Financial Health Economics*

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Abstract

We analyze the joint determination of real and financial markets for health care services and products. Asset markets are informative about the risks to which the health care sector is exposed, which affect the incentives to invest in medical R&D that in turn drive the growth in the real health care sector. Empirically, we document a "medical innovation premium" - a large risk premium for firms engaged in medical R&D that is higher than predicted by standard asset pricing models. We interpret this premium as compensating investors for bearing risk about continued profitability of the large share of demand that is government financed. Our model implies that removing government risk would triple medical R&D spending and thereby increase health spending further by 7% of GDP. We discuss the implications of the analysis for valuation of the large share of future US liabilities comprised of Medicare and Medicaid spending.

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Improvements in health have been a major component in the overall gain in economic welfare and reductions in world inequality during the last century (Becker, Philipson, and Soares (2005) and Murphy and Topel (2006)). Indeed, an emerging literature finds that the value of improved health is on par with much of other forms of economic growth as represented by material per-capita income reflected in GDP measurements. As such, the increase in the quantity and quality of life is economically perhaps the most valuable change of the last century.

The growth of medical innovation, and the demand for it, has been central to the improvements in health. Through medical progress, including improvements in knowledge, procedures, drugs, biologics, devices, and the services associated with them, there has been an increased ability to avoid disease and sickness. Many analysts emphasize that this surge in medical innovation may be the central factor leading to the expansion of the health care sector (Newhouse (1992), Cutler (1995), and Fuchs (1996)). At the same time, however, the size of this sector is now rapidly approaching one fifth of the US economy.

To understand trends in medical spending and the medical R&D that induce them, it is important to understand the financial returns of those investing in medical innovation. However, economists have not offered any explicit analysis of the relationship between financial markets, determining the returns for those investing in medical R&D, and real health care markets, expanding as a result of such investments. This has lead to a lack of understanding to one of the central issues in health economics of what determines the growth of the health care sector, and in particular how growth is related to investments in medical R&D. Therefore, what is needed is a better theoretical and empirical understanding of how financial returns of medical R&D firms are related to the growth real health care sector and vice versa. To address this need, this paper provides an analysis of the joint determination of returns of medical R&D firms and the growth of the health care sector.

We first consider whether investments into the US medical R&D sector has experienced unusual return patterns. Asset prices of firms in the health care industry are informative about the risks to which the sector is exposed. As expected asset returns drives the discounting of future profits in medical R&D decisions, understanding expected returns is central to understanding the incentives to undertake medical R&D and the trends in medical spending they imply. We provide empirical evidence that the returns on firms in the health care industry are substantially higher, around 4-6% per annum, than what is predicted by standard asset pricing models such as the Capital Asset Pricing Model (Sharpe (1964)) and the Fama and French (1992) model. This large "medical innovation premium" suggests that the health care industry may be exposed to risks other than captured in standard asset pricing models.

Our theoretical analysis derives the link between financial markets and the growth in the real health care sector, that is, how the documented medical innovation premium affects the expansion of the sector. We interpret the medical innovation premium to arise from one distinguishing feature of the health care sector: the large role of the public sector. Government demand subsidy programs such as Medicare and Medicaid make up about half of medical spending, and thus clearly affect returns of innovators. We stress the important role of uncertainty of future government activity in affecting asset returns and medical R&D investments. We argue that investors need be compensated for holding firms that engage in medical innovation as they are exposed to these unique government shocks, resulting in a medical innovation premium. We analyze when the risk facing investors is that US converts to the "European model" in which markups are reduced more than quantity expands.[1] Such markup reductions are more likely if the size of the government subsidy programs are large as it increases the government's monopsony power. The resulting medical innovation premium that must be paid to compensate for this risk is in contrast to arguments that health care is a "recession-proof sector," implying low expected returns according to traditional asset pricing models such as the CAPM.

The central implication, that government risk may discourage innovation, is perhaps evidenced by current freeze in health care markets given the uncertain fate of US health care reform. One important implication of our model in light of this is that medical R&D spending may be limited relative to the enormous value in health gains estimated by economists. For instance, the analysis by Murphy and Topel (2006) suggests that the gains to health may justify even larger investments in medical R&D. The medical innovation premium resulting from government risk slows down the investment in medical R&D. Even though the health care sector is large, the presence of the medical innovation premium has in fact limited its growth.

We build a dynamic model to quantify these effects to the US economy for the period 1960-2010. Trends in health care spending and medical R&D as well as asset returns allow us to calibrate technology and preference parameters. We use these to calibrate two counterfactuals to assess the impact of the medical innovation premium. We first consider the case in which we remove the risk premium, but preserve the impact on expected profits of government markup risk. As government markup risk affects both expected cash flows and discounting of firms, we want to separate the two. We find that the size of the

[1] See Golec, Hegde, and Vernon (2010) for an example around the Clinton health care reform.

health care sector would increase by 6% of GDP if the risk premium was removed, and an additional 1% if also removed the impact on expected profits. Thus, if government risk was removed altogether, about. 86% of the growth in the sector would be due to the risk premium. In terms of impacting R&D spending, we find that it would be three times as high in the absence of the medical innovation premium. These large effects of the medical innovation premium also has implications for the long-run health care share. By 2050, our model suggests that 35% of GDP is spent on health care, conditional on no government intervention. The long-run steady state share is slightly below 50% of GDP. The CBO projects that the total spending on health care would rise from 16 percent of gross domestic product (GDP) in 2007 to 25 percent in 2025, 37 percent in 2050, and 49 percent in 2082. Hence, our model closely mimics the CBO projections for the health care share.

Our analysis has important implications for valuation and predicting the current value of future liabilities of public health care spending, such as through Medicare and Medicaid in the US, that are central to governments balance sheets. According to the CBO's long-term budget outlook,[2] the future fraction of primary government spending allocated to these health care programs is estimated to be 41% in 2035. Our analysis offers a consistent framework to analyze the impact of various interventions on valuing such programs, in terms of how they affect both cash flows and discounting. One clear implication is that discounting future medical care liabilities by US Treasury rates rather than market rates, seems highly inappropriate in light of medical innovation premium documented in this paper.

The paper relates to several strands of previous research but differs from it by examining the joint determination of the asset returns for those engaged in the medical innovation and the resulting increase in the health care sector. One related literature discusses the relationship between health and growth, but it does not analyze the returns to investment in medical R&D, see for instance Barro (1996) and Sala-i-Martin, Doppelhofer, and Miller (2004). A large empirical literature, see Gerdtham and Jonsson (2000) for a review, has estimated the impact of economic growth on health care spending. Even though health care spending increases with income, the evidence concerning the "luxury good" nature of health care as predicted by theoretical work, see for instance Hall and Jones (2007), is mixed, see Acemoglu, Finkelstein, and Notowidigdo (2009) and the references therein. More importantly, in the cross-section health care is eventually a necessity in the richest part of the income distribution, suggesting that technology is ultimately the barrier to

[2] "CBO Long-Term Budget Outlook," Revision August 2010.

rich people from buying even greater health.

The paper may be briefly outlined as follows. Section 1 lays out the basic ideas in a simple analysis to display the main intuition behind the results. Section 3 considers the empirical analysis that motivates the full examination of the dynamic model. Section 4 studies dynamics and calibrates quantitative behavior of the health care sector resulting from the medical innovation premium. Lastly, section 5 contrasts the analysis to related work and discusses the many new issues raised by our analysis that we believe are important for future research

1 A Simple Exposition of the Basic Ideas

This section conveys the basic ideas of the relationship between returns to medical R&D and the expansion of the health care sector in a simple two-period model. Time is indicated by $t = 1, 2$.

1.1 Households

Households maximize the utility from consumption c_t and health h_t by choosing the level of medical care m_t

$$\max_{(m,c)}[u(c_1, h_1)] + \beta E[u(c_2, h_2)]$$

subject to the budget constraint:

$$c_t + (1 - \sigma)p_t m_t = y_t - \tau_t + \pi_t.$$

Medical care is used to produce health:

$$h_t = h(m_t).$$

Consumption together with medical care m_t at a subsidized price $(1 - \sigma)p_t$ are financed from non-asset after-tax income income, $y_t - \tau_t$, and asset income, π_t, made up of the profits of health care firms. Firms face a constant marginal cost x_t of production and prices are chosen to maximize profits

$$\pi_t = \max_{p_t} m(p_t(1 - \sigma))(p_t - x_t),$$

where $m(.)$ is the decreasing demand function for medical care. The households own the health care firms and that the health care subsidy is financed by taxes $\tau_t = \sigma p_t m_t$. Substituting in profits and taxes implies that available resources are either spent on consumption or medical care:

$$c_t + x_t m_t = y_t$$

Thus, this directly implies that in states of nature where more health care resources are demanded and produced less of the available income is used for non-medical consumption.

1.2 Government Shocks

We analyze how the returns of health care firms is affected by government uncertainty. The uncertainty considered is in terms of government intervention through price controls. This is interpreted as the government mandating an upper bound ζ on the price so that the feasible prices of the firm is $p \in [0, \zeta]$. This directly implies that both the optimal price of the firm $p(\zeta)$ and profits $\pi(\zeta)$ increases weakly with the bound. This is because the firm could always choose a price below the bound before a price control is implemented but may not find it optimal to do so.

1.3 Risk Premium of Health Care Firms Due to Government Shocks

Uncertainty over the government intervention is captured by the distribution $F(\zeta)$ which turn induces a distribution of consumption levels and profits $(c(\zeta), \pi(\zeta))$ across the future states of government intervention. As $m(p)$ is downward sloping, profits and consumption will be positively correlated as both profits and consumption fall with more constrained pricing. Consumption is lower under constrained pricing as more resources (xm) are used to produce medical care rather than being consumed.

This positive covariance between profits and consumption has important implications for the asset returns on health care firms. The preferences of households imply a stochastic discount factor (SDF). For the uncertain states of government intervention, this SDF is given by marginal rate of substitution of consumption over different levels of intervention; $M_2 = u'\left(c_2(\zeta)\right)/u'\left(c_1\right)$. As profits of health care firms are high when consumption is high, this occurs when the marginal utility of consumption is low. As a result, health-care firms must earn a positive risk premium to compensate for the fact that they pay off when consumption is high. More precisely, the value of the firm in the first period equals:

$$v = E\left(M_2(\zeta)\pi_2(\zeta)\right).$$

This implies the standard asset pricing condition $E(M_2\left(g\right)R_2\left(\zeta\right)) = 1$, where $R_2(\zeta) \equiv \pi_2\left(\zeta\right)/v$ is the return on firms in the health care industry for a given state of government intervention. Applying this condition to a risk-free asset as well, one obtains $E(M_2(\zeta)(R_2(\zeta) - R_f)) = 0$ which in turn implies the risk-premium

$$E(R_2(\zeta)) - R_f = -R_f Cov(M_2(\zeta), R_2(\zeta)).$$

A stricter price control ζ leads to a decline in the price of care and thus a decrease in both non-medical consumption and profits of health care firms. As a result, the covariance between consumption and profits is positive, which means that the covariance between marginal utility and profits is negative. The results is a positive "medical innovation premium," which compensates investors for the government risk to which the health care sector is exposed.

