Financial Health Economics[*]

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Abstract

Medical innovations and the expansion of the US health care sector are of first-order importance. Incentives for innovation are linked to their financial returns. This paper provides a first, explicit analysis linking medical R&D, health sector growth and financial returns. We document evidence of a "medical innovation premium" – a significant risk premium for firms engaged in medical R&D that is higher than predicted by benchmark asset pricing models, and therefore is unique to or particularly strong in the health sector. We interpret this premium as compensating investors for bearing government risk to markups on developed innovations and analyze its quantitative implications for the growth of future health care spending. Our calibration implies substantial effects of the premium on innovation and health care spending. Removing government risk would almost triple medical R&D spending and thereby increase health spending further by 4% of GDP.

Improvements in health are a major component of the overall gain in economic welfare and reduction in world inequality during the last century (Murphy and Topel (2006) and Becker, Philipson, and Soares (2005)). Indeed, an emerging literature finds that the value of improved health is on par with many other forms of economic growth as represented by material per-capita income reflected in conventional GDP measurements. As such, the increase in the quantity and quality of life may be the most economically valuable change of the last century. At the same time, the current size of this sector, now close to a fifth of the US economy, and its continued growth have given rise to concerned public debates.

Medical innovation and its demand are central to these improvements in health. Through medical progress, including improvements in knowledge, procedures, drugs, biologics, devices, and the services associated with them, there is an increased ability to prevent and treat old and new diseases. Many analysts emphasize that this surge in medical innovation is key to understanding the rapid expansion of the health care sector (Newhouse (1992), Cutler (1995), and Fuchs (1996)).

To understand the growth of this sector, and the medical R&D that induces it, it is important to understand the financial returns of those investing in medical innovation. This paper provides a first, quantitative analysis of the joint determination of returns and return risks of medical R&D firms with their innovation activities and the growth of the health care sector.

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 that are not captured by standard asset pricing models.

Our theoretical analysis then investigates the link between financial markets, incentives for medical innnovation and the growth in the real health care sector. A standard asset pricing perspective implies that the health industry risk premium should reflect an aggregate risk component to which the health care industry is exposed in a particularly strong way. It also implies that a high risk premium diminuishes incentives for medical R&D, since the investments there must recoup the high returns on average. Put differently, if that risk premium could be eliminated, we should observe more medical R&D. This is reminiscent of the analysis by Murphy and Topel (2006), which suggests that the gains to health may justify even larger investments in medical R&D.

In this paper, we offer one possible interpretation of the documented innovation premium and trace out its quantitative implications for the growth in health care spending. We interpret it to arise from one distinguishing feature of the health care sector: the important role of the public sector in affecting profitability. We analyze the growth of the health care sector when the risk that investors face is that the US government converts to the "European model" in which price controls or monopsony power threaten future markups[1] An illustration of government risk affecting medical innovation is the current slow down in investments due to the uncertain fate of US health care reform.[2] There are three major reasons why we focus on government risk as driving the medical innovation premium. First, government greatly affects both the approval of medical products as well as the profits conditional on such approval. Indeed, demand subsidy programs such as Medicare and Medicaid currently make up about half of medical spending in the US, clearly an important component affecting the profits of innovators. 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. Second, we seek an aggregate risk component, to which the health sector is particularly exposed: government intervention risk in that sector has that property. Third, we argue that other forces than government risk often imply a negative medical innovation premium in standard consumption-based asset pricing models, which is the opposite of what we find empirically.

We quantify the implications of the medical innovation premium stemming from government risk using data on publicly traded firms engaged in medical R&D in the US during the period 1960-2010. It is important to separate the firms that invest in medical R&D that expands the health care sector from those that deliver care or finance it. Our empirical analysis is for the former that are mainly device-, biologic-, and drug-manufacturers that are largely publicly held firms. The providers delivering care are mainly hospitals, doctors, and nursing homes that are largely either non-profit or privately held.[3] Payers or insurance companies are largely publicly held and our evidence suggests the medical innovation premium is not present for them, consistent with an interpretation that such firms are not exposed to the mark-up risk.

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

[2]See for instance "Insurers at Risk in Challenge to Health Law's Medicaid Plan," Bloomberg.com, March 20, 2012.

[3]For example, CMS data indicate that the three largest spending categories in 2010 were hospitals (31%), doctors (20%), nursing home and home care (14%) of which a small fraction is publicly traded. The annual American Hospital Association survey for 2010 indicate that only 17% of the nation's 5,754 hospitals are investor-owned, which includes both privately- and publicly-held hospitals. Although data on physician groups is not readily available, the vast majority is believed to be privately held.

Using these 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 parameters to study two counterfactuals to assess the quantitative importance of the medical innovation premium for future health care spending growth. We find that the medical innovation premium has large effects on future health care spending growth. More precisely, 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 the discounting of firms, we want to separate the two. We find that the size of the health care sector would increase by 4% of GDP if the risk premium is removed, and an additional 1% if the impact on expected profits is removed as well. Hence, the largest impact of government intervention risk on health care spending and investment in medical R&D is due to risk premia as opposed to changes in expected cash flows. As one implication, we note that discounting future medical care liabilities by US Treasury rates rather than how markets discount health care spending seems inappropriate in light of the medical innovation premium documented in this paper.

In terms of impacting R&D spending, we find that it is almost three times as high in the absence of the medical innovation premium. These large effects of the medical innovation premium also have implications for the long-run health care share. By 2050, our model suggests that 31% of GDP is spent on health care, conditional on no government intervention. The long-run steady state share is slightly below 35% of GDP. The CBO projects that the total spending on health care would rise from 16% of gross domestic product (GDP) in 2007 to 25% in 2025, 37% in 2050, and 49% in 2082. Hence, our model produces estimates for the health care share that are somewhat lower than the CBO projections.

The paper relates to several strands of previous research by attempting to merge insights from the three separate fields of health economics, finance, and macroeconomics. It differs from previous work in those fields by examining the joint determination of the asset returns for those investing in medical innovation and the resulting growth in the real health care sector. In these fields, 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, estimates the impact of economic growth on health care spending. There a central question has been whether the share of income spent on health care rises with income. This "luxury good" nature of health care is also predicted by more recent theoretical work, see for instance Hall and Jones (2007), but the evidence is mixed, see Acemoglu, Finkelstein, and Notowidigdo

(2009) and the references therein. More importantly, in the cross-section health care is a necessity in the upper part of the income distribution, suggesting that technology may ultimately be the barrier to rich people from spending larger shares of their incomes on health care. In asset pricing, a recent literature studies the implications of uncertainty of government policy for asset prices, see for instance Pastor and Veronesi (2011) and Pastor and Veronesi (2012). However, none of these papers study the implications for asset prices of firms that invest in medical innovation or, vice versa, the impact of financial asset returns on investment decisions of these firms and overall health care spending, which is the main focus of our paper.

1 Empirical analysis

1.1 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 Kenneth 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,[4] pharmaceutical products,[5] and health services.[6] We also study the 48 industry classification, which splits the health care industry into the three aforementioned 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 the entire health care industry or for the three sub-industries. We closely replicate the returns reported by Kenneth 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.

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

[5]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.

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

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.

1.2   Risk premia in health care markets

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 account for other sources of systematic risk outside of the model. Table 1 reports the intercepts, or "alphas," of the following time-series regression:

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

where F_t is a set of risk 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 by standard asset pricing models.

