

# Financial Health Economics<sup>\*</sup>

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## Abstract

We provide a theoretical and empirical analysis of the link between financial and real health care markets. We document a “medical innovation premium” of 4-6% annually for equity of medical firms and analyze the implications it has for the growth of the health care sector. We interpret the premium as compensating investors for government-induced profit risk. We provide supportive evidence for this hypothesis through company filings and abnormal return patterns surrounding threats of government intervention. We quantify the implications of the premium for growth in real health care spending by calibrating our model to match historical trends. Policies that remove government risk would lead to a tripling of medical R&D and would increase the current share of health care spending by 4% of GDP, with a predicted long run share of 36%.

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## 1. INTRODUCTION

Improvements in health have been a major component of the overall gain in economic welfare and the reduction in world inequality during the last century (Murphy and Topel (2006) and Becker, Philipson, and Soares (2005)). Indeed, 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 might 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 U.S. economy, and its continued growth give 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 quantitative analysis of the joint determination of the financial returns of firms that invest in medical R&D and the resulting growth of the health care sector.

We first provide empirical evidence that the returns on firms engaged in medical R&D are substantially higher, around 4-6% per annum, than what is predicted by standard empirical 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 investors in the health care industry need to be compensated for risks not captured by these asset pricing models.

We interpret the medical innovation premium to result from government-induced profit

risk for which investors demand higher returns on medical R&D investments beyond standard risk-adjusted returns. We consider U.S. government risk to be a plausible explanation for the medical innovation premium for three reasons. First, government greatly affects both the onset of profits through approval regulations and the variable profits conditional on such approval. For example, demand subsidy programs such as Medicare and Medicaid currently make up about half of medical spending in the United States and, thus, are clearly an important component affecting the profits of innovators. Second, we seek an aggregate risk component to which the health sector is particularly exposed. Government intervention risk has that property. Third, we discuss that other plausible risk factors, such as longevity risk, often imply a negative medical innovation premium in standard consumption-based asset pricing models, which is the opposite sign of the premium we document.

We provide supportive evidence for the hypothesis that government risk contributes to the medical innovation premium in three ways. First, we provide a text-based analysis of 10-K filings that companies need to file with the Securities and Exchange Commission (SEC). The 10-K filings contain a section that asks the company the risk factors it faces. We show that firms in the health care sector discuss government-related risk significantly more frequently than firms in other sectors do. Second, we study when investors in the health care sector suffer large negative returns, which we measure via drawdowns. We find that the worst drawdowns coincide with severe threats of government intervention. Third, examining the Clinton health care reform of the 1990s, we find that health care firms experienced abnormally low returns. Moreover, we find that firms for which the abnormal returns were more negative during this period, and hence are more sensitive to threats of future government intervention, have higher unconditional betas with respect to the health care factor that earns the medical innovation premium. This finding is consistent with our interpretation of the medical innovation premium as compensation for government-induced profit risk.

Our theoretical analysis then investigates the link between financial markets, incentives

for medical innovation, and the growth in the real health care sector. The medical innovation premium reduces investments into medical R&D given that those investments must recoup the higher returns required by investors. This provides a potential qualitative explanation for the “missing R&D” implied by the analysis by Murphy and Topel (2006), which suggests the enormous value of the recent gains in health justify much larger investments in medical R&D than are actually observed.

We analyze the quantitative growth of the health care sector when investors face profit risk  $f$  as a result of U.S. government intervention.<sup>1</sup> This is akin to creating a rare disaster to profits from the perspective of the innovators,<sup>2</sup> although what might be a disaster from the perspective of the innovators could be beneficial for society as a whole. We obtain a medical innovation premium that has two parts: an actuarially fair disaster premium and the risk premium arising from the entrepreneurial consumption reduction in the wake of the disaster. More precisely, we find that the medical innovation premium has large effects on future spending on health care and medical R&D by calibrating our model to trends in health care spending, investment in medical R&D, and asset returns from 1960 to 2010.

We find that the size of the health care sector would increase by 4% of GDP if the risk premium is removed, and by another 1% if the actuarially fair disaster premium is removed as well. Hence, the largest impact of the government intervention risk is due to risk aversion against the the disaster as opposed to changes in expected profits. Furthermore, our calibration implies that R&D would triple in the absence of the medical innovation premium.

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 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

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<sup>1</sup>See Ellison and Mullin (2001) and Golec, Hegde, and Vernon (2010) for an example the Clinton health care reform.

<sup>2</sup>The rare-disaster approach has been used in a number of recent papers to explain equity premia; see, for instance, Barro and Ursua (2008), Barro and Jin (2011) or Gabaix (2012). We apply this idea specifically to the health industry.

model produces estimates for the health care share that are somewhat lower than the CBO projections are.