1.4 Medical Innovation and Asset Prices

To introduce medical innovation in our model, we assume firms can lower the real price of medical care, or marginal cost of production,by doing medical R&D, $x_2 = g(d)$, where d is the period-1 R&D investment. Firms choose the optimal level of R&D to maximize firm value which is now net of investment

$$v = \max_d E\left(M_2\pi_2\right) - d$$

This implies that the optimal R&D investment maximizes the net-present value (NPV) of the firm as in:

$$E\left(M_2\frac{\partial\pi_2}{\partial d}\right) = 1.$$

Consider when the gross profits as a function of medical R&D investment has the form

$$f(d)\pi_2$$

where $f(d)$ is an increasing and concave function. We show in the dynamic model below that this form arises naturally under monopolistic competition, for instance. Under this condition, the firm's first-order condition simplifies to:

$$E\left(M_2\pi_2\right)f'(d) = 1$$

Substituting in that $E\left(M_2\pi_2\right) = E(\pi_2)/E(R_2)$ we get

$$\frac{E(\pi_2)}{E(R_2)}f'(d) = 1$$

This simply states that the marginal benefit of R&D investments are discounted by the returns in required in asset markets. The important end result here is that there is a negative relationship between medical innovation and the medical innovation premium in asset markets, in the sense that $d(R_2)$ is a decreasing function. We study the implications of this decreasing relationship between government uncertainty and investment below.

1.5 The Link between Asset Markets and Health Care Spending

Ignoring time subscripts, health care spending in a given period is given by $s = pm$. Given that the risk premium drives R&D investments according to $d(R)$, the premium drives the cost of production of care through the neagtive relationship $x(R) \equiv x(d(R))$, which in turn drives the real price of care through the positive relationship $p(x)$. This directly provides a link between asset markets and real health care spending $s(R)$, defined by

$$s(R) = p(x(R))m(p(x(R)).$$

The elasticity of health care demand affects the general impact of asset markets on health care spending. When more government uncertainty discourages R&D, real prices of health care remain higher and this translates into higher or lower health care spending dependent on how elastic health care demand is

$$\frac{ds}{dR} = [m + pm_p]p_x x_d d_R \geq 0 \Leftrightarrow |\frac{m_p p}{m}| \geq 1$$

The behavior of such absolute levels of spending may differ from trends relative to income. If $S_t \equiv \frac{s_t}{y_t}$ denotes the share of income devoted to health care spending its behavior in the *cross-section* may differ from its behavior in the *time-series*. The total effect of on the share of both income and medical innovation is given by

$$dS = S_y dy + (S_p p_x x_d)dd.$$

In the cross-section, the second innovation effect is zero. Income may initially raise the sahre but then lowers it as very rich individuals are limited by technology in how much health they can buy. Thus, health care may be a luxury for low levels of income and a neceassity for high levels when holding technology constant in the cross-section.. In the time-series, growth in income changes at the same time as medical innovation progresses in a way that may lead the health care share to rise over time. The share of income devoted to health care over time thus is likely to decline if income growth is the only source of additional spending, similar to the effect in the cross-sectional effect of income. However, the share may well be increasing over time if medical innovation lowering the real cost of care, potentially spurred by such income growth. The impact of increased government risk on this evolution will be to slow down medical innovation and thus a slowdown of the growth in health care spending. Governmenr risk reduces the luxury nature of health care over time.

2 Empirical analysis

2.1 Data

We use data from various sources. Information on overall health care spending comes from the National Health Expenditure Accounts from the Centers for Medicare and Medicaid Services. International data on health expenditures to GDP and the data on pharmaceutical expenditures are from the OECD Health Data 2010.

We use data on industry returns, the Fama and French factors, and market capitalization from Ken French's website. The first classification we use divides the universe of stocks in five industries: "Consumer goods," "Manufacturing," "Technology," "Health care," and a residual category "Other." The health care industry includes medical equipment,[3] pharmaceutical products,[4] and health services.[5] We also study the 48 industry classification, which splits the health care industry into the three before-mentioned categories.

In addition, we merge data from CRSP and Compustat to measure profitability, sales, and R&D investment. We follow the same industry classification as Ken French for either

[3]The corresponding SIC codes are 3693: X-ray, electromedical app., 3840-3849: Surgery and medical instruments, 3850-3851: Ophthalmic goods.

[4]The corresponding SIC codes are: 2830: Drugs, 2831: Biological products, 2833: Medical chemicals, 2834: Pharmaceutical preparations, 2835: Invitro, in vivo diagnostics, and 2836: Biological products, except diagnostics.

[5]The corresponding SIC codes are 8000-8099: Services - health.

the entire health care industry or for the three sub-industries. We closely replicate the returns reported by Ken French for the various portfolios. In selecting stocks that go into the different portfolios, we focus on common stocks and stocks that are traded at NYSE, AMEX or NASDAQ. CRSP and Compustat may report different SIC codes. Following Gomes, Kogan, and Yogo (2009), we use the Compustat SIC code as of 1983 if available, and the CRSP SIC code otherwise. We sort firms at the end on June each year and hold the firms for one year. If a firms defaults, we record the de-listing return if available.

2.2 Empirical results: Asset markets

Risk premia We first study the returns of firms in the health care industry. In computing the returns to health care companies, we correct for standard risk factors to correct for other sources of systematic risk outside of the model. Table 1 reports the intercepts, or "alphas," of the following regression:

$$r_t - r_{ft} = \alpha + \beta' F_t + \varepsilon_t,$$

where F_t is a set of pricing factors. We are interested in the returns of health care firms relative to firms that are not in the health care industry. To compute the relative returns, we regress the returns on a constant, the alpha, and a set of benchmark factors, F_t. The alpha measures the differential average return of health care firms that cannot be explained standard asset pricing models. We provide one potential explanation of a risk factor to which health care firms are exposed, namely shocks to the productivity of health care.

Asset pricing models are distinguished by the factors F_t. As a first model, we use the excess return on the CRSP value-weighted return index, which is comprised of all stocks traded at AMEX, NYSE, and Nasdaq. We refer to this model "CAPM." The second benchmark asset pricing model we consider is the 3-factor Fama and French (1992) model, which is labeled "Fama-French."

For robustness, we estimate the model either at a monthly frequency or an annual frequency. If we estimate the model at a monthly frequency, we multiply the alphas by 12 to annualize them. We also consider three sample periods: 1927-2010, 1946-2010, and 1961-2010. The first sample period is the longest sample available. The second sample focuses on the post-war period. The third sample coincides with the period for which we have data on the trend in health care spending. The returns on services start only in the late sixties, and we therefore exclude them from the table.

The annual results are in Panel A and the monthly results in Panel B. The first number corresponds to the alpha; the second number is the t-statistic using OLS standard errors. We find that the health care industry tends to produce economically and statistically significant alphas betwen 3-5% per annum, depending on the benchmark model and the sample period. If we remove health services and focus on pharmaceutical products and medical equipment, the alphas are even higher at 4-7% per annum. We also report the alphas on the other industries, which do not have large alphas relative to the standard model. We typically find that the results are somewhat stronger using the Fama-French model. We conclude that there is a risk premium for holding health care stocks that cannot be explained by standard asset pricing factors. In this paper, we suggest that health care firms are exposed to medical innovation shocks that are compensated in equilibrium.

Market capitalization Given the trends in health expenditures, it is interesting to study the trends in market capitalization of health care firms. Figure 1 plots the share of all publicly-traded equity that is part of the health care industry. The figure shows that the health care industry becomes an increasingly important share of publicly-traded equity. If we look at the relative contributions of medical equipment ("devices") and pharmaceutical products ("pharma"), we find that pharmaceutical products make up the vast majority of market capitalization.[6]

2.3 Trends in health care and R&D spending

Health care spending Figure 2 summarizes health care spending as a fraction of GDP from 1960 to 2009. The share of health care spending rises from about 5% to almost 18% towards the end of the sample period. This trend is in the same order of magnitude as the relative market capitalization of the health care firms. In addition, we plot the share of expenditures on CMS programs, which include Medicare, Medicaid, and CHIP as well as the share coming from non-CMS programs. This illustrates that all expenditures tend to share a similar trend.

The fact that health expenditures increase as a fraction of GDP is not only a feature of the US economy, but is more common across OECD countries. Table 2 reports the shares in 1971 and 2007 for a large set of countries for which these shares are available.

[6] It is important to point out that trends in shares of market capitalization do not necessarily imply positive alphas. In fact, if we look at the change in shares across all 48 industries from 1945-2010, then there appears to be no link to either CAPM or Fama and French alphas. The market share of an industry may increase not only due to exceptional returns on existing companies, but largely due to new companies going public. In support of this argument for health care companies, we do not find that the average firm size increases more in the health care industry than in other industries.

The share of health expenditures to GDP increased over time for all the countries for which data is available. The average increase is from 5.6% in 1971 to 9.5% in 2007.

Table 2 also reports the fraction of health expenditures that are pharmaceutical expenditures. Our asset pricing facts are largely based on pharmaceutical companies, so we verify that the trend in overall health expenditures is also present in pharmaceutical expenditures. We find that this is indeed the case. The share of expenditures that can be attributed to pharmaceutical expenditures is stable around 14%.

R&D spending In addition to health spending, also medical R&D spending increased rapidly over time. Following the methodology in Jones (2011) using data from the OECD, we plot in Figure 3 the share R&D relative to GDP. The share increased from 0.14% in 1987 to 0.37% in 2006, which compares to 11% to 16% for the share of medical spending to GDP. This implies that medical R&D spending increased even more rapidly than medical spending itself. In this paper, we try to understand the interaction between the risk premia in the health care industry, medical R&D spending, and medical spending.

3 Dynamic model of medical innovation and spending

In this section, we build a dynamic model to understand the interaction between the risk premia in the health care industry and both medical innovation and spending.

3.1 The environment

Time is infinite, $t = 0, 1, \ldots$. There is a continuum $i \in [0,1]$ of infinitely-lived households.