Asset pricing models are distinguished by the factors F_t they account for. 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. This is a common implementation of the Capital Asset Pricing Model (CAPM), see Sharpe (1964). The second benchmark asset pricing model we consider is the 3-factor Fama and French (1992) model, which is labeled "Fama-French." In addition to the market factor, this model also accounts for firm size (the "SMB" factor) and the value factor (the "HML" factor). Empirically, smaller firms and firms with high book-to-market ratios tend to have higher average returns. These additional two factor account for these regularities.[7]

For robustness, we estimate the model both at a monthly frequency and 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 different sample periods: 1927-2010, 1946-2010, and 1961-2010. The first sample period is the longest sample available. The second

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[7]There is a large literature that provides explanations for the size and value effects, see for instance Berk, Green, and Naik (1999), Zhang (2005), Lettau and Wachter (2007), and Koijen, Lustig, and Van Nieuwerburgh (2012). In this paper, we are particularly interested in the risk premium in the health care industry above and beyond the standard risk factors and do not provide an explanation for the market, size, and value risk premia or exposures.

sample focuses on the post-war period. The third sample coincides with the period for which we have data on aggregate health care spending. The returns on services start only in the late sixties, and we therefore exclude them from the table. However, their returns are well explained by standard models and the alphas are close to zero.

The annual results are in Panel A and the monthly results in Panel B of Table 1. 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. This is because the alphas on medical services are close to zero.

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.[8]

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 firms working on pharmaceutical products make up the vast majority of market capitalization.

It is important to point out that trends in shares of market capitalization do not mechanically 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. That is, the change in market share and alphas are virtually uncorrelated. 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 in case of the health care sector, we do not find that the average firm size increases more in the health care industry than in other industries.

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[8]Fama and French (1997) study the performance of the Fama and French (1992) model for a large cross-section of 48 industries. Their Appendix B shows that the model is rejected in particular due to two industries: the real-estate and the health-care industries. Despite the large and growing literature on returns in real estate markets, little is known about health care markets.

1.3 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 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. 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, medical R&D spending also 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.

2 A dynamic model of medical innovation and spending

In this section, we build a dynamic model to study the interaction between the risk premia in the health care industry, investment in medical R&D, and medical spending. To understand the basic intuition before getting into the full details, consider a two-period model of a medical R&D firm, generating payoffs or profits in the second period given by $\pi f(d)$, where π are the normalized profits for $f(d) = 1$, while d are $R\&D$ expenditures in the first period and $f(\cdot)$ is a positive, strictly increasing, strictly concave and twice differentiable function. Assume that π is random and correlated with the

aggregate stochastic discount factor M, equal to the stochastic discount factor of the shareholders and firm owners. They therefore seek to maximize the firm value

$$v = E[M\pi]f(d) - d$$

resulting in the first order condition

$$f'(d) = \frac{1}{E[M\pi]} = \frac{E[R]}{E[\pi]} \tag{1}$$

where

$$R = \frac{\pi f(d)}{E[M\pi]f(d)} = \frac{\pi}{E[M\pi]}$$

is the second-period return on purchasing one unit of resources worth of shares of the firm in the first period after the R&D investment. Equation (1) implies that the higher the risk premium, i.e. the higher the expected return $E[R]$, the lower the R&D investment d in the first period[9]. In the calibrated dynamic model below, we postulate this risk premium to be due to government intervention risk, and seek to quantify the sullying effect of the risk premium on medical R&D and health care spending overall.

2.1 The environment

2.1.1 Preferences and endowments

Time is infinite, $t = 0, 1, \ldots$. There are two types of infinitely-lived households: "normal" or "non-entrepreneurial" households $i \in [0, 1]$ and "entrepreneurial" households $i \in (1, \kappa]$ for some $\kappa > 1$. We shall think of the latter is constituting a small fraction of the entire population, i.e., we shall think of $\kappa - 1$ being small. We focus on symmetric allocations and equilibria, with a representative household for each type.

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

$$U = E\left[\sum_{t=0}^{\infty} \beta^t \frac{\left(c_{nt}^{\xi} h_{nt}^{1-\xi}\right)^{1-\eta}}{1-\eta}\right], \tag{2}$$

where c_{nt} is the non-health care consumption of a normal household at date t, h_{nt} 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-

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[9] This in turn has implications for aggregate health care spending and individual health care spending, which depend on the relative sizes of certain elasticities. The appendix B examines the details.

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).

Normal households are endowed with one unit of time each period, which they supply inelastically as labor. The productivity of labor for producing consumption goods is growing exogenously with $\gamma > 1$. Households are further endowed with a base level of health, given by $\underline{h}\gamma^t$ for some parameter $\underline{h} > 0$, and thus assumed to be growing at the same rate as labor productivity.

For entrepreneurial households e, we abstract from health care consumption as well as labor supply. We think of these as rich households, for which labor income does not matter much, whose labor supply does matter much in the aggregate, and who purchase the best medical care available, but which nonetheless constitutes only a small fraction of their income. We therefore concentrate entirely on their consumption c_{et} and, below, their asset holdings. We assume that they have potentially non-separable preferences

$$U_t = V\left(c_{et}, E_t[U_{t+1}]\right). \tag{3}$$

Rather than fully specifying these preferences, we impose properties on the resulting stochastic discount factor below, with which these preferences need to be consistent.

2.1.2 Technologies and feasibility

Let $c_t = c_{nt} + \kappa c_{et}$ and $h_t = h_{nt}$ denote aggregate non-health and health care consumption at date t. The production of aggregate consumption c_t is given by

$$c_t = \gamma^t L_{ct}, \tag{4}$$

where L_{ct} are the total units of labor devoted to producing consumption goods. We use the consumption good at time t as numeraire.

Health is produced according to the production function

$$h_t = \underbrace{\underline{h}\gamma^t}_{\text{Exogenous health}} + \underbrace{m_t}_{\text{Health due to medical care}}, \tag{5}$$

where $\underline{h}\gamma^t$ is the base health level the household is endowed with and m_t is medical care, an input to increase the health level beyond the base health level. One may wish to

impose some upper bound $\bar{h}\gamma^t$ as the maximal level of health that can be reached with state-of-the-art medical care, in order to motivate our assumption above of abstracting from medical care for entrepreneurial households.

Medical care is produced from a continuum of individual types, indexed by $j \in [0,1]$,

$$m_t = \left(\int_0^\kappa m_{jt}^{1/\phi} dj \right)^\phi, \tag{6}$$

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

The production of m_{jt} units of type-j medical care is given by

$$m_{jt} = q_{jt}\gamma^t L_{mjt},$$

where L_{mjt} is the total units of labor used for producing type-j medical care, γ^t is the general productivity increase, and q_{jt} is the productivity or quality level for producing type-j medical care relative to producing the consumption good. Therefore, q_{jt}^{-1} is also the marginal cost for producing m_{jt} in terms of the consumption good at time t. The evolution of the quality is given by

$$q_{j,t+1} = \left(q_{jt}^\nu + d_{jt}^\nu \right)^{1/\nu}, \tag{7}$$

where $\nu \leq 1$ is a parameter, and d_{jt} is the amount of R&D invested in the type-j-knowledge q_{jt}, created with labor per

$$d_{jt} = \gamma^t L_{djt},$$

where L_{djt} is the total labor used for undertaking type-j R&D, and γ^t is the general level of productivity. We drop the j-subscript to denote aggregates. We shall focus on symmetric equilibria, so that $q_t \equiv q_{jt}$, *et cetera*. Aggregate feasibility requires

$$L_{ct} + L_{mt} + L_{dt} = 1. \tag{8}$$

2.2 Government, markets and equilibrium

2.2.1 Government and government risk

We assume that the government intervenes in three ways that all affect the health care sector. First, it proportionally subsidizes R&D undertaken by the firm, so that firms only need to privately pay for a fraction $1 - \chi$ of the costs of R&D, for some $0 < \chi < 1$. We keep this level of subsidy fixed throughout. Second, it proportionally subsidizes the purchases of medical care by households, so that households only pay for a fraction $(1-\sigma)$ of the market price of medical care, for some $0 < \sigma < 1$. We keep this level of subsidy fixed throughout.

