_t$$

$$rp_{H,t} - rp_{H,t-1} = \pi_{H,t} - \pi_t$$

Resource constraint

$$y_{R,t} = \left(1 - \frac{\overline{G}_C}{\overline{Y}_R}\right) c_t + \frac{\overline{G}_C}{\overline{Y}_R} g_{C,t}$$

$$y_{H,t} = \left(1 - \frac{\overline{G}_H}{\overline{Y}_H}\right) h_t + \frac{\overline{G}_H}{\overline{Y}_H} g_{H,t}$$

Aggregate demand

$$-\gamma_C c_t + e_{X,t} = \tilde{\lambda}_{D,t} + rp_{r,t}$$

$$\tilde{\lambda}_{X,t} + i_t^X - h_t = \tilde{\lambda}_{D,t} + rp_{h,t}$$

$$\tilde{\lambda}_{X,t} + i_t^X + \frac{\overline{N}}{1 - \overline{N}} n_t = \tilde{\lambda}_{D,t} + \tilde{w}_t$$

$$\tilde{\lambda}_{D,t} = r_t^n - E_t \pi_{t+1} + \tilde{\lambda}_{D,t+1}$$

$$\tilde{\lambda}_{X,t} = [1 - \beta(1 - \delta_X)] \left(-\gamma_X x_t + a_t^X\right) + \beta(1 - \delta_X) \tilde{\lambda}_{X,t+1}$$

$$i_t^X = e_{X,t} + \kappa_H h_t - \kappa_L \frac{\overline{N}}{1 - \overline{N}} n_t$$

$$x_t = \delta_X i_t^X + (1 - \delta_X) x_{t-1}$$

Aggregate supply

$$y_t = \frac{\overline{Y}_R}{\overline{Y}} y_{R,t} + \frac{\overline{Y}_H}{\overline{Y}} y_{H,t}$$

$$y_{R,t} = a_{R,t}^s + \mu_N n_{R,t} + \mu_X x_t$$

$$y_{H,t} = a_{H,t}^s + \mu_N n_{H,t} + \mu_X x_t$$

$$n_t = \frac{\left(\frac{\overline{Y}_R}{\overline{Y}}\right)^{\mu_N^{-1}}}{\left(\frac{\overline{Y}_R}{\overline{Y}}\right)^{\mu_N^{-1}} + \left(\frac{\overline{Y}_H}{\overline{Y}}\right)^{\mu_N^{-1}}} n_{R,t} + \frac{\left(\frac{\overline{Y}_H}{\overline{Y}}\right)^{\mu_N^{-1}}}{\left(\frac{\overline{Y}_R}{\overline{Y}}\right)^{\mu_N^{-1}} + \left(\frac{\overline{Y}_H}{\overline{Y}}\right)^{\mu_N^{-1}}} n_{H,t}$$

$$\tilde{w}_t = a_{R,t}^s + mc_{R,t} + (\mu_N - 1) n_{R,t} + \mu_X x_t$$

$$\tilde{w}_t = a_{H,t}^s + mc_{H,t} + (\mu_N - 1) n_{H,t} + \mu_X x_t$$

$$\pi_t = \frac{\overline{Y}_R}{\overline{Y}} \left[\pi_{R,t} + rp_{R,t-1} + y_{R,t} - y_t\right] + \frac{\overline{Y}_H}{\overline{Y}} \left[\pi_{H,t} + rp_{H,t-1} + y_{H,t} - y_t\right]$$

$$\pi_{R,t} = \frac{(1 - \rho_R)(1 - \beta\rho_R)}{\rho_R} mc_{R,t} + \beta E_t \pi_{R,t+1}$$

$$\pi_{H,t} = \frac{(1 - \rho_H)(1 - \beta\rho_H)}{\rho_H} mc_{H,t} + \beta E_t \pi_{H,t+1}$$

Law of motion of shocks

$$s_{m,t} = \rho_M s_{m,t-1} + e_{m,t}$$

$$g_{C,t} = \rho_C^d g_{C,t-1} + e_{G,t}$$

$$g_{H,t} = \rho_H^d g_{H,t-1} + e_{G,t}$$

$$a_{R,t}^s = \rho_R^s a_{R,t-1}^s + e_{R,t}^s$$

$$a_{H,t}^s = \rho_H^s a_{H,t-1}^s + e_{H,t}^s$$

Appendix E: The IES for Health

This appendix presents the method used to estimate (the inverse of) the intertemporal elasticity of substitution (IES) for health γ_X. The value of this parameter is used in our baseline analysis. The empirical method we apply is similar to the method used to estimate the IES for consumption in the literature (Hansen and Singleton, 1982, 1983; Hall, 1988), except that we use health status in the Euler condition instead of consumption.