3.1.1 Preferences and endowments

Households have Cobb-Douglas preferences over health and non-health care consumption:

$$U = E\left[\sum_{t=0}^{\infty} \beta^t \frac{\left(c_{it}^{\xi} h_{it}^{1-\xi}\right)^{1-\eta}}{1-\eta}\right], \tag{1}$$

where c_{it} is the non-health care consumption of household i at date t, h_{it} is the health care consumption, $\eta > 1$ is the coefficient of relative risk aversion, $\beta \in (0,1)$ the time discount factor, and $\xi \in (0,1)$ determines the trade-off between health and non-health care consumption. Cobb-Douglas preferences imply that the marginal utility of consumption increases in health, which is consistent with the empirical results in Viscusi and Evans

(1990), Finkelstein, Luttmer, and Notowidigdo (2008), and Koijen, Van Nieuwerburgh, and Yogo (2011).

Households are endowed with one unit of time each period, which they supply inelastically as labor. With c_t and h_t, we denote aggregate non-health and health care consumption at date t, respectively,

$$c_t = \int_0^1 c_{it} di, h_t = \int_0^1 h_{it} di.$$

3.1.2 Technology

Aggregate output is given by aggregation across the output of each household,

$$y_t = \int_0^1 y_{it} di.$$

The output y_{it} of household i at time t is given exogenously,

$$y_{it} = \gamma^t, \tag{2}$$

for $\gamma > 1$.

Health is produced according to the production function

$$h_{it} = \underbrace{\underline{h}\gamma^t}_{\text{Exogenous health}} + \underbrace{m_{it}}_{\text{Health due to medical care}}, \tag{3}$$

where $\underline{h} > 0$ is a parameter and m_{it} is medical care, an input. $\underline{h}\gamma^t$ is the base health level without any medical care, which is assumed to grow at the same rate as output. Health can be increased further by purchasing medical care, m_{it}. Medical care is produced from a continuum of individual types, indexed by $j \in [0, 1]$,

$$m_{it} = \left(\int_0^1 m_{ijt}^{1/\phi} dj \right)^{\phi}, \tag{4}$$

where $\phi > 1$. As is standard in models of monopolistic competition, ϕ determined the degree of competition in the industry, and hence the market power of producers.

The production of each individual type requires the output good of period t,

$$m_{jt} \equiv \int_0^1 m_{ijt} di = q_{jt} x_{jt},$$

where x_{jt} is the input for producing m_{jt} and where q_{jt} denotes the technology level or quality level for providing medical care of type j at time t: therefore, q_{jt}^{-1} is also the marginal cost for producing m_{jt}. The evolution of the quality is given by

$$q_{j,t+1} = \left(q_{jt}^{\nu} + (\chi d_{jt})^{\nu}\right)^{1/\nu}, \tag{5}$$

where $\nu \leq 1$ is a parameter, and d_{jt} is the amount of R&D invested in the type-j-knowledge q_{jt}. The parameter $\chi \geq 1$ is a subsidy on medical R&D. We assume that the government's investment in medical R&D is complementary to private R&D.

We drop the j-subscript to denote aggregates,

$$d_t = \int_0^1 d_{jt} dj,\ x_t = \int_0^1 x_{jt} dj,\ \frac{1}{q} = \left(\int \left(\frac{1}{q_j}\right)^{\frac{1}{1-\phi}} dj\right)^{1-\phi}.$$

3.2 Government risk and risk preferences

Government risk The main risk factor we consider initially is government risk. Without government intervention, firms act monopolistically competitive, which implies that prices equal marginal cost times a constant markup, $p_{jt} = \phi/q_{jt}$.

However, with probability $\omega \in [0, 1]$, the government intervenes and caps markups that firms can charge. One can think of this as the European model. In this case, the government imposes price controls and health care prices are limited to $p_{jt} = \zeta/q_{jt}$, where $\zeta \in [1, \phi)$. For simplicity, we consider a one-time switch that is permanent. We introduce a state variable z_t that equals zero if the government has not yet intervened, and one thereafter. We denote the markup at time t by $\mu_t = z_t\zeta + (1 - z_t)\phi$ and therefore prices by $p_{jt} = \mu_t/q_{jt}$.

Risk preferences We assume an exogenous stochastic discount factor to price future cash flows. We model the stochastic discount factor as:

$$M_{t+1} = \begin{cases} \overline{M} & , \text{ if } \Delta z_{t+1} = 1 \\ \underline{M} & , \text{ if } \Delta z_{t+1} = 0 \text{ and } z_t = 0 \\ R_F^{-1} & , \text{ if } z_t = 1 \end{cases}$$

where $\overline{M} > \underline{M}$ and:

$$R_F = \left(\omega\overline{M} + (1 - \omega)\,\underline{M}\right)^{-1}, \tag{6}$$

where R_F is the risk-free rate of interest. The fact $\overline{M} > \underline{M}$ implies that when the government intervenes, the marginal utility of wealth of the agent pricing the assets is high. This generates a positive risk premium for health care firms that is left unexplained by standard asset pricing models.

It is straightforward to account for other risk factors such as the aggregate stock market risk or even the Fama and French (1992) factors. However, to focus on the economic mechanism at work, we focus on the government risk factor only.

3.3 Markets and equilibrium

3.3.1 Firms

We assume that medical care and goods are traded on markets. We assume that each period t, a new continuum of firms $j \in [0,1]$ is created, one for each type of medical care type. A firm is given a one-period patent for developing the type-j medical technology and a monopoly for providing it in the next period. The level of technology achieved is then made freely available to new next firm created.

Taking into account the government risk, firm j in period in period t maximizes the firm value v_{jt} given by:

$$v_{jt} = \max_{d_{jt}} E_t \left(M_{t+1} \pi_{j,t+1} \right) - d_{jt}.$$

where M_{t+1} is the market stochastic discount factor between period t and $t+1$ and $\pi_{j,t+1}$ are the date-$(t+1)$ profits of firm j created at date t. These profits are obtained in monopolistic competition against all other firms present for the other types of medical care. The firm sells medical care at price $p_{j,t+1}$ per unit. Given all aggregate variables, let $m_{j,t+1} = D_{j,t+1}(p_{j,t+1})$ be the demand function for medical services of type j and thus firm j in period $t+1$. In $t+1$, the firm maximizes profits per

$$\pi_{j,t+1} = \max_{p_{j,t+1}} p_{j,t+1} D_{j,t+1}(p_{j,t+1}) - D_{j,t+1}(p_{j,t+1}) / q_{j,t+1}.$$

3.3.2 Households

The households demand consumption and medical care. They therefore maximize the utility U given by (1) by choosing c_{it} and m_{ijt}, subject to (2) and (4) and the sequence of budget constraints

$$c_{it} + \int_0^1 (1-\sigma) p_{jt} m_{ijt} dj = y_{it}, \tag{7}$$

taking prices p_{jt} for medical care of type j at date t. In the households' budget constraint, we allow for a subsidy σ for the purchase of medical care.

The maximization problem of the household implies a demand function $m_{ij,t+1} = D_{ij,t+1}(p_{j,t+1})$ for medical care of type j by household i at date $t+1$, given all aggregates. This implies an aggregate demand function:

$$D_{j,t+1}(p_{j,t+1}) = \int_0^1 D_{ij,t+1}(p_{j,t+1})\, di, \tag{8}$$

for type-j medical care at date $t+1$. We also define the aggregate price index as:

$$p_t = \int_0^1 p_{jt} \frac{m_{jt}}{m_t} dj.$$

3.3.3 Equilibrium

We focus on symmetric equilibria, where all households make the same choices and where all firms make the same choices. Given the exogenous process z_t as well as the initial value a_0, an equilibrium is an adapted stochastic sequence

$$\Psi = (c_t, y_t, m_t, x_t, q_t, d_t, p_t, \pi_t, v_t, D_t(\cdot))_{t=0}^{\infty},$$

with q_t measurable at $t-1$, such that:

1. Given p_t, z_t, d_t, π_t, the choices c_t, y_t, h_t for the representative household maximize

$$U = E\left[\sum_{t=0}^{\infty} \beta^t \frac{\left(c_{it}^{\xi} h_{it}^{1-\xi}\right)^{1-\eta}}{1-\eta}\right], \tag{9}$$

   subject to

$$\begin{aligned} c_t + (1-\sigma)\, p_t m_t &= y_t, & (10)\\ y_t &= \gamma^t. & (11)\end{aligned}$$

   The demand function $D_t(\cdot)$ equals the demand function $D_{jt}(\cdot)$ arising from (8), given symmetry and the sequence Ψ.

2. Given the (stochastic) demand function $D_{t+1}(\cdot)$, the stochastic discount factor M_{t+1} and the stochastic process z_{t+1}, the choices $d = d_t$, $\pi = \pi_{t+1}, p = p_{t+1}$ for the

representative firm maximize the value v_t, per

$$\begin{aligned}
v_t &= \max_{d,a} E_t\left[M_{t+1}\pi\right] - d, \\
\pi &= \max_{p} pD_{t+1}(p) - D_{t+1}(p)/q, \text{ if } z_{t+1} = 0, \\
\pi &= (\xi - 1)/qD_{t+1}, \text{ if } z_{t+1} = 1, \\
q &= \left(q_t^{\nu} + (\chi d_t)^{\nu}\right)^{1/\nu}.
\end{aligned}$$

3. Markets clear

$$\begin{aligned}
m_t &= D_t(p_t), \\
m_t &= q_t x_t,
\end{aligned}$$

and the R&D choice by the firm induces the aggregate evolution of medical progress,

$$q_{t+1} = \left(q_t^{\nu} + (\chi d_t)^{\nu}\right)^{1/\nu}. \tag{12}$$

4 Model solution and implications

We provide the solution to the model and its implications in this section.

Optimal demand for medical care The demand function arising from monopolistic competition is

$$D_t(p_{jt}) = \left(\frac{p_{jt}}{p_t}\right)^{\phi/(1-\phi)} m_t. \tag{13}$$

The marginal cost for producing a unit of medical care of type j is given by $1/q_{jt}$. As discussed in Section 3.2, profit maximization with monopolistic competition of the form above leads to markup pricing over marginal costs:

$$p_{jt} = \mu_t/q_{jt}, \tag{14}$$

for any individual firm or to

$$p_t = \mu_t/q_t, \tag{15}$$

in the aggregate.