Third, the government may restrict the prices firms can charge for medical care. We assume that this restriction may randomly change over time: indeed, the main risk factor we consider is this government price intervention risk. Without government intervention, firms act monopolistically competitive, which implies that prices equal marginal cost times a constant markup, $p_t = \phi/q_t$. However, with probability $\omega \in [0, 1]$, the government intervenes and caps markups that firms can charge. In this case, the government imposes price controls and health care prices are limited to $p_t = \zeta/q_t$, 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 $p_t = \mu_t/q_t$.

Only the first two types of intervention create a flow of payments from the government, so that the government budget constraint is given by

$$\sigma p_t m_t + \chi d_t = \tau_t + \kappa \tau_{t,e}, \tag{9}$$

where τ_t are the lump sum taxes collected from normal households at time t and $\tau_{t,e}$ are the lump sum taxes collected from entrepreneurial households at time t. We assume that the taxes of each type of household pays for the subsidies received by that type of household,

$$\sigma p_t m_t = \tau_t,$$
$$\chi d_t = \kappa \tau_{t,e}.$$

Lump sum taxes and infinitely lived households imply Ricardian equivalence, provided we do not also redistribute between households: we may therefore assume wlog that there is no government debt.

2.2.2 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 by the households and owned by the households, 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 a new next firm created.

Taking into account the government risk, and dropping the sub-index j, a firm in period in period t maximizes the firm value v_t given by:

$$v_t = \max_{d_{jt}} E_t \left(M_{t+1} \pi_{t+1} \right) - (1 - \chi) d_t,$$

where M_{t+1} is the market stochastic discount factor between period t and $t + 1$, arising from the preferences of the household, where $(1 - \chi)$ reflects net costs for doing R&D after the government subsidy, and where π_{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, subject to the potential markup restriction by the government.

2.2.3 Households

We assume that normal households neither trade assets on financial markets nor hold shares in firms. They receive labor income. They receive medical care purchase subsidies from the government and pay taxes. They therefore maximize the utility U given by (2) by choosing c_{nt} and m_t, subject to (6) and the sequence of budget constraints

$$c_{nt} + (1 - \sigma) \int_0^1 p_{jt} m_{jt} dj + \tau_t = \gamma^t, \tag{10}$$

taking prices p_{jt} for medical care of type j at date t as well as the medical care purchase subsidy σ as given. The maximization problem of the households implies an aggregate demand function $D_{j,t+1} (p_{j,t+1})$ for medical care of type j.

Entrepreneurial households create new firms, pay for their costs arising from R&D, and receive income from profits generated by the firms, which they have created in the previous period. They maximize (3) subject to the sequence of budget constraints:

$$c_{et} + \tau_{t,e} + (1 - \chi) \frac{1}{\kappa} d_t = \frac{1}{\kappa} \pi_t. \tag{11}$$

Note the division of R&D expenses and profits by κ, in order to properly "distribute" the continuum $j \in [0,1]$ of firms over the "small" continuum $j \in [1, \kappa]$ of entrepreneurial households.

2.2.4   Equilibrium

We focus on symmetric equilibria where all normal households make the same choices, all entrepreneurial households make the same choices, and where all firms make the same choices. Given the exogenous process z_t, an equilibrium is an adapted stochastic sequence

$$\Psi = (M_t, c_t, m_t, h_t, c_{t,e}, m_{t,e}, h_{t,e}, \tau_t, L_{ct}, L_{mt}, q_t, d_t, L_{dt}, p_t, \pi_t, v_t, D_t(\cdot))_{t=0}^\infty,$$

with q_t measurable at $t-1$, such that households maximize their utility, given prices, government interventions, and firm choices, firms maximize profits and value per setting their own price, given prices set by other firms, wages, the stochastic discount factor and government intervention, and markets clear.

3   Model solution and implications

3.1   Health care demand

The budget constraint of the entrepreneurial households as well as the government budget constraint implies

$$\kappa c_{t,e} = \pi_t - d_t, \tag{12}$$

so that consumption of the entrepreneurial households is current period profits minus the expenses for creating the next generation of firms.

Profit maximization with monopolistic competition leads to the usual markup pricing over marginal costs, subject to government intervention,

$$p_t = \mu_t / q_t, \tag{13}$$

where

$$\mu_t = \begin{cases} \phi & \text{if } z_{t+1} = 0, \\ \zeta & \text{if } z_{t+1} = 1. \end{cases} \tag{14}$$

The resulting profits are

$$\pi_t = \frac{\mu_t - 1}{q_t} m_t. \tag{15}$$

13

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 the household budget constraint (10) as well as (5). This solves to

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

where p_t is given by (13).

Let $\varphi_t = p_t m_t / \gamma^t$ be the share of gross labor income spent by (normal) households on medical care. Note that $\tau_t = \sigma p_t m_t = \sigma \varphi_t \gamma^t$. With this, rewrite (17) as

$$\varphi_t = \left(\frac{1-\xi}{1-\sigma}\right)(1 - \sigma\varphi_t) - \xi\underline{h}p_t$$

and solve for φ_t. We find that the share evolves as

$$\varphi_t = \frac{p_t m_t}{\gamma^t} = \frac{1-\xi}{1-\sigma\xi} - \frac{1-\sigma}{1-\sigma\xi}\xi\underline{h}p_t. \tag{18}$$

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 do not fluctuate over time, holding markups constant. Hence, medical spending share increases only due to medical R&D, which lowers prices. Second, the long-run share equals $(1 - \xi)/(1 - \sigma\xi)$, and therefore increases with the importance of health in the utility function $(1 - \xi)$ and the size of the subsidy in the output market (σ).

3.2 Optimal medical R&D

Aggregate profits are

$$\pi_t = x_t(\mu_t - 1). \tag{19}$$

Consider a single firm j, choosing some R&D level d_{jt}, resulting in $q_{j,t+1} = \left(q_t^\nu + d_{jt}^\nu\right)^{1/\nu}$. Suppose the R&D choices of all other firms result in the aggregate state of medical knowledge q_{t+1}. The standard monopolistic competition formulas imply

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

14

The value maximization problem of the firm can therefore be written as

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

$$\text{s.t. } q_{j,t+1} = \left(q_{jt}^\nu + d_{jt}^\nu \right)^{1/\nu},$$

taking as given the aggregate variables q_t, q_{t+1}, M_{t+1} and π_{t+1}, and q_{t+1} known at date t. In case of an interior solution, the first-order condition is

$$1 - \chi = \frac{\left(q_{jt}^\nu + d_{jt}^\nu \right)^{1/\nu-1} d_{jt}^{\nu-1}}{q_{t+1}(\phi-1)} \left(\frac{q_{j,t+1}}{q_{t+1}} \right)^{\frac{1}{\phi-1}-1} E_t \left(M_{t+1}\pi_{t+1} \right). \tag{20}$$

Imposing symmetry yields

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

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

This equation illustrates how the risk premium we document in Section 1 slows down the investment in medical R&D. The left-hand side of equation (20) measures the marginal cost of investing in medical R&D and the right-hand side measures the marginal benefit. The marginal benefit is lowered if $E_t \left(M_{t+1}\pi_{t+1} \right)$ is lower. Expected returns of health care companies are given by:

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

which implies:

$$E_t \left(M_{t+1}\pi_{t+1} \right) = \frac{E_t \left(\pi_{t+1} \right)}{E_t \left(R_{t+1} \right)}. \tag{22}$$

We find in Section 1 that the expected returns on health care companies tend to be higher than suggested by standard asset pricing models, which according to (22) lowers the discounted value of profits and per (20) the incentives to invest in medical R&D.

4 Calibration and quantitative implications

In Section 4.1, we discuss the model of the stochastic discount factor, M_t. In Section 4.2, we discuss how we calibrate the model's parameters, and provide intuition for how pa-

rameters are identified. We then use the model in Section 4.3 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. We conclude this section by studying the long-run implications of the model in Section 4.4.

4.1   Risk preferences: Modifying the stochastic discount factor

For the quantitative calculations, we shall directly impose assumptions on the evolution of the stochastic discount factor and assume that preferences of entrepreneurial households in (3) are such that they imply this evolution rather than derive it from it.