The first order necessary condition for the optimal choice of health spending is

$$MU_{H,t} = \lambda_{X,t} \left(\kappa_H \frac{I_t^X}{H_t} \right) = \lambda_D \frac{P_{H,t}}{P_t},$$

combining this equation with the two intertemporal efficiency conditions (equation (8) and (9) in the main text) and applying the full depreciation condition $\delta_X = 1$ used in the baseline parameterization yields

$$\left(\frac{X_{t+1}}{X_t} \right)^{\gamma_X - 1} = \beta R_t^n \left(\frac{A_{t+1}^X}{A_t^X} \right) \left(\frac{P_t^H H_t}{P_{t+1}^H H_{t+1}} \right).$$

Log-linearizing the equation yields,

$$(\gamma_X - 1) \Delta \log(X_{t+1}) = constant + \log(R_t^n) - \Delta \log(P_{t+1}^H H_{t+1}),$$

where the (log of) discount factor and the growth rate of health care shock are collected into one constant term. The equation states that the representative household adjusts its health status in response to the interest rate (=opportunity cost of spending) and the growth rate of health spending.

To estimate γ_X, we use the Generalized Method of Moments (GMM). Following the literature, we construct lagged variables as instruments. To ensure the instruments are exogenous, we avoid the first and second lag, and instead use the third lag of the interest rate, nominal health care expenditure, and health status.

We use two interest rate measures for this exercise (3-month Treasury bill: secondary market rate and 5-year Treasury constant maturity rate) and they are obtained from the FRED. For nominal health care expenditure, we use quarterly personal consumption expenditure, health care services, obtained from Bureau of Economic Analysis (Table 2.4.5). Health status is the percentage of population reporting their health as good and excellent based on a question in the NHIS micro data. We construct two health measures based on the overall population and the 16-64 years old working population separately. The original health measure is collected at the annual frequency. We interpolate the annual data in a linear way to obtain quarterly frequency data. Our sample period is 1980 - 2012.

Table A.2 shows the results. The γ_X for the overall population is 5.46 (3 month TB) and 5.23 (5 year constant) depending on the interest rate used. The γ_X for the working population is 4.39 (3 month TB) and 4.23 (5 year constant). All estimates are statistically significant at the 5% level.

The test for over-identifying restrictions (OIR test) is performed and the results are shown in the last row of Table A.2. We fail to reject the null hypothesis in all cases, implying that our instruments are uncorrelated with the error term. We also perform a likelihood ratio test by comparing the model that includes all the instruments and the model without the instruments in predicting the interest rate. The test strongly rejects the model without the instrument (test stat = 254.61 and 276.11 for the 3 month TB and 5 year constant), indicating that our instruments are not weak. The R^2 for the models that include the instruments are 0.85 and 0.87 for the 3-month and 5 year interest rate, respectively.

In the baseline analysis, we use the value of 5.46 that corresponds to the overall sample and the 3 month TB as the reference rate.

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Table A.1: Additional Macroeconomic Variables from FRED

	Mnemonics	Slow-vars	Trans-code	Descrip-tion
1	IPFINAL	*	5	IP: Final Products (Market Group)
2	IPCONGD	*	5	IP: Consumer Goods
3	IPDCONGD	*	5	IP: Durable Consumer Goods
4	IPNCONGD	*	5	IP: Nondurable Consumer Goods
5	IPBUSEQ	*	5	IP: Business Equipment
6	IPMAT	*	5	IP: Materials
7	IPDMAT	*	5	IP: Durable Materials
8	IPNMAT	*	5	IP: nondurable Materials
9	IPMAN	*	5	IP: Manufacturing (NAICS)
10	INDPRO	*	5	Industrial Production Index
11	USASARTMISMEI	*	5	Total Retail Trade in United States
12	MCUMFN	*	1	Capacity Utilization: Manufacturing (NAICS)
13	NAPM	*	1	ISM Manufacturing: PMI Composite Index
14	NAPMPI	*	1	ISM Manufacturing: Production Index
15	DSPIC96	*	5	Real Disposable Personal Income
16	W875RX1	*	5	Real personal income excl. current transfer receipts
17	CE16OV	*	5	Civilian Employment
18	UNRATE	*	1	Civilian Unemployment Rate
19	UEMPMEAN	*	1	Average (Mean) Duration of Unemployment
20	UEMPLT5	*	1	Civilians Unemployed - Less Than 5 Weeks
21	LNU03008756	*	1	Number Unemployed for 5 to 14 Weeks
22	LNU03008516	*	1	Number Unemployed for 15 Weeks and over
23	LNU03008876	*	1	Number Unemployed for 15 to 26 Weeks
24	LNU03008636	*	1	Civilians Unemployed for 27 Weeks and Over
25	PAYEMS	*	5	All Employees: Total nonfarm
26	USPRIV	*	5	All Employees: Total Private Industries
27	USGOOD	*	5	All Employees: Goods-Producing Industries
28	USMINE	*	5	All Employees: Mining and logging
29	USCONS	*	5	All Employees: Construction
30	MANEMP	*	5	All Employees: Manufacturing
31	DMANEMP	*	5	All Employees: Durable goods
32	NDMANEMP	*	5	All Employees: Nondurable goods
33	USTPU	*	5	All Employees: Trade, Transportation & Utilities
34	USWTRADE	*	5	All Employees: Wholesale Trade
35	USTRADE	*	5	All Employees: Retail Trade