Total demand for health care is obtained from the intra-temporal optimization problem of the households,

$$\max_{m_t} \frac{\left(c_t^{\xi} h_t^{1-\xi}\right)^{1-\eta}}{1-\eta}, \tag{16}$$

subject to $(1-\sigma)p_t m_t + c_t = y_t$, solving to

$$m_t = \left(\frac{1-\xi}{1-\sigma}\right)\left(\frac{y_t}{p_t}\right) - \xi \underline{h}\gamma^t = y_t\left(\frac{1-\xi}{1-\sigma}\frac{1}{p_t} - \xi \underline{h}\right). \tag{17}$$

Dynamics health care share Given the optimal demand for medical care, the share of output spent on medical care evolves as:

$$\frac{p_t m_t}{y_t} = \frac{1-\xi}{1-\sigma} - \xi \underline{h} p_t.$$

The model has two important implications. First, if firms do not undertake any R&D, that is, $d_t = 0$, then q_t and hence p_t does not fluctuate over time, holding markups constant. That implies that the medical spending share increases only due to medical R&D, which lowers prices. Second, the long-run share equals $(1-\xi)/(1-\sigma)$, and therefore increases with the importance of health in the utility function (ξ) and the size of the subsidy in the output market (σ).

Optimal R&D investment First, aggregate profits are

$$\pi_t = \int_0^1 \pi_{jt} dj = x_t(\mu_t - 1). \tag{18}$$

To then solve for the optimal level of R&D at date t, we consider a single firm j. Suppose that all other firms have made their R&D choice resulting in the aggregate state of medical knowledge q_{t+1}, while the firm at hand chooses some R&D level d_{jt} resulting in some other level $q_{j,t+1} = \left(q_t^{\nu} + d_{jt}^{\nu}\right)^{1/\nu}$. Equation (13) implies:

$$\pi_{jt} = \left(\frac{q_{jt}}{q_t}\right)^{1/(\phi-1)} \pi_t,$$

recognizing the common aggregate risk z_t in π_t. Therefore, the value maximization problem of the firm can be written as

$$\max_{d_t \geq 0} E_t \left[\left(\frac{q_{j,t+1}}{q_{t+1}} \right)^{1/(\phi-1)} M_{t+1}\pi_{t+1} \right] - d_{jt},$$
$$\text{s.t. } q_{j,t+1} = \left(q_{jt}^{\nu} + (\chi d_{jt})^{\nu} \right)^{1/\nu},$$

where one should note that firm j takes the aggregate variables q_t, q_{t+1}, M_{t+1} and π_{t+1} as given. Note furthermore, that q_{t+1} and $q_{j,t+1}$ are already known at date t. In case of an interior solution, the first-order condition is

$$1 \quad = \quad \frac{\left(q_{jt}^{\nu} + (\chi d_{jt})^{\nu} \right)^{1/\nu - 1} \chi^{\nu} d_{jt}^{\nu-1}}{q_{t+1}(\phi - 1)} \left(\frac{q_{j,t+1}}{q_{t+1}} \right)^{\frac{1}{\phi-1}-1} E_t \left(M_{t+1}\pi_{t+1} \right). \tag{19}$$

This equation illustrates how the risk premium we document in Section 2 slows down the investment in medical R&D. The left-hand side of equation (19) measures the marginal cost of investing in medical R&D and the right-hand side the marginal benefit. The marginal benefit is lowered if $E_t \left(M_{t+1}\pi_{t+1} \right)$ is lower. Expected returns on health care companies are given by:

$$E_t \left(R_{t+1} \right) = \frac{E_t \left(\pi_{t+1} \right)}{E_t \left(M_{t+1}\pi_{t+1} \right)}, \tag{20}$$

which implies:

$$E_t \left(M_{t+1}\pi_{t+1} \right) = \frac{E_t \left(\pi_{t+1} \right)}{E_t \left(R_{t+1} \right)}. \tag{21}$$

We find in Section 2 that the expected returns on health care companies tend to be higher than suggested by standard asset pricing models, which according to (21) lowers the discounted value of profits and per (19) the incentives to invest in medical R&D.

We can simplify the first-order condition in (19) by imposing symmetry:

$$d_t = \frac{(\chi d_t)^{\nu}}{a_t^{\nu} + (\chi d_t)^{\nu}} \frac{1}{\phi - 1} E_t \left(M_{t+1}\pi_{t+1} \right),$$

which can be solved for d_t, if q_t and $E_t \left(M_{t+1}\pi_{t+1} \right)$ are known.

5 Calibration and quantitative implications

We discuss in Section 5.1 how we calibrate the model's parameters, and provide intuition for how parameters are identified. We use the model in Section 5.2 for two counterfactuals. First, we consider the case in which the government risk is removed all together ($\omega = 0$). Second, we consider the case in which the government risk is still present ($\omega > 0$), but the stochastic discount factor is uncorrelated with government risk ($\underline{M} = \overline{M}$). Lastly, we study the model's long-run implications in Section 5.3.

5.1 Moments, parameters, and sensitivity

We need to calibrate the following set of parameters:

$$\Theta = \left\{\gamma, \underline{h}, \nu, q_0, \underline{M}, \overline{M}, \phi, \xi, \zeta, \chi\right\}. \tag{22}$$

The parameters β and η have no implications for medical innovation or spending decisions and therefore do not need to be calibrated. We calibrate the model to five periods of 10 years starting in 1960. Thus, $t = 0$ corresponds to 1960 and $t = 5$ corresponds to 2010. For the calibration we shall additionally impose that $z_t = 0$, which corresponds to no government intervention.

We set γ so that output growth equals 3.1% per annum, that is, $\gamma = 1.36$. Second, we consider the case in which $\zeta = 1$, which implies that once the government intervenes, the prices decline to marginal costs. Even though this is a rather extreme case, it simplifies some of the analysis below. We set the probability of government intervention to 10% per decade, which implies that the probability that the government did not intervene in a 50-year period equals 59%. We also show the robustness of our results below to $\omega = 5\%$ and $\omega = 20\%$. Further, we set the R&D subsidy to $\chi = 2$, which roughly matches Jones (2011).[7]

The profitability of health care firms is given by $(p_t m_t - m_t/q_t)/(p_t m_t) = (\mu_t - 1)/\mu_t$. For the period in which the government did not intervene, that is, $z_t = 0$, profitability therefore equals $(\phi - 1)/\phi$. We set profitability to 50% motivated by CITE. This implies $\phi = 2$. Next, the expected return on health care firms equals $E_t(R_{t+1}) = \underline{M}^{-1}$. We are mainly interested in understanding the impact of the additional return differential relative to standard asset pricing models of around 4-6% per annum we document in Section 2. We therefore set $\underline{M} = 1.06^{10}$.

[7]The ratio of private to public medical R&D spending increased in the last decade, which may also justify a lower value of χ.

We select the remaining four parameters, $\underline{h}, \nu, a_0$, and ξ, to match the R&D share in 1990 and 2010, as well as the health share in 1960 and 2010. We illustrate the fit of the model relative to the data in Figure 4. In Table 3 we report the model parameters for different values of ω.

To provide further intuition for the parameters, we show in Table 4 how the health care share and the R&D share change, for $\omega = 10\%$, if we change $\underline{h}, \nu, a_0$, and ξ.

First, if ξ increases, then health care receives a smaller weight in the utility function. As a result, health care spending declines. As a result of the decline in health care demand, the incentives for innovation weaken as well. Second, if $\underline{h}$ is higher, exogenous health is higher. As such, households do not need to spend as much on medical care and the health share and, for similar reasons as before, the R&D share falls.

Third, if q_0 increases, the level of medical knowledge is higher, which implies marginal cost are lower and prices are lower. This all implies that health care spending is higher, which in turn leads to a higher R&D share. Fourth and final, if ν increases, the returns to R&D are lower. As a result, firms do not innovate, which leaves prices virtually unchanged. As a result, health care spending is much flatter.

5.2 Risk premia, medical innovation, and medical spending

5.2.1 First counter-factual: No government risk

The first counterfactual we consider is when all government risk is removed, that is, $\omega = 0$. Since there is no risk, the stochastic discount factor takes the same value in both states, that is, $\underline{M} = \overline{M} = 1$. The results are presented in Figure 5. The solid line presents the benchmark case. The dotted line corresponds to the case in which we remove government risk altogether. In this case, the health care share and the R&D share rise more rapidly. In particular, the health care share would equal 24.5% in 2010 instead of 17.6%. Likewise, the R&D share would triple from 0.45% in the presence of government risk to 1.84% in the absence of government risk.

If we use the calibration corresponding to $\omega = 5\%$ or $\omega = 20\%$. The results are presented in Table 5. It follows that the main conclusions are not very sensitive to the level of government risk.

5.2.2 Second counter-factual: No government risk premium

As a second counterfactual, we consider the case in which the government risk is present ($\omega = 10\%$), but the risk is not associated with a risk premium, that is, $\underline{M} = \overline{M} = 1$.

This case corresponds to the dashed line in Figure 5. This case allows us to understand two effects that are in play in the first counterfactual separately. More precisely, if all government risk is removed, then $E_t(\pi_{t+1})$ increases and the price of this cash flow, $E_t(M_{t+1}\pi_{t+1})$, increases as well. We are particularly interested in the effect of risk premia on medical innovation and spending, and therefore want to hold constant the impact on expected profits, $E_t(\pi_{t+1})$.

Based on Figure 5, we see that the discount rate effect is the main driver of the increased health care and R&D share. Even holding expected profits constant, the health share would have increased to 23.3% and the R&D share would have increased to 1.51%.

If we use the calibration corresponding to $\omega = 5\%$ or $\omega = 20\%$. The results are presented in Table 5. It follows that the main conclusions are not very sensitive to the level of government risk.

The main insight of both counterfactuals is that accounting for government can lead to different conclusions on spending and innovation trends. Comparing the second to the first counterfactual highlights that the results are mostly driven by the presence of a risk premium as opposed to an effect on expected cash flows.

5.3 Long-run implications

The long-run health care share implied by the model equals $(1-\xi)/(1-\sigma)$, which equals 46.9% in the presence of subsidies. If subsidies in the output market are removed, that is, $\sigma = 0$, the share increases to 33%. Figure 6 illustrates the evolution of the health care spending share and the R&D share as implied by the model. Obviously, the convergence is rather slow and the health care share is expected increase to 35% by 2050. This prediction is similar to the model of Hall and Jones (2007).

For alternative assumptions about government risk, the long-run health share varies between 47.2% for $\omega = 5\%$ and 43.9% for $\omega = 20\%$. Hence, the long-run implications of our model are fairly independent of the amount of government risk.