We take this approach for two reasons. First, we wish to generate interesting risk premia in the health care sector without distorting inter-temporal and intra-temporal choices such as for instance the risk-free rate, except through the choices for R&D as described above. Second, it considerably simplifies the numerical analysis. Note that (12) essentially implies an exogenous evolution of the consumption of the entrepreneurs, given R&D and profit decision of firms, which we have derived before, given the evolution of the stochastic discount factor.

We consider the following model of the stochastic discount factor:

$$M_{t+1} = R^{-1} M_{t+1}^H, \tag{23}$$

where R is the rate of discounting that is not particular to the health care risk. In a model with standard productivity shocks *et cetera*, R is determined by the risk pricing of such shocks. It is straightforward to account for other risk factors such as the aggregate stock market risk or even the Fama-French factors. However, to focus on the economic mechanism at work, we restrict attention to the government risk factor only.

The second component of the stochastic discount factor, M_{t+1}^H, is the component that is specific to the health care sector, which in our model corresponds to the risk of government intervention. We model M_{t+1}^H as:

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

where $\overline{M} > \underline{M}$. Once the government intervenes ($z_t = 1$), $M_{t+1}^H = 1$ and risk premia in the health care sector can be explained by standard risk factors. The fact $\overline{M} > \underline{M}$ implies

16

that when the government intervenes, the marginal utility of wealth of the agent pricing the assets is high. This covariance of marginal utility and profits generates a positive risk premium for health care firms that is left unexplained by standard asset pricing models.

4.2 Moments, parameters, and sensitivity

We need to calibrate the following set of parameters:

$$\Theta = \left\{\gamma, \underline{h}, \nu, q_0, \underline{M}, \overline{M}, \phi, \xi, \zeta, \chi, \sigma\right\}. \tag{24}$$

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 $z_t = 0$, $t = 0, \ldots, 5$, which corresponds to no government intervention.

In the model, we label γ^t the labor income of the normal households, whereas total output is given by

$$y_t = (1 + \kappa)\gamma^t + \pi_t,$$

and includes the profits of health-care companies. To compare this equation to the data, it is reasonable to think of y_t as income from a growing stock of capital and labor that can be spent on consumption and health care, that is, as gross domestic product net of gross investment. Furthermore, profits of health care companies are a small share of GDP, so it is reasonable to equate $(1 + \kappa)\gamma^t$ with GDP net of gross investment.

Based on data from the St. Louis Fed, we set γ so that output growth equals 3.0% per annum, that is, $\gamma = 1.35$. 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, $z_t = 0$, profitability equals $(\phi - 1)/\phi$. Caves, Whinston, and Hurwitz (1991) show that prices of drugs fall by 80% if a patent of a drug expires and generic drugs become available. This suggests $\phi = 5$. However, other expenses, such as marketing costs, decline as well after patent expiration, which suggests a lower number. As a starting point, we therefore set $\phi = 3$.

We then turn to the subsidy on medical care and medical R&D. According the the CMS, about 50% of aggregate health care spending occurs via Medicare and Medicaid. We therefore set $\sigma = 50\%$. Further, we set the R&D subsidy to $\chi = 2$, which roughly matches Jones (2011).[10]

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[10]The ratio of private to public medical R&D spending increased in the last decade, which may also

In calibrating government intervention risk, we initially consider the case in which government intervention reduces health care prices to marginal costs. This implies $\zeta = 1$. We set the probability of government intervention to $\omega = 10\%$, which implies that the probability that the government did not intervene in a 50-year period equals 59%. We also explore the implications for our main results of changing ω from $\omega = 10\%$ to $\omega = 20\%$.

Next, we calibrate the stochastic discount factor. R is the relevant discount rate in the absence of government intervention risk. For the arguments given in McGrattan and Prescott (2003), we set R equal to 4% per annum, or $R = 1.48$ in our model in which a period corresponds to a decade. To calibrate M_{t+1}^H, we first note that, using the assumptions made before:

$$\frac{E(\pi_{t+1})}{E(\pi_{t+1} M_{t+1})} = R\underline{M}^{-1}. \tag{25}$$

We think of R as the return coming from the CAPM or the Fama-French model. $\underline{M}^{-1}$ is the medical innovation premium that we estimate to be around 4-6% per year, and we calibrate to a baseline return R of 4% as discussed above and an additional risk premium of 5%. We therefore set $R\underline{M}^{-1} = 1.09^{10} = 2.37$. Also, given our assumptions made previously, $\overline{M}$ no longer affects spending or R&D decisions.

We select the remaining four parameters, $\underline{h}$, ν, q_0, and ξ to match the R&D share in 1990 and 2010, as well as the health share in 1960 and 2010. We use data on health care spending from the CMS and data on R&D spending is from Jones (2011).

We illustrate the fit of the model relative to the data in Figure 4. In Table 3 we summarize the model parameters for $\omega = 10\%$ as well as $\omega = 20\%$.

4.3   Risk premia, medical innovation, and medical spending

To understand the impact of government intervention risk and risk premia on health care spending and investment in medical R&D, we proceed in two steps. First, we remove all government risk. Removing government risk altogether has two effects. On the one hand, there is no risk premium effect anymore. On the other hand, the expected profits of firms engaged in medical R&D increase. To separate both effects, we also consider the case where the government risk is still present, but there is no risk premium effect. By comparing both counterfactuals, we can assess the cash flow and discount rate effects separately.

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justify a lower value of χ.

4.3.1 First counterfactual: 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, $M_{t+1} = R^{-1}$. 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 the absence of government risk, the discount rate firms apply to medical R&D investments is lower and the expected profits are higher. As such, medical R&D rises more rapidly. By 2010, the R&D share almost triples the R&D share in the presence of risk premia and government risk.

As a result of medical R&D, the price of medical care falls and the health care share rises more rapidly as well. The impact is quantitatively large as the share of GDP spent on medical care rises from about 20% to 25% in 2010 in this counterfactual scenario.

If we use the calibration corresponding to $\omega = 20\%$. The results are presented in Table 4. Even though the R&D share rises somewhat more rapidly in this case, the effect is quantitatively small. We conclude that changing ω and re-calibrating the model has a minor effect on this counterfactual.

4.3.2 Second counterfactual: No government risk premium

As a second counterfactual, we consider the case in which the government risk is present ($\omega = 10\%$), but we set the price of government intervention risk to zero, $\underline{M} = \overline{M} = 1$. 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 increase to 24.5% and the R&D share would increase to 1.9%.

If we use the calibration corresponding to $\omega = 20\%$. The results are presented in Table 4. 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.

4.4 Long-run implications

The long-run health care share implied by the model equals $(1-\xi)/(1-\sigma\xi)$, which equals 36% in the presence of subsidies. If subsidies in the output market are removed, that is, $\sigma = 0$, the share increases to only 22%. 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 to increase to 31% 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 increases to 35% for $\omega = 20\%$. Hence, the long-run implications of our model are fairly independent of the amount of government risk.

5 Mechanisms for health care risk premia

5.1 Broad intuition for alternative mechanisms

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. This is meant as an exploratory exercise, not some all-encompassing theory. Simply put, some approaches throw up harder challenges than others. This section uses a broad theory brush to discuss how and why, focussing on the key economic arguments and without providing a comprehensive list of assumptions and caveats. We first provide a broader overview, and then examine some approaches in somewhat more careful detail.

The key insight from the empirical asset pricing results is as follows. Given the positive health industry alphas, it should be the case that $\partial U/\partial c_{t+1}$ is low when health industry profits π_{t+1} are high. *Ceteris paribus*, marginal utility is low if consumption is high.

Consider a representative household that demands medical care m, resulting in health $h = m$. Medical care can be provided with productivity (or "quality", "inverse of marginal costs") q, and sold at price p, subsidized at rate σ. The subsidies are financed per lump-sum taxes τ on the household. Assume a linear production function and denote

the markup with ϕ. Profits of the medical sector are π. Aggregate income is y, while aggregate consumption is c. Preferences by the household are given by a utility function $u(c, h)$.