Table A.1: Additional Macroeconomic Variables (continued)

36	USFIRE	*	5	All Employees: Financial Activities
37	SRVPRD	*	5	All Employees: Service-Providing Industries
38	USGOVT	*	5	All Employees: Government
39	AWHMAN	*	1	Average Weekly Hours of Production and Nonsupervisory Employees: Manufacturing
40	AWOTMAN	*	1	Average Weekly Overtime Hours of Production and Nonsupervisory Employees: Manufacturing
41	NAPMEI	*	1	ISM Manufacturing: Employment Index
42	PCE	*	5	Personal Consumption Expenditures
43	PCEDG	*	5	Personal Consumption Expenditures: Durable Goods
44	PCEND	*	5	Personal Consumption Expenditures: Nondurable Goods
45	PCES	*	5	Personal Consumption Expenditures: Services
46	HOUST		4	Housing Starts: Total: New Privately Owned Housing Units Started
47	HOUSTNE		4	Housing Starts in Northeast Census Region
48	HOUSTMW		4	Housing Starts in Midwest Census Region
49	HOUSTS		4	Housing Starts in South Census Region
50	HOUSTW		4	Housing Starts in West Census Region
51	PERMIT		4	New Private Housing Units Authorized by Building Permits
52	NAPMII		1	ISM Manufacturing: Inventories Index
53	NAPMNOI		1	ISM Manufacturing: New Orders Index
54	NAPMSDI		1	ISM Manufacturing: Supplier Deliveries Index
55	SP500		5	S&P 500 Stock Price Index
56	DJIA		5	Dow Jones Industrial Average
57	DJUA		5	Dow Jones Utility Average
58	TB3MS		1	3-Month Treasury Bill: Secondary Market Rate
59	TB6MS		1	6-Month Treasury Bill: Secondary Market Rate
60	GS1		1	1-Year Treasury Constant Maturity Rate
61	GS5		1	5-Year Treasury Constant Maturity Rate
62	GS10		1	10-Year Treasury Constant Maturity Rate
63	AAA		1	Moody's Seasoned Aaa Corporate Bond Yield
64	BAA		1	Moody's Seasoned Baa Corporate Bond Yield
65	M1SL		5	M1 Money Stock
66	M2SL		5	M2 Money Stock
67	CURRCIR		5	Currency in Circulation
68	BUSLOANS		5	Commercial and Industrial Loans at All Commercial Banks
69	TOTALSL		5	Total Consumer Credit Owned and Securitized, Outstanding
70	NAPMPRI	*	1	ISM Manufacturing: Prices Index

Table A.1: Additional Macroeconomic Variables (continued)

71	PPIFGS	*	5	PPI: Finished Goods
72	PPIFCG	*	5	PPI: Finished Consumer Goods
73	PPIITM	*	5	PPI: Intermediate Materials: Supplies & Components
74	PPICRM	*	5	PPI: Crude Materials for Further Processing
75	CPIAUCSL	*	5	CPI: All Items
76	CPIAPPSL	*	5	CPI: Apparel
77	CPITRNSL	*	5	CPI: Transportation
78	CPIMEDSL	*	5	CPI: Medical Care
79	CUSR0000SAC	*	5	CPI: Commodities
80	CUSR0000SAD	*	5	CPI: Durables
81	CUSR0000SAS	*	5	CPI: Services
82	CPIULFSL	*	5	CPI: All Items Less Food
83	CUSR0000SA0L2	*	5	CPI: All Items Less Shelter
84	CUSR0000SA0L5	*	5	CPI: All Items Less Medical care
85	CES2000000008		5	Average Hourly Earnings of Production and Nonsupervisory Employees: Construction
86	CES3000000008		5	Average Hourly Earnings of Production and Nonsupervisory Employees: Manufacturing
87	CES0600000008		5	Average Hourly Earnings of Production and Nonsupervisory Employees: Goods-Producing

Note: Mnemonics are the abbreviations used in FRED. * represents slow-moving variables. transformation code is 1 = no transformation, 4 = log transformation, 5 = quarter-to-quarter growth rates.

Table A.2: Estimates of (Inverse of) the IES for Health

Health status	Overall sample	Overall sample	16-64 years old	16-64 years old
Interest rate	3 month TB	5 year constant	3 month TB	5 year constant
IES for health	5.46**	5.23**	4.39**	4.23**
(standard error)	(0.98)	(0.86)	(0.78)	(0.69)
OIR test	2.07	1.94	2.80	2.99
(p-value)	(0.35)	(0.38)	(0.25)	0.22)

Note: the GMM method and quarterly data during 1980 - 2012 are used in estimation. The instruments are the third lag of the interest rate, nominal health care expenditure, and health status. OIR stands for overidentifying restrictions. ** stand for statistically significant at 5% level.