6 Mechanisms for health care risk premia

In this section, we discuss various economic mechanisms that may give rise to a positive risk premium in the health care industry. This boils down to understanding how certain shocks, in general equilibrium, co-move with the investors' marginal utility. We first show that several mechanisms that may first come to mind, such as shocks to longevity, including health in the utility function, shocks to government subsidies generate a *negative* risk premium in equilibrium. We suggest two mechanisms that give rise to a positive risk premium: medical innovations increase productivity and uncertainty about a government intervention that affects the industry's markups. To focus on the economic intuition, we focus on two-period models. In Section 3, we build a dynamic model to understand the interaction between trends in medical R&D, medical spending, and risk premia.

Risk premia due to longevity effects A natural extension of our model is explicitly model the effect health has on longevity as in the model of Hall and Jones (2007). We consider a 3-period version of such a model, $t = 0, 1, 2$, where the household surely survives until $t = 1$. The probability of survival from $t = 1$ to $t = 2$ depends on health, $f(h_1)$, where $f'(h_1) > 0$. The household's problem can then be summarized by:

$$\max_{(h_1)} u(c_0) + \beta E_0 [u(c_1)] + \beta^2 E_0 [f(h_1) u(c_2)], \tag{23}$$

where the maximization is subject to the resource constraints, $y_t + \pi_t = p_t h_t + c_t$, the prices of medical care, $p_t = \phi_t / q_t$, and firm profits, $\pi_t = h_t (\phi_t - 1) / q_t$.[8] Unless noted otherwise, we focus on shocks to q_t that lower the marginal cost of producing medical care.

Optimal period-1 health follows from $\max_{(h_1)} u(c_1) + f(h_1) b$, where $b = \beta E_1 [u(c_2)] > 0$ a constant. In this case, we have $c_1 = y_1 - h_1 q_1^{-1} = y_1 - (\phi_1 - 1)^{-1} \pi_1$, which implies that consumption and profits are negatively correlated. Since $M_1 = \beta u'(c_1) / u'(c_0) = \beta u' \left(y_1 - (\phi_1 - 1)^{-1} \pi_1\right) / u'(c_0)$, profits and the stochastic discount factor are positively correlated. This implies a negative risk premium for health care firms. This holds true regardless of the survival function $f(h_1)$ and as long as $u'(c) < 0$.

Risk premia due to health in the utility function As a second extension of our basic model, we allow for a model in which health and non-consumption enter in a non-separable way in the utility function. We then relate the intra-period elasticity between

[8] Relative to our full model, we consider a simpler production for health with $\underline{h}= 0$ and $\nu = 1$, which implies that medical spending maps one-to-one to health, $m_t = h_t$.

health and non-health consumption to the risk premium for health care firms. We consider a two-period model without longevity effects ($f(h_1) = 0$). Households solve the problem:

$$\max_{(h_1)} u(c_0) + \beta E_0 [u(c_1, h_1)] .$$

To make further progress, we specialize the utility function to be of the CES type:

$$u(c,h) = \frac{1}{1-\gamma} \left(\alpha c^{1-1/\rho} + (1-\alpha) h^{1-1/\rho}\right)^{\frac{1-\gamma}{1-1/\rho}} ,$$

where $\gamma > 1$, $\rho \geq 0$, and $\alpha \in [0,1]$. For $\rho \to 1$, we obtain Cobb-Douglas preferences. The limits of $\rho \to \infty$ or $\rho \to 0$ imply that health and non-health consumption are perfect substitutes or complements, respectively. The SDF is given by $M_1 = \beta u_c(c_1, h_1) / u_c(c_0)$.

As we show in Appendix B, health always increases in q, while consumption increases (decreases) in q for $\rho < 1$ ($\rho > 1$). The opposite is true for profits. The bottom right panel shows that the marginal utility of consumption declines, regardless of ρ. Hence, for $\rho < 1$, which we consider empirically to be the most relevant one, profits and marginal utility are positively correlated and thus results in a negative risk premium. For $\rho > 1$, though, profits and marginal utility are negatively correlated. This says that if health and consumption are *sufficiently strong substitutes*, households can shift towards health, which then in turn also lowers the marginal utility of consumption.

Risk premia due to inter-temporal substitution Instead of relaxing the intra-period elasticity of substitution between health and non-health consumption, we can relax the inter-temporal elasticity of substitution. To illustrate the mechanism, we return to the model in equation (23), and allow for non-separabilities between $t = 1$ and $t = 2$ consumption:

$$c_0 + \beta E_0 \left[c_1^{1-1/\rho} + \beta f(h_1)^{1-1/\rho} E_1 \left(c_2^{1-\gamma}\right)^{\frac{1-1/\rho}{1-\gamma}} \right]^{\frac{1}{1-1/\rho}} ,$$

where ρ now denotes the elasticity of inter-temporal substitution. This problem is mathematically very similar to the previous problem in which health enters into the utility function. In this case, high values of ρ correspond to high values of the elasticity of inter-temporal substitution. If we consider a simple linear model for $f(h_1)$,[9] then the results in the previous section imply that the risk premium is positive if $\rho > 1$. The exact value of the elasticity of inter-temporal substitution is debated in the macro-finance literature. Hall (1988), for instance, argues that the value of the elasticity of inter-temporal substi-

[9] We assume that the model parameters are such that $f(h_1) \in [0,1]$.

tution is well below one, but there is a strand of recent asset pricing models that heavily relies on values above one, see for instance Bansal and Yaron (2004).

Risk premia due to subsidy shocks As an alternative to shocks to the marginal cost of producing care, q_t, we can introduce subsidies in the output market, σ_t, and allow for uncertainty about future subsidies. This implies that households face a price $(1-\sigma_t)p_t h_t$, but at the same time pay taxes $\sigma_t p_t h_t$ to finance subsidies. This affects the marginal incentives, but leaves aggregate resources unchanged. We again use the preferences in equation (23), but subject to the resource constraints $y_t + \pi_t = (1-\sigma_t)\, p_t h_t + c_t + \tau_t$. Profits of health care firms equal $\pi_t = (\phi_t - 1)\, h_t/q_t$. As before, it directly follows $c_1 = y_1 - (\phi_1 - 1)^{-1} \pi_1$, which implies that consumption and profits are negatively correlated. The demand for medical care follows from:

$$u'(y_1 - h_1/q_1)(1-\sigma_1)\, p_1 = f'(h_1)\, \beta E_1 (u(c_2)) .$$

In case of a positive subsidy shock, the household increases the demand for medical care. However, this implies that health care profits increase, but consumption decreases, and hence produces a negative risk premium. At a basic level, the equation $c_1 = y_1 - (\phi_1 - 1)^{-1} \pi_1$ implies a negative risk premium in case of longevity effects and subsidy shocks.

Risk premia due to productivity shocks To be done.

Risk premia due to markup shocks As a final way to extend our model, we consider shocks to markups, ϕ_t. We use the same preferences as in (23). In this case, we still have $\pi_1 = (\phi_1 - 1)\, h_1/q_1$ and $c_1 = y_1 - h_1/q_1$. If the markups decline, profits for health care firms fall, which relies on the assumption that $\mid \epsilon_{h_1/q_1,\phi_1} \mid < 1$. At the same time, because prices are lower, households spend more on health, and hence h_1/q_1 increases $(\partial(h_1/q_1)/\partial\phi < 0)$. This implies that consumption declines and the marginal utility of consumption rises. Hence, profits are low when the marginal utility of consumption is high, resulting in a positive risk premium.

7 Conclusion

Despite that improvements in health have been a major component of the overall gain in economic welfare during the last century, the continued incentives for medical innovation and the resulting growth of the health care sector are poorly understood. In particular, although it is generally believed that technological change through medical innovation is a central component of the expansion of this sector, little is understood about what risks affects the returns of these R&D investments and how those risks affects future spending growth in health care.

We provided an empirical and theoretical analysis of the link between asset markets and health care spending. We first documented a "medical innovation premium" for the returns of medical R&D firms in the US during the period 1960 to 2010. The excess returns relative to standard risk-adjustments were estimated between 3-5% per annum, which is very large and about the same size as the equity risk premium and the value premium during this period. Motivated by this finding, we provided a first theoretical analysis of the joint determination of financial- and real health care markets, analyzing the joint behavior of medical R&D returns in asset markets and the growth of the real health care sector.

We interpreted the medical innovation premium to result from government markup risks that may require investors to demand higher returns on medical R&D investments beyond standard risk-adjusted returns. We simulated the quantitative implications of our analysis and found that there would have been a sizeable expansion of the health care sector, on the order of 7%, in absence of this government risk.

Our analysis raises many future research questions that need to be addressed to more fully understand the growth of health care sectors around the world. First, if government uncertainty discourages health care R&D, then how is standard analysis of government interventions altered taking into account of this effect? For example, most government across the world attempt to stimulate medical R&D through various push and pull mechanisms. But if the government uncertainty attached to such mechanisms discourages R&D, how much does this uncertainty reduce the intended effects of such R&D stimuli? Second, our analysis suggests how to improve valuation of the future US federal debt as implied by Medicare and Medicaid spending growth. Clearly discounting such spending with Treasury rates seems inappropriate in light of a medical innovation premium documented here. It appears the market discounts the same type of cash flows present in government liabilities more than if they were risk less. Third, many policy proposals to slow spending growth in health care need to incorporate the government risk and medical R&D effects. For example, the 2010 report of the National Commission On Fiscal Responsibility And Reform recommends health care cost growth to below the growth to GDP plus 1%. Historically, the growth in overall health care spending has been about 2% above

GDP growth. In our model, it is optimal that health care expenditures increase over time as a fraction of income. Our framework and analysis can be used to consider imposing government restrictions on health care spending and quantity their effects, particularly in light of uncertainty about government imposing the restrictions.