For a linear production function, the relationship between prices, marginal costs, markups and profits are:

$$p = \frac{\phi}{q} \text{ and } \pi = (\phi - 1)\frac{h}{q}. \tag{26}$$

The household budget constraint is:

$$y + \pi = c + (1 - \sigma)ph + \tau. \tag{27}$$

The government budget constraint is:

$$\sigma ph = \tau. \tag{28}$$

Together, we obtain the following two key equations:

$$c = y - h/q = y - \pi/(\phi - 1), \tag{29}$$
$$\pi = (\phi - 1)h/q. \tag{30}$$

These equations imply that approaches that treat y, ϕ, q as parameters or constants are challenging to pursue. Consider the following sources of uncertainty:

1. Medical progress, including longevity: see subsection 5.2 for more elaboration. If q increases, so will h.

2. Preference shocks for h, with c and h separable or complements in the utility function $u(\cdot, \cdot)$.

3. A shock to the subsidies σ.

The challenge is the following. Suppose that these shocks result in surprise increases in profits π. They will then lead to lower consumption. Conversely, lower profits go together with higher consumption. In the cases above, this should yield a negative, not a positive alpha.

Approaches which treat all of π, h, c, y, ϕ, q as endogenous have more potential to be successful. Consider the following sources of uncertainty:

21

1. Medical progress and productivity. Suppose a surprise increase in q leads to a more productive workforce, thereby increasing y. It is then possible, in principle, to have both π and c increase.

2. A preference shock for h, where c and h are (strong) substitutes in the utility function $u(\cdot, \cdot)$. Suppose that h is increased and thus profits π increase, while consumption c decreases. In principle, it is nonetheless possible that the marginal utility of consumption decreases as well.

3. Government regulatory risk regarding ϕ: if ϕ declines unexpectedly, then so will π and c, while h increases.

These approaches face challenges on their own. The first one may not be sufficient quantitatively: while medical progress has perhaps led to somewhat longer working life and to fewer absentee hours due to sickness in the US after the Second World War, these effects may be too small to sensibly generate the medical innovation premium that we estimate in our empirical work. The second approach may not be plausible. Per own introspection, it does seem to us that consumption, and marginal increases thereof, are more fun and not less fun, if one is healthy.[11] We therefore chose the third approach as the key approach in this paper. The arguments above are painted with a broad brush: it is entirely conceivable, even plausible, that reasonable exceptions can be found that allow the pursuit of other alternatives. For some of them, more detail is useful to reveal where the challenges lie exactly. We shall do so in particular for longevity risk.

5.2   Risk premia due to longevity effects

Longevity is the key to understanding the growth of health expenditures in the model of Hall and Jones (2007). Our paper is not in contrast to theirs; rather, it is complementary. While longevity may indeed be key (and indeed, our long-run improvements in health may well be interpreted as increases in longevity), we argue here that they are unlikely to be the risk factor giving rise to the medical innovation premium.

Consider a three-period extension of the model above, $t = 0, 1, 2$, 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:

$$\max_{(h_1)} u(c_0) + \beta E_0\left[u(c_1)\right] + \beta^2 E_0\left[f(h_1) u(c_2)\right], \tag{31}$$

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[11]This is also with the empirical results in Viscusi and Evans (1990), Finkelstein, Luttmer, and Notowidigdo (2008), and Koijen, Van Nieuwerburgh, and Yogo (2011).

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, $\pi_t = h_t (\phi_t - 1)/q_t$.[12] 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 $M_1 = \beta u'(c_1)/u'(c_0) = \beta u'(y_1 - (\phi_1 - 1)^{-1} \pi_1)/u'(c_0)$, 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 $u'(c) < 0$.

6   Conclusion

Despite the fact 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 not well-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 known about what risks affect the returns of these R&D investments and how those risks affect 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 to be between 4-6% per annum, which is non-trivial and about the same size as other asset pricing puzzles such as the equity risk premium and the value premium during this period. Motivated by this finding, we provide 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 interpret 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

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[12]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, $m_t = h_t$.

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 are standard analyses of government interventions altered taking into account of this effect? For example, most governments 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, discounting future medical care liabilities by US Treasury rates rather than how markets discount health care spending seems inappropriate in light of the medical innovation premium documented in this paper. 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 be below the growth to GDP plus 1%. Historically, the growth in overall health care spending is 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 quantify their effects, particularly in light of uncertainty about government imposing restrictions.

More generally, we believe future analyses 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 on overall health care spending.

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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

| | | Probability of government intervention | |
Parameter	Description	$\omega = 10\%$	$\omega = 20\%$
γ		1.35	1.35
ϕ	Markup	3	3
ζ	Constrained markup	1	1
χ	R&D subsidy	50%	50%
σ	Medical care subsidy	50%	50%
R	Baseline discount rate	1.48	1.48
$\underline{M}$	Price of government risk	0.63	0.63
q_0	Initial level of medical knowledge	2.80	1.60
ν	Curvature R&D production function	0.44	0.46
$\underline{h}$	Health endowment	0.45	0.24
ξ	Weight non-health consumption in U	0.78	0.79

Table 3: Model parameters

	Probability of government intervention: $\omega = 10\%$		
	Benchmark	No government risk	No government risk premium
Health share			
1960	6.1%	6.1%	6.1%
1970	7.8%	9.0%	8.7%
1980	10.2%	12.8%	12.2%
1990	13.2%	17.2%	16.4%
2000	16.7%	21.5%	20.6%
2010	20.4%	25.3%	24.5%
R&D share			
1960	0.1%	0.2%	0.2%
1970	0.1%	0.5%	0.4%
1980	0.2%	0.9%	0.7%
1990	0.4%	1.4%	1.1%
2000	0.6%	1.9%	1.5%
2010	0.8%	2.3%	1.9%
	Probability of government intervention: $\omega = 20\%$		
	Benchmark	No government risk	No government risk premium
Health share			
1960	6.1%	6.1%	6.1%
1970	7.7%	9.3%	8.7%
1980	10.0%	13.7%	12.2%
1990	13.0%	18.4%	16.5%
2000	16.6%	22.7%	20.7%
2010	20.3%	26.2%	24.5%
R&D share			
1960	0.1%	0.3%	0.2%
1970	0.1%	0.7%	0.4%
1980	0.2%	1.2%	0.7%
1990	0.4%	1.8%	1.1%
2000	0.6%	2.3%	1.6%
2010	0.8%	2.6%	1.9%