More generally, we believe future analysis needs to better incorporate the feedback role of financial markets, government risk, and the growth of the health care sector. The fact that the health care sector depends on the growth in medical R&D, which in turn is affected by government risk means that greater uncertainty introduced by government intervention discourages medical R&D which in turn affects future growth of government programs. Further explicit analysis of the dynamic incentives for continued medical progress seems warranted given the dramatic effects such progress has had on overall

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A Tables and figures

Panel A: Annual returns

	Cnsmr	Manuf	HiTec	Health	Other	MedEq	Drugs
1927-2010							
CAPM	1.2%	1.2%	0.7%	3.9%	-0.9%	4.3%	4.2%
	1.12	1.60	0.57	2.24	-0.93	2.08	2.33
Fama-French	0.6%	0.6%	2.2%	5.4%	-2.6%	5.6%	5.8%
	0.55	0.89	1.78	3.18	-3.39	2.64	3.19
1946-2010							
CAPM	1.1%	1.7%	-0.3%	4.2%	-0.7%	4.3%	4.5%
	0.98	1.89	-0.19	2.01	-0.64	1.77	2.12
Fama-French	-0.3%	0.9%	2.1%	5.7%	-3.0%	6.6%	5.9%
	-0.20	0.96	1.28	2.63	-3.59	2.41	2.69
1961-2010							
CAPM	1.7%	1.7%	-0.8%	3.1%	0.4%	3.9%	3.5%
	1.27	1.60	-0.51	1.47	0.31	1.43	1.60
Fama-French	-0.4%	1.0%	1.9%	4.9%	-2.5%	6.8%	5.2%
	-0.27	0.80	0.89	2.23	-2.48	2.08	2.36

Panel B: Monthly returns

	Cnsmr	Manuf	HiTec	Health	Other	MedEq	Drugs
1927-2010							
CAPM	1.4%	0.9%	0.5%	2.9%	-1.2%	3.3%	3.2%
	1.90	1.45	0.56	2.20	-1.40	1.99	2.26
Fama-French	1.4%	0.4%	1.6%	3.7%	-2.6%	3.5%	4.1%
	1.91	0.80	2.05	2.92	-3.66	2.13	2.99
1946-2010							
CAPM	1.2%	1.5%	-0.5%	3.0%	-0.8%	3.1%	3.3%
	1.40	2.08	-0.49	2.14	-0.97	1.77	2.23
Fama-French	0.4%	0.4%	1.7%	4.8%	-2.9%	4.1%	5.3%
	0.55	0.67	1.83	3.56	-3.72	2.35	3.69
1961-2010							
CAPM	1.6%	1.4%	-0.9%	2.3%	0.1%	3.0%	2.7%
	1.67	1.68	-0.72	1.45	0.05	1.64	1.53
Fama-French	0.6%	0.4%	1.5%	4.6%	-2.3%	4.4%	5.3%
	0.62	0.45	1.26	3.03	-2.40	2.38	3.20

Table 1: Industry alphas

	Health exp. (% of GDP)		Pharma. exp. (% health exp.)	
Country	1971	2007	1971	2007
Australia	4.8	8.5	14.8	14.3
Austria	5.1	10.3	-	13.3
Belgium	4.0	10.0	28.3	15.0
Canada	7.2	10.1	-	17.2
Denmark	7.9	9.7	-	8.6
Finland	5.7	8.2	13.6	14.1
Germany	6.5	10.4	15.5	15.1
Iceland	5.2	9.1	17.3	13.5
Ireland	6.0	7.5	-	17.7
Japan	4.7	8.1	-	20.1
New Zealand	5.2	9.1	11.4	10.2
Norway	4.7	8.9	7.3	8.0
Spain	4.0	8.4	-	21.0
Sweden	7.1	9.1	6.9	13.4
Switzerland	5.6	10.6	-	10.3
United Kingdom	4.5	8.4	14.8	12.2
United States	7.3	15.7	11.5	12.0
Average	5.6	9.5	14.1	13.9
Median	5.2	9.1	14.2	13.5

Table 2: Health care spending for OECD countries

ω	5%	10%	20%
γ	1.36	1.36	1.36
$\underline{h}$	11.49	8.62	4.70
ν	0.39	0.40	0.41
q_0	36.49	27.76	16.79
$\frac{\underline{M}}{\overline{M}}$	1.79	1.79	1.79
ϕ	2	2	2
ξ	0.669	0.672	0.693
ζ	1	1	1
χ	2	2	2

Table 3: Model parameters

Health share	Benchmark	$\xi = 0.68$	$\underline{h} = 9$	$q_0 = 30$	$\nu = 0.5$
1960	5.12%	3.46%	3.30%	8.24%	5.12%
1970	6.47%	4.54%	4.39%	9.79%	5.23%
1980	8.30%	6.08%	5.95%	11.78%	5.37%
1990	10.73%	8.21%	8.14%	14.28%	5.59%
2000	13.84%	11.06%	11.10%	17.30%	5.88%
2010	17.60%	14.68%	14.86%	20.78%	6.31%
R&D share					
1960	0.03%	0.02%	0.02%	0.05%	0.00%
1970	0.05%	0.03%	0.03%	0.09%	0.00%
1980	0.09%	0.06%	0.06%	0.14%	0.00%
1990	0.17%	0.12%	0.12%	0.23%	0.00%
2000	0.29%	0.22%	0.22%	0.35%	0.00%
2010	0.45%	0.37%	0.38%	0.51%	0.00%

Table 4: Understanding the calibration

Level of government risk: $\omega = 5\%$

Health share	Benchmark	No government risk	No government risk premium
1960	5.1%	5.1%	5.1%
1970	6.5%	7.3%	7.2%
1980	8.4%	10.4%	10.2%
1990	10.8%	14.2%	13.9%
2000	13.9%	18.8%	18.4%
2010	17.6%	23.7%	23.2%
R&D share			
1960	0.0%	0.1%	0.1%
1970	0.1%	0.2%	0.2%
1980	0.1%	0.4%	0.4%
1990	0.2%	0.7%	0.7%
2000	0.3%	1.2%	1.0%
2010	0.5%	1.7%	1.5%

Level of government risk: $\omega = 10\%$

Health share	Benchmark	No government risk	No government risk premium
1960	5.1%	5.1%	5.1%
1970	6.5%	7.4%	7.2%
1980	8.3%	10.6%	10.1%
1990	10.7%	14.7%	13.9%
2000	13.8%	19.4%	18.4%
2010	17.6%	24.5%	23.3%
R&D share			
1960	0.0%	0.1%	0.1%
1970	0.1%	0.2%	0.2%
1980	0.1%	0.5%	0.4%
1990	0.2%	0.8%	0.7%
2000	0.3%	1.3%	1.0%
2010	0.5%	1.8%	1.5%

Level of government risk: $\omega = 20\%$

Health share	Benchmark	No government risk	No government risk premium
1960	5.1%	5.1%	5.1%
1970	6.4%	7.7%	7.2%
1980	8.3%	11.2%	10.2%
1990	10.7%	15.7%	14.1%
2000	13.9%	20.7%	18.6%
2010	17.6%	25.7%	23.3%
R&D share			
1960	0.0%	0.1%	0.1%
1970	0.1%	0.3%	0.2%
1980	0.1%	0.6%	0.4%
1990	0.2%	1.1%	0.7%
2000	0.3%	1.7%	1.1%
2010	0.5%	2.2%	1.5%

Table 5: Health and R&D share dynamics for both counterfactuals and different levels of government risk.