Table 4: Health and R&D share dynamics for both counterfactuals and different levels of government risk.
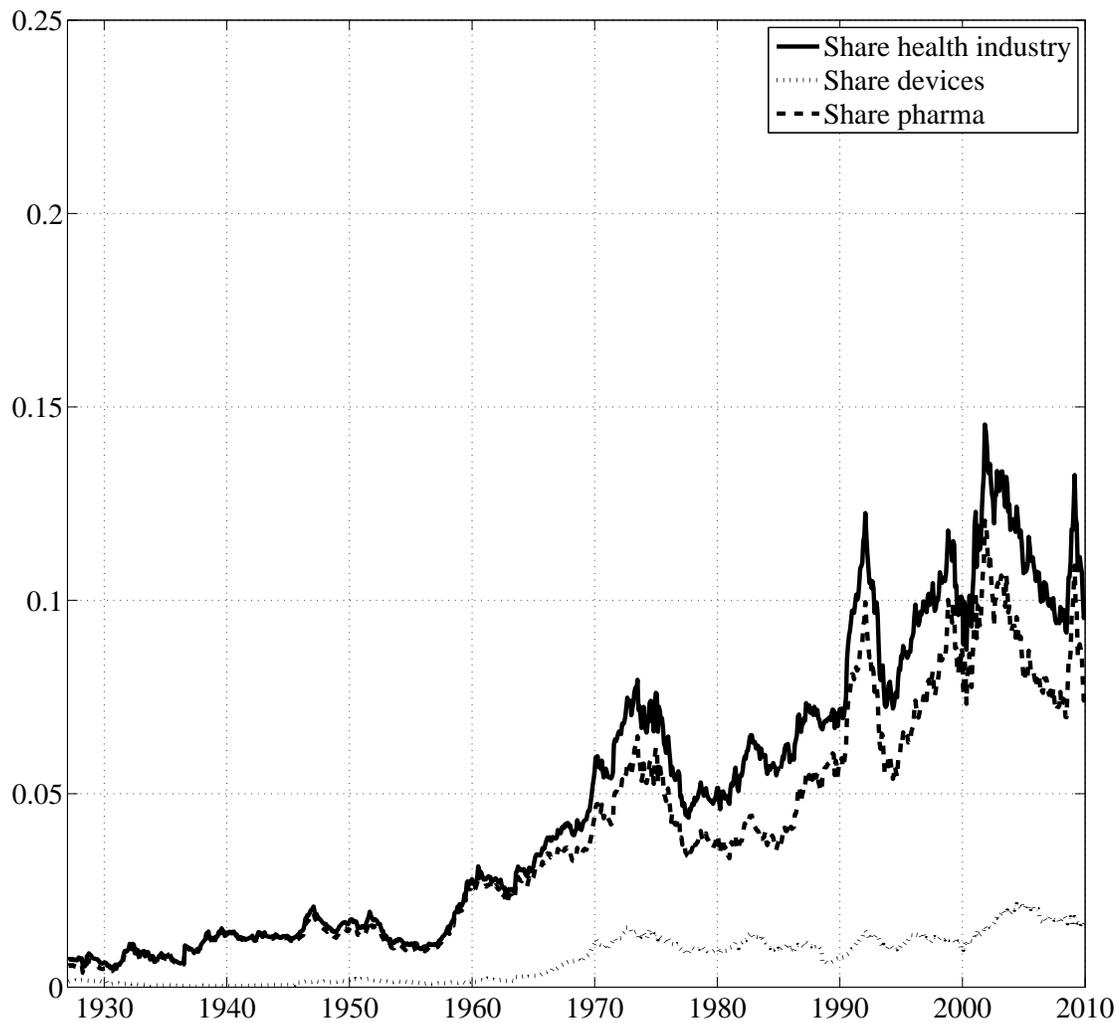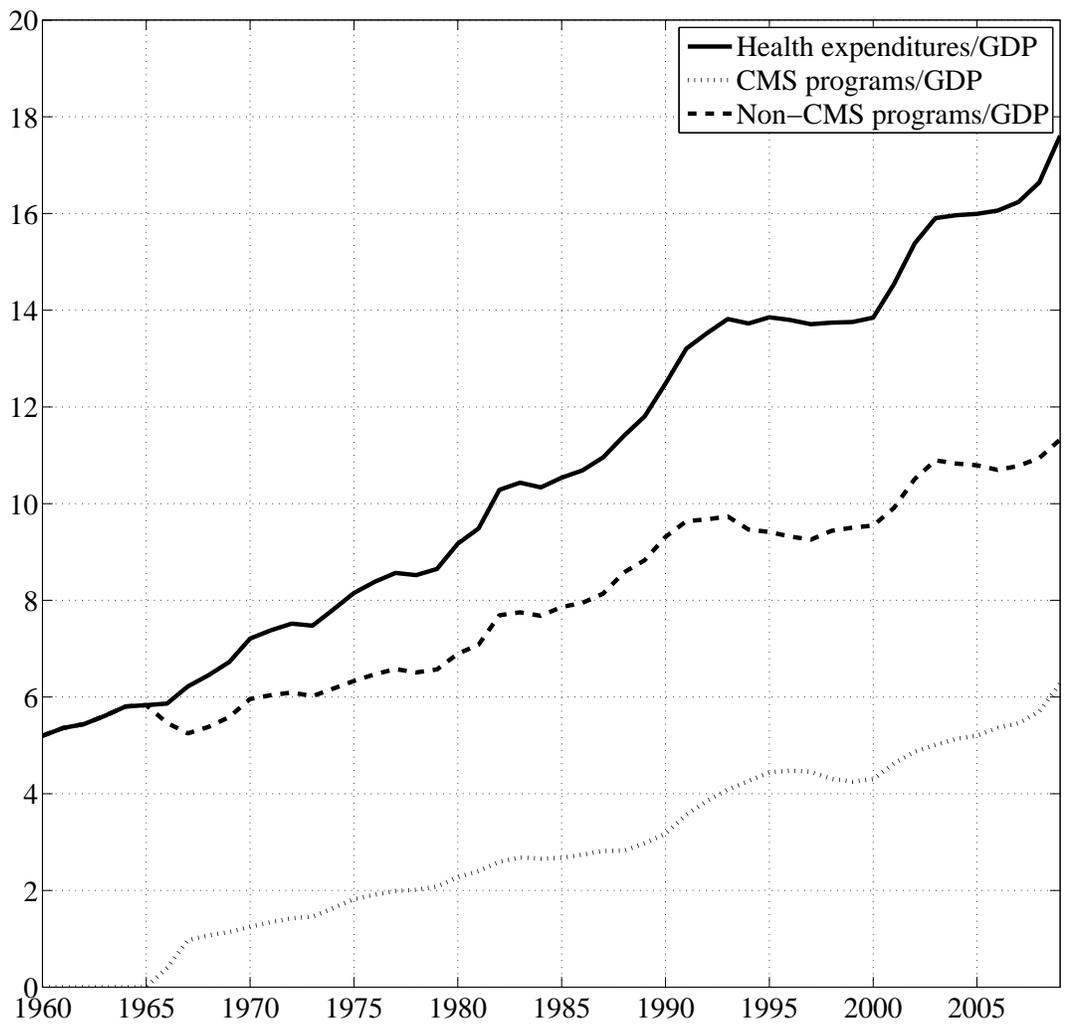
Figure 1: Relative market capitalization

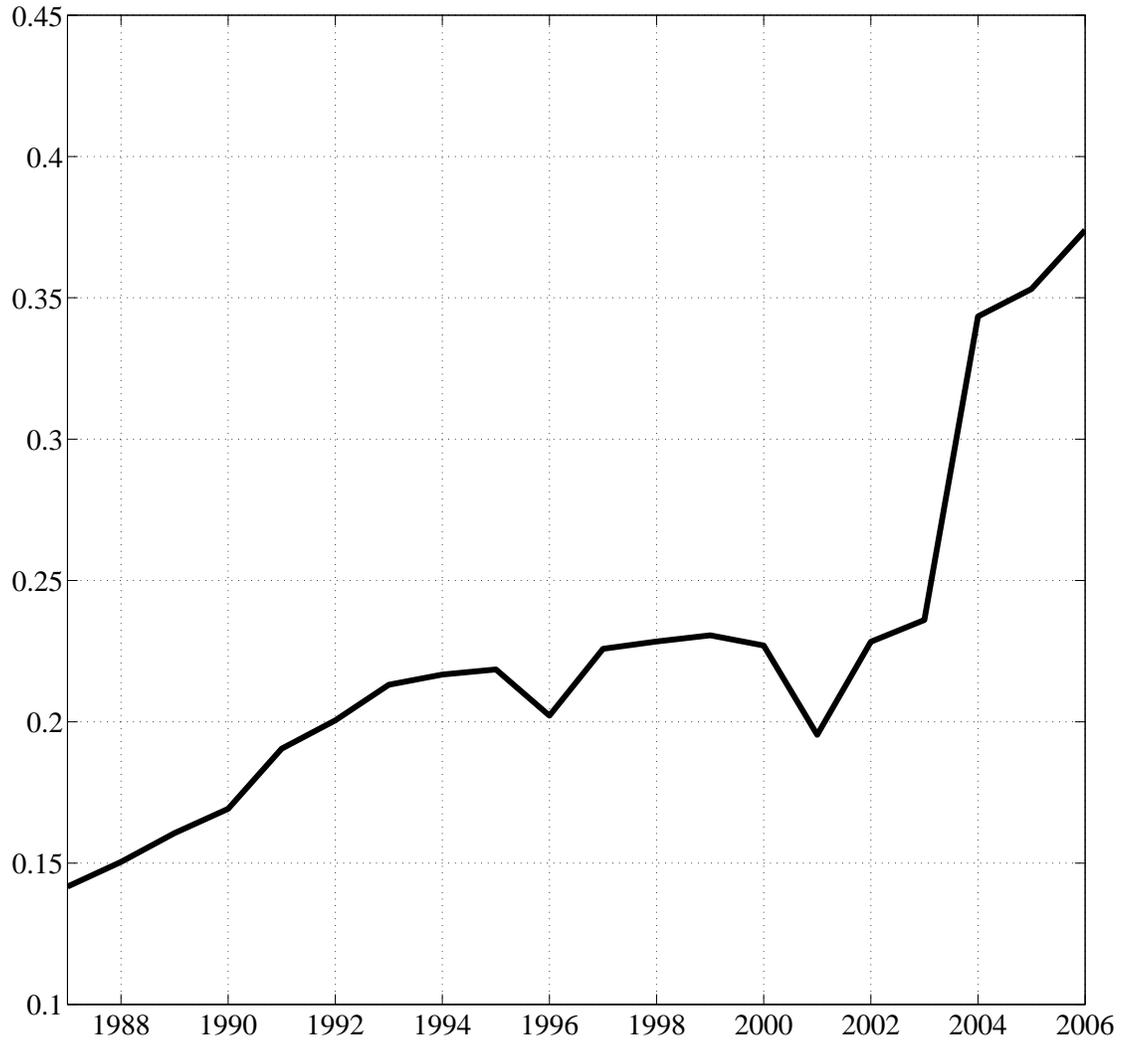Figure 2: Medical spending relative to GDP
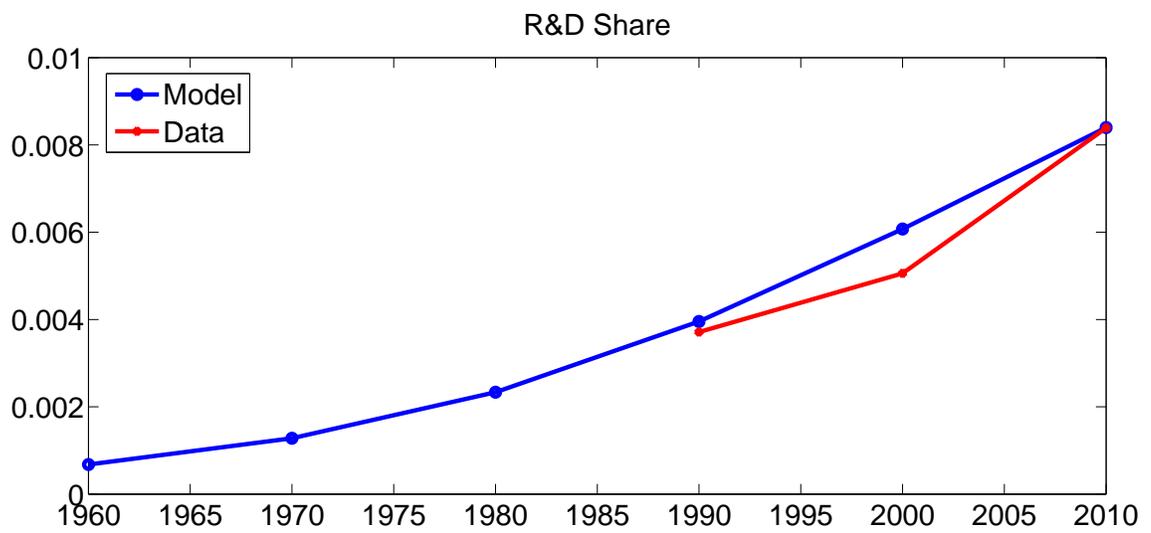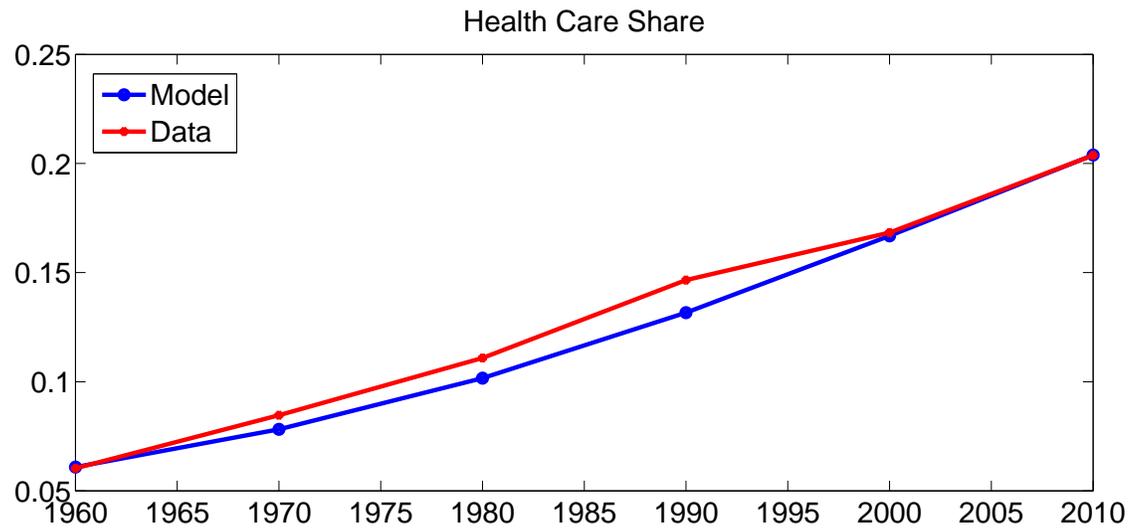
Figure 3: Medical R&D spending relative to GDP