Figure 1: Relative market capitalization

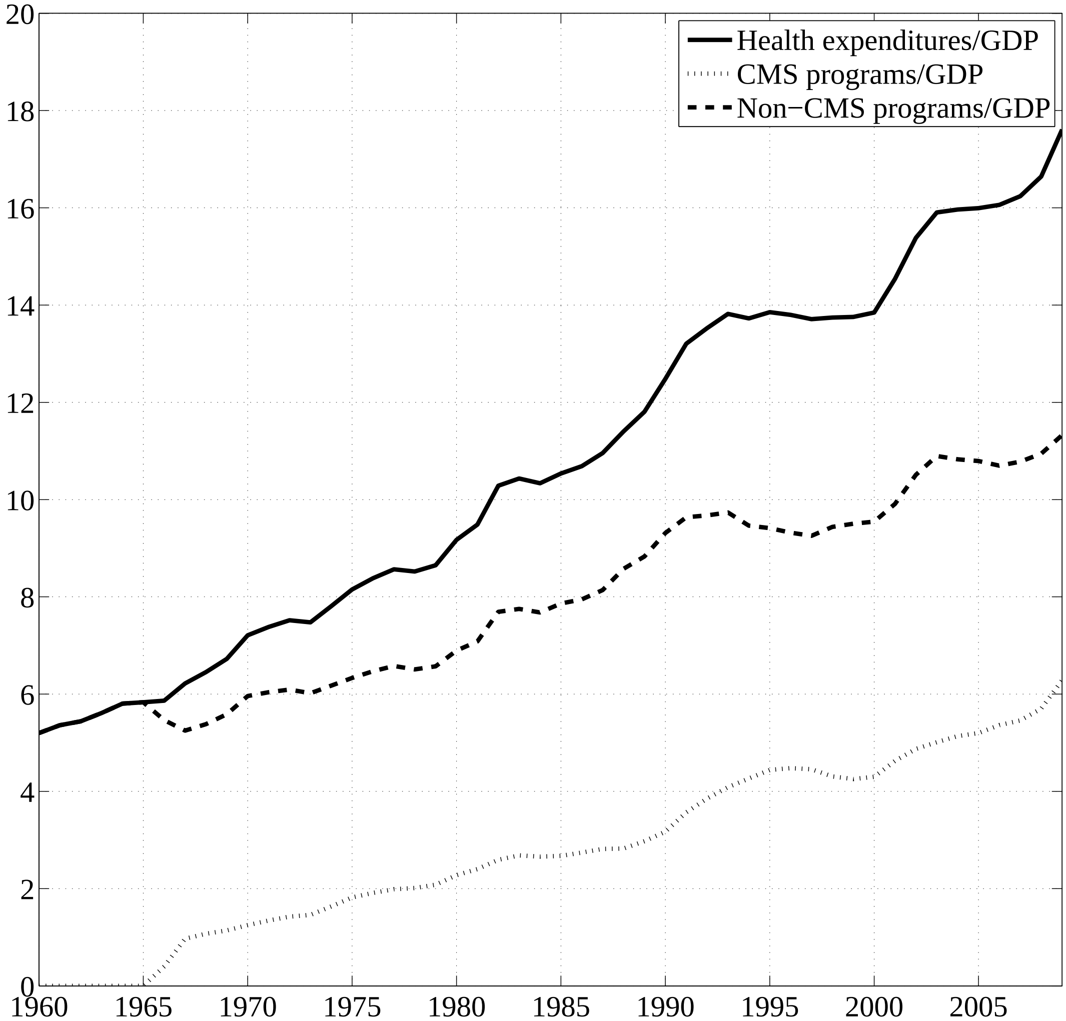

Figure 2: Medical spending relative to GDP

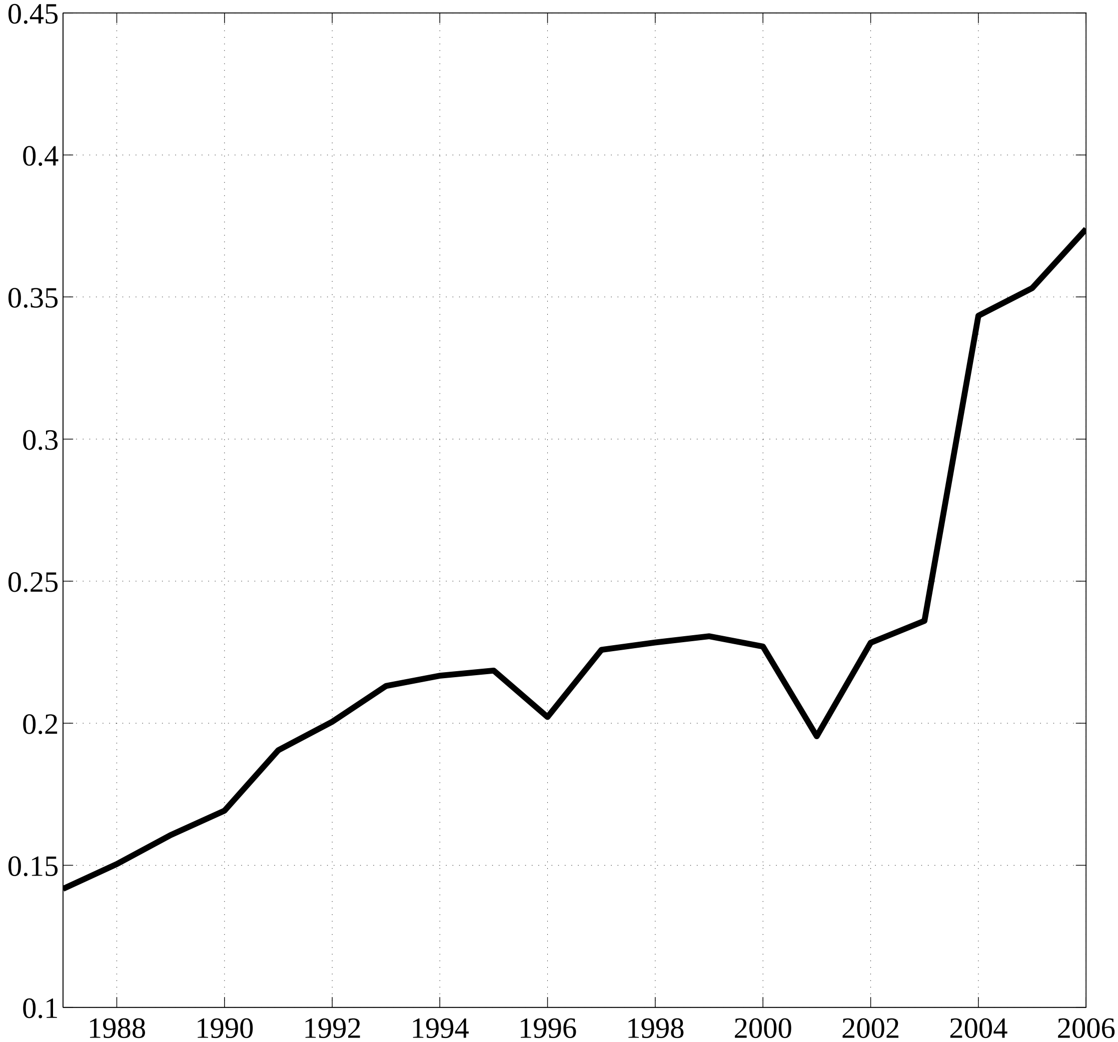

Figure 3: Medical R&D spending relative to GDP

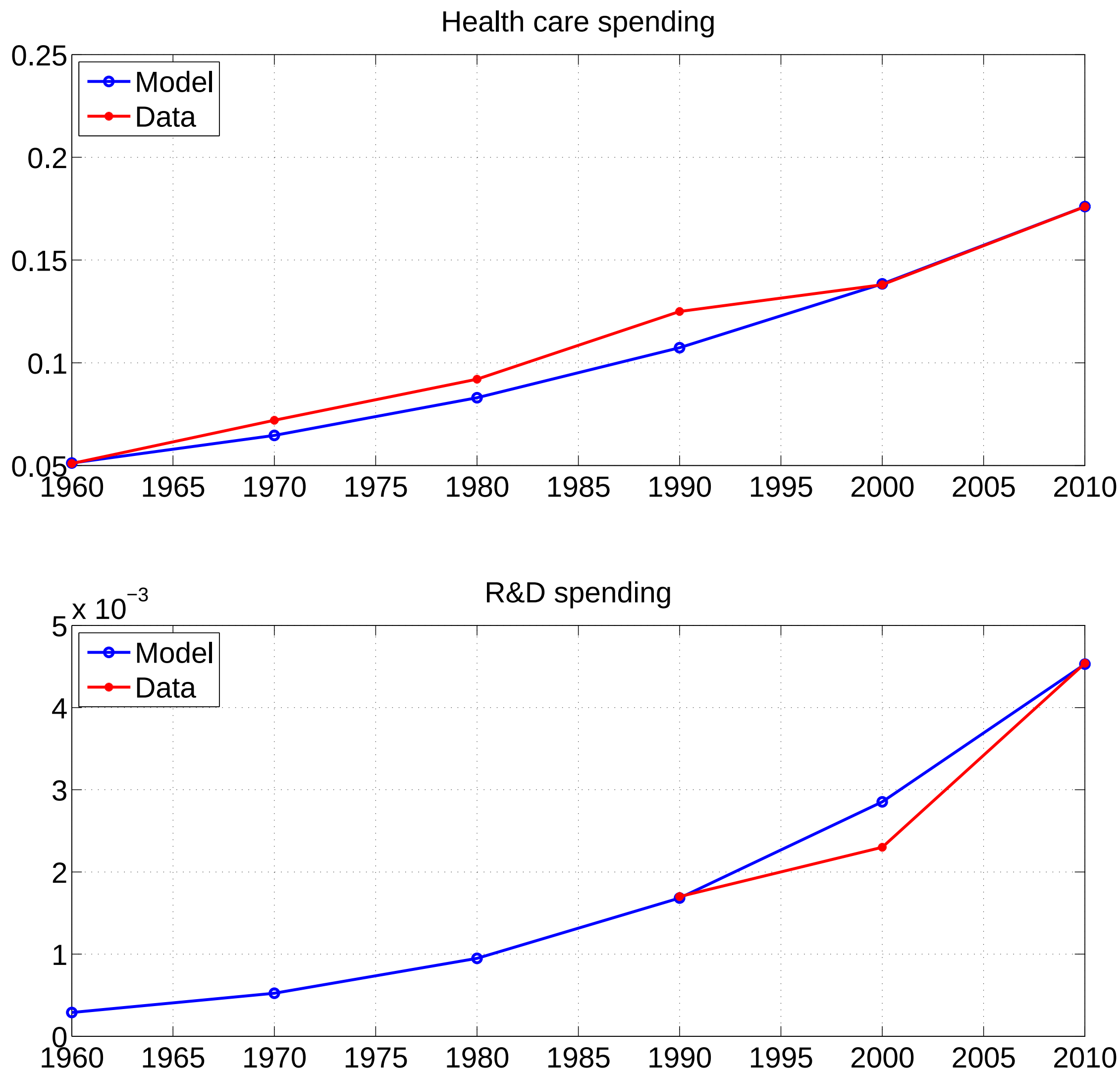

Figure 4: Health and R&D share in the model and in the data

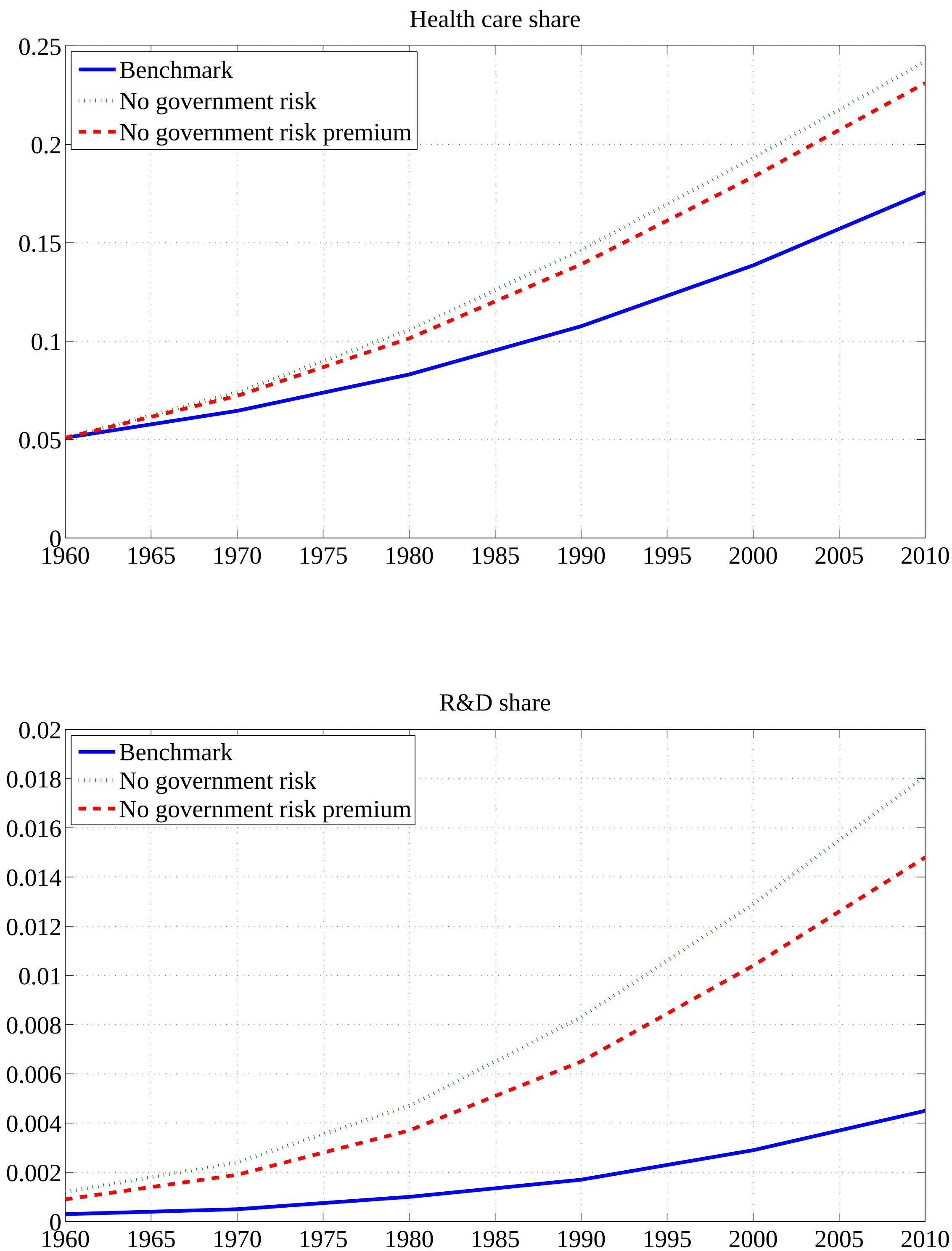

Figure 5: Counterfactuals

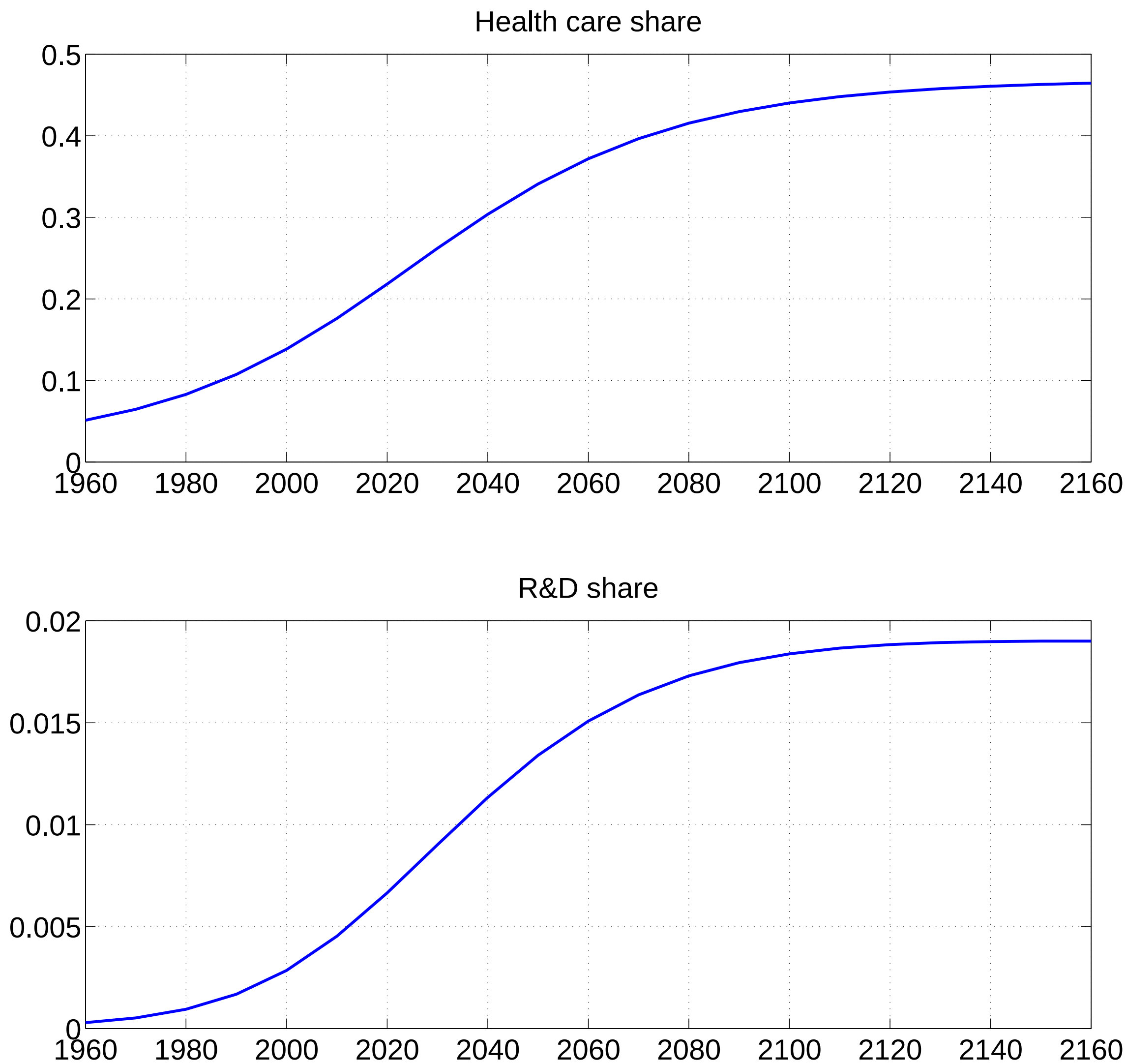

Figure 6: Long-run dynamics of the health and R&D share in the model

B Alternative mechanisms for health care risk premia

The results in Finkelstein, Luttmer, and Notowidigdo (2008) and Koijen, Van Nieuwerburgh, and Yogo (2011) suggest that the marginal utility of non-health consumption increases with health, that is, $u_{ch} > 0$. With CES preferences, this implies that $\rho < 1/\gamma$ as:

$$u_{ch} = (1/\rho - \gamma)\left(\alpha c^{1-1/\rho} + (1-\alpha)\, h^{1-1/\rho}\right)^{\frac{1/\rho-\gamma}{1-1/\rho}-1} \alpha c^{-1/\rho}\,(1-\alpha)\, h^{-1/\rho}.$$

Hence, for $\gamma > 1$, it follows directly that $\rho < 1$ in case $\gamma > 1$.

To understand the implications from this model, we solve for optimal health in the first period:[10]

$$\max_{h} \frac{1}{1-\gamma}\left(\alpha\,(y + \pi - ph)^{1-1/\rho} + (1-\alpha)\, h^{1-1/\rho}\right)^{\frac{1-\gamma}{1-1/\rho}},$$

which implies:

$$h = y\left(\theta q^{-\rho} + q^{-1}\right)^{-1},$$

where $\theta = \left(\alpha^{-1} - 1\right)^{-\rho} \phi^{\rho} > 0$. For any value of $\rho \geq 0$, we have $h_q > 0$. Non-health consumption equals:

$$c = y - h/q = y\theta\left(\theta + q^{\rho-1}\right)^{-1}.$$

This implies $c_q = -y\theta\left(\theta + q^{\rho-1}\right)^{-2} q^{\rho-2}\,(\rho - 1)$,which is positive for $\rho < 1$ and negative for $\rho > 1$. Hence, for the most relevant case of $\rho < 1$, medical innovation lowers consumption. Profits equal:

$$\pi = (\phi - 1)\, h/q = (\phi - 1)\, y\left(\theta q^{1-\rho} + 1\right)^{-1},$$

which implies $\pi_q = -\,(\phi - 1)\, y\left(\theta q^{1-\rho} + 1\right)^{-2} \theta\,(1-\rho)$. This implies that profits of health care companies fall in case of medical innovation when $\rho < 1$. Lastly, we can compute the marginal of consumption:

$$u_c\,(c, h) = \left(\alpha c^{1-1/\rho} + (1-\alpha)\, h^{1-1/\rho}\right)^{\frac{1/\rho-\gamma}{1-1/\rho}} \alpha c^{-1/\rho}.$$

Lastly, for Cobb-Douglas preferences, that is, $\rho \to 1$, it holds $h = yq\,(\phi - 1)$, $c = (2 - \phi)\, y$, and $\pi = y\,(\phi - 1)$, which implies that the risk premium is zero as profits and consumption are constant.

[10] We omit subscripts for brevity.

The following figure plots h, c, π, and u_c for $\alpha = 0.5$, $y = 1$, $\phi = 2$, $\gamma = 2$, and $\rho = 0.5$ or $\rho = 1.5$.

INCLUDE FIGURE

As shown analytically before, health always increases in q, while consumption increases (decreases) in q for $\rho < 1$ ($\rho > 1$). The opposite is true for profits. The bottom right panel shows that the marginal utility of consumption declines, regardless of ρ. Hence, for $\rho < 1$, which we consider empirically to be the most relevant one, profits and marginal utility are positively correlated and thus results in a negative risk premium. For $\rho > 1$, though, profits and marginal utility are negatively correlated. This says that if health and consumption are *sufficiently strong substitutes*, households can shift towards health, which then in turn also lowers the marginal utility of consumption.

C Individual insurance against health shocks [UPDATE]

The results discussed generalize directly to when health shocks are insured individually through private or public insurance. The main point emphasized is that when idiosyncratic risks due to individual health shocks, are pooled through health or earnings insurance, they do not affect the results discussed for systematic risks affecting asset prices.

To illustrate this in a simple manner consider when individuals can either be sick or healthy in the future with probability $(g, 1 - g)$, the probability g also representing the prevalence of the disease[11]. If the individual is sick then he produces health care according to $f(m, z)$ and he is healthy he does not need any care. Clearly if both earnings and health care are fully insured, the individuals consumption across the two states does not vary, though the consumption level will be lower due to the premium paid for covering health and earnings shocks, for instance through health insurance, disability, or workers compensation coverage. If individual health shocks can be diversified away, by the same reasoning as before, medical innovation will be positively related to consumption growth and hence a premium on asset will be implied.

[11]Productivity gains in non-health care production may affect the prevalence of a disease through a function $s(w)$. For example, as discussed in Philipson and Posner (1999) higher productivity through automated production may lead to more obesity through less on-the job exercise, in which case it has a positive slope. Alternatively, work safety environments that rise with development may induce a negative slope.

Even if there is no earnings insurance, health insurance alone may still lead to the same implications.[12] The insurance policy for medical care sells at a competitive (fair) premium ρ that equals the average costs of covering the (ex-post optimal) health care spending; $\rho = gpm(z)$ Each individual maximizes expected utility over future wellness states

$$gU(c_g) + (1-g)U(c)$$

subject to the budget constraint:

$$\begin{aligned} c_g &= \gamma f(m(z), z) - \rho \\ c &= \gamma - \rho \end{aligned}$$

where $\gamma \geq f(m(z), z)$ is reduced form for the higher earnings when not sick assuming without loss of generality $h = 1$.As health care is productive, perfect consumption smoothing across health states may now not take place even under complete markets. This is because medical technology determines how much consumption can be generated given the occupance of a health shock. Put differently, health care shocks can be pooled but health shocks cannot. The share of output that is made up of health care spending is now just premium spending divided by total output

$$S = \frac{\rho}{y} = g(\frac{pm}{y})$$

The implied profits of health care firms is determined by the health care of the sick population

$$\pi(z) = gM(p; z)(p - x)$$

Thus both the expenditure share and profits are just proportional to the quantities analyzed before. The returns on health care firms do still require a premium because when medical productivity is larger, sicker individuals are richer

$$\frac{d\pi}{dz} > 0, \frac{dc_g}{dz} > 0$$

[12] Koijen, Van Nieuwerburgh, and Yogo (2011) show how standard retirement products such as life insurance, health insurance, and annuities can be used to implement a complete-markets solution in which households are exposed to health and mortality risks.