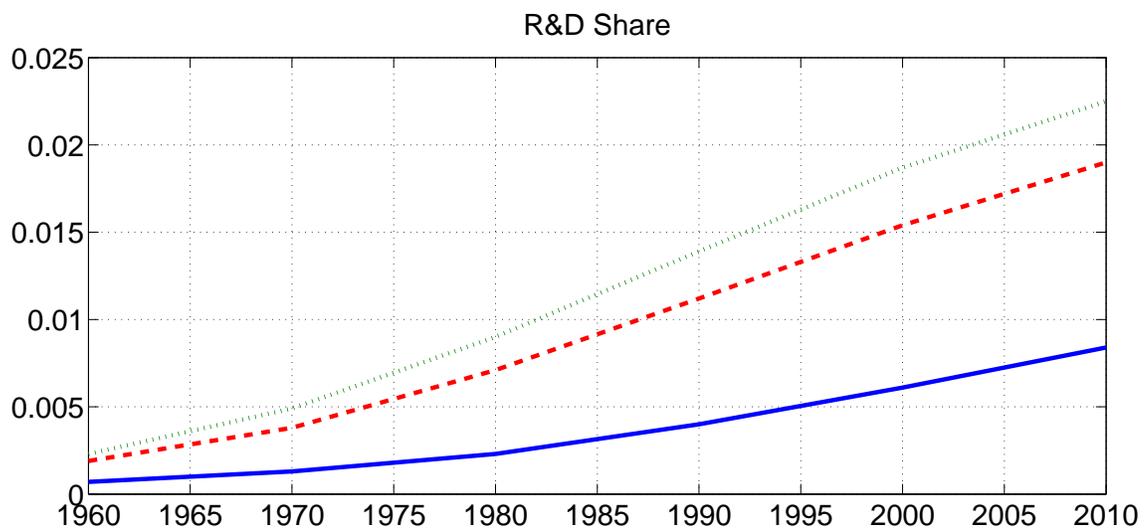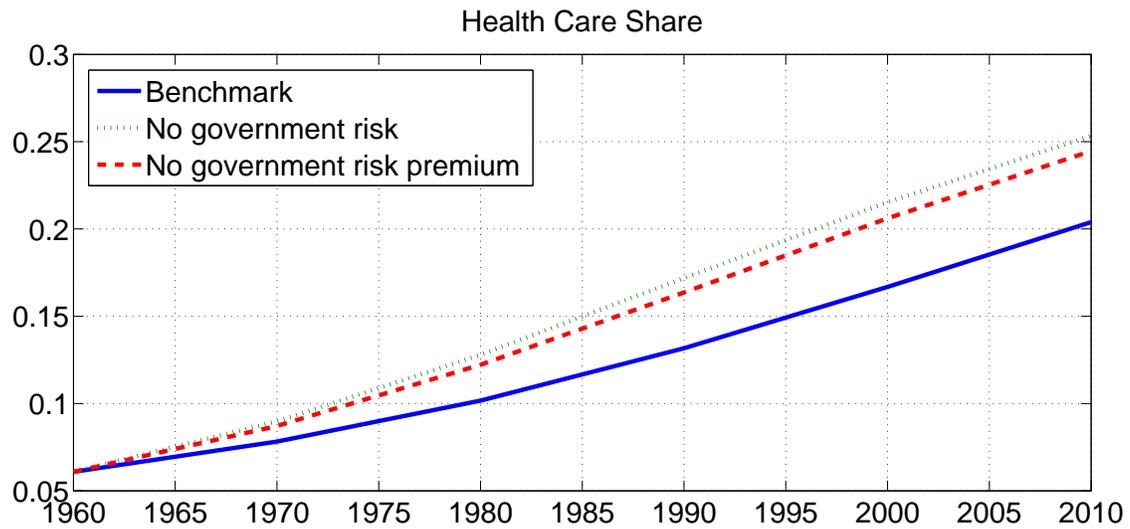Figure 4: Health and R&D share in the model and in the data
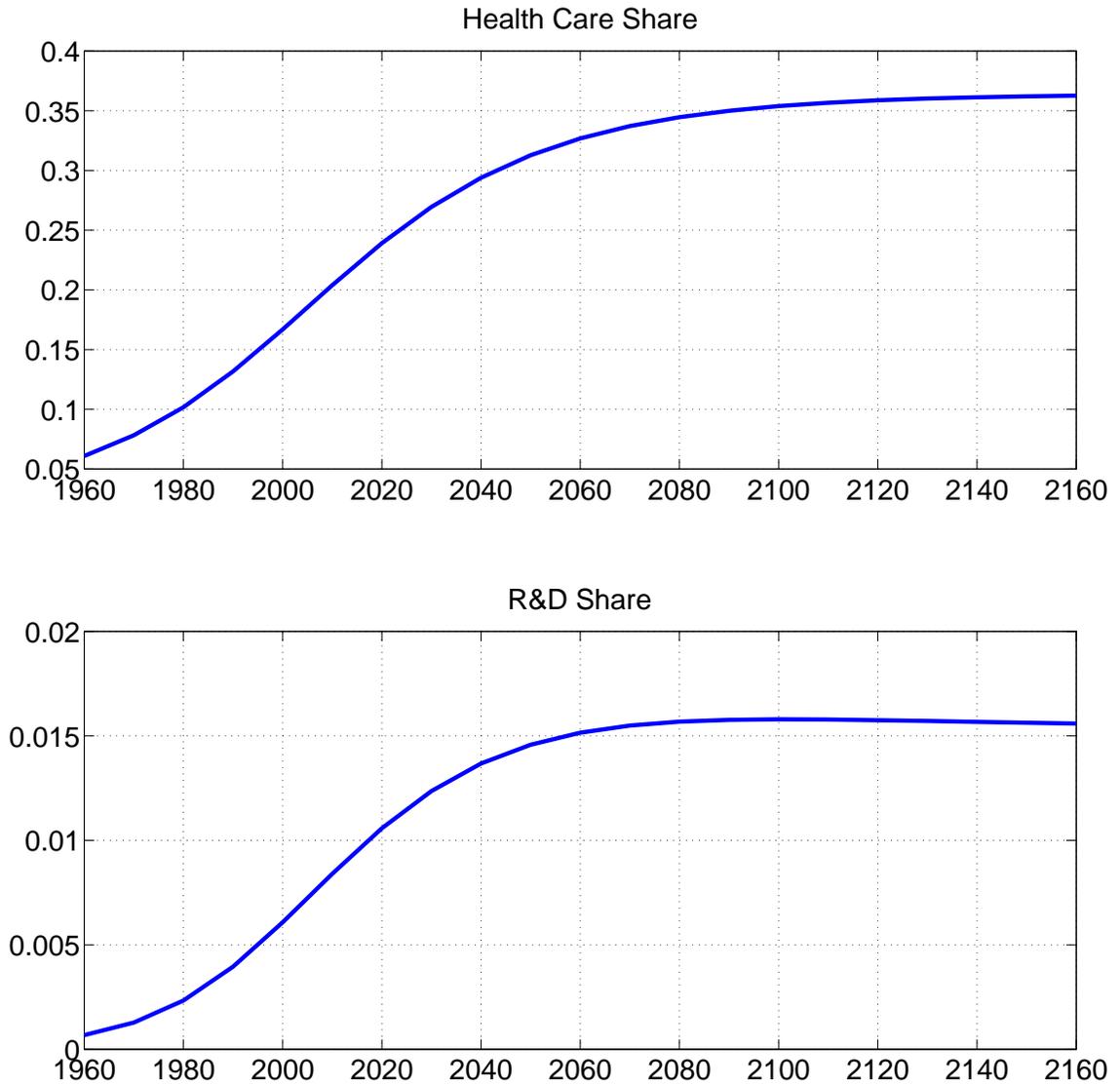
Figure 5: Counterfactuals

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

B The Simple Economics of The Medical Innovation Premium and Future Health Care Spending

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.

Future health care spending is given by price times quantity of medical care, $S = pm$.

We denote expected returns by $\mu = E[R]$ and it negatively affects medical R&D through the decreasing function $d(\mu)$. Medical R&D in return drives the cost of production x of care through the negative relationship $x(\mu) \equiv x(d(\mu))$, which in turn drives the real price of care through how costs raise prices $p(x(\mu))$. Innovation may also expand the aggregate quantity of care directly as represented through a demand function $m(p, d)$. This directly provides the qualitative nature of the link between required returns in asset markets for medical R&D firms and real health care spending $S(\mu)$, as given by

$$S(\mu) = p(x(\mu))m(p(x(\mu)), d(\mu)).$$

The effect of the medical innovation premium on health care spending is thus made up of its effect on real health care prices and medical care demand through lowering prices and potentially expanding quantities

$$\frac{dS}{d\mu} = p_\mu m + p m_\mu = p_x x_d d_\mu m + p[m_p p_x x_d + m_d]d_\mu.$$

For example, in the case of the government risk to future markups we consider, such risk discourages R&D, raises real prices of health care, and may directly lower quantity of care and translates into higher or lower health care spending depending on how elastic health care demand is.

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

$$ds = [s_y + s_S S_y]dy + (s_S S_d)dd.$$

In the cross-section, the second innovation effect is zero. Income may initially raise the share 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 good for low levels of income and a necessity 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 is therefore 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 lowers the real cost of care, potentially spurred by such income growth. The impact of increased

government risk on this evolution is to slow down medical innovation and thus a slowdown of the growth in health care spending. Government risk thus reduces the luxury good nature of health care in the time-series.