## 2. RELATED LITERATURE AND INSTITUTIONAL BACKGROUND

### *2.1. Related Literature*

Our paper relates to several strands of previous research by merging insights from the three separate fields of health economics, macro-economics, and finance. We therefore briefly review some key papers in all three literatures. Our paper differs from previous work in those fields by examining the joint determination of asset returns for those investing in medical innovation and the resulting growth in the health care sector. Our paper thus adds the analysis of R&D incentives to the macro-economic literature, which has analyzed the relationship between health and growth, see for instance Barro (1996) and Sala-i-Martin, Doppelhofer, and Miller (2004). A large empirical literature in health economics, see Gerdtham and Jonsson (2000) for a review, estimates the impact of economic growth on health care spending.

A seminal paper analyzing the interrelationship between macroeconomic growth and the share of income spent on health is Hall and Jones (2007). These authors point out that a rise in the share is predicted by many reasonable preference specifications, as additional health spending increases longevity while the marginal utility for extra consumption declines with growth. Hall and Jones (2007) provide a detailed quantitative analysis of the effect and social desirability of health spending.<sup>3</sup> We view our paper as complementary to theirs. In particular, our focus is on the innovation in the health sector and the entrepreneurial risks associated with that investment, while these authors assume technological progress in the health sector to be deterministic and exogenous. While the long-run demand for new innovations in health may well be due to the forces discussed by Hall and Jones (2007), the

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<sup>3</sup>The empirical evidence showing that health care is a luxury good is mixed, see Acemoglu, Finkelstein, and Notowidigdo (2009) and the references therein. Also, 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.

key entrepreneurial risks arise from the possibility of governmental intervention rather than, say, risks in the effectiveness of health spending in increasing longevity, as we discuss in Section 7. Compared to their model, our model puts the incentives for R&D at center stage, which requires us to extend the model along this dimension, while simplifying the longevity analysis performed by Hall and Jones (2007).

In finance, our paper relates to a recent literature that shows that government risk affects asset prices.<sup>4</sup> The main contribution of our paper is to document the medical innovation premium in the health care sector and to map out the implications for investment in medical R&D and health care expenditures. As a potential explanation of this risk premium, we point to the risk of government intervention.

Most closely related to our paper are Ellison and Mullin (2001) and Golec, Hegde, and Vernon (2010) who study the impact of the Clinton health care reform proposals in 1992 and 1993 on stock prices. Both papers find that health care stocks are negatively impacted by the Clinton reform plans. Furthermore, Golec, Hegde, and Vernon (2010) also show that the effect is more pronounced for R&D intensive firms and that (unexpected) R&D declines more for those firms who are more exposed to government intervention risk.<sup>5</sup> This evidence is consistent with the main mechanism of our model.

Our empirical findings may have important implications for other questions in public finance, and in particular the valuation of government programs such as Medicare and Medicaid.<sup>6</sup> Discounting such liabilities using the Treasury curve may be inappropriate as these liabilities may be exposed to the same risk as the health care sector as a whole, which implies

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<sup>4</sup>For instance, Belo, Gala, and Li (2013) link the cross-section of expected stock returns to firms' exposures to the government sector. Brogaard and Detzel (2013) use the political uncertainty index of Baker, Bloom, and Davis (2013) to show that spikes in political uncertainty go together with declines in the stock market, which is largely the result of increases in risk premia. Kelly, Pastor, and Veronesi (2014) show how political uncertainty is priced in the option market using national elections and global summits, building on the theory developed in Pastor and Veronesi (2011) and Pastor and Veronesi (2012). These papers do not focus on the health care sector.

<sup>5</sup>Julio and Yook (2012) show more generally how corporate investment is affected negatively by political uncertainty.

<sup>6</sup>See Geanakoplos and Zeldes (2011) and Lucas (2010) for recent work on the valuation of government liabilities.

that the discount rate should reflect the medical innovation premium.

## *2.2. Institutional Background*

Technological change that raises health care spending comes mainly from three categories: medical devices, biologics, and drugs, and the services associated with them. In the U.S., the variable profits on these new technologies are determined both by private and public reimbursement policies. According to the Centers for Medicare & Medicaid Services (CMS), in 2012 about 44% of US spending was publicly financed, mainly through the Medicare and Medicaid programs. However, returns in other parts of the world are more contingent on public reimbursement policies. For example, in many European countries, roughly 85% of health care is publicly financed (OECD, 2013). For drugs and biologics in the US, reimbursements can be paid directly to manufactures, such as in the Medicaid drug program, or indirectly, through premium subsidies in the Medicare Part D program for outpatient drugs. However, for devices, reimbursements are often indirect through reimbursements to providers, for instance, through the Medicare diagnosis-based payments to hospitals (DRGs) in the US that cover the use of a given device for a certain diagnosis.

The time and cost of bringing these new medical technologies to the market has been estimated to be substantial. For drugs and biologics, DiMasi and Hansen (2003) find that for 68 randomly selected new drugs of 10 pharmaceutical firms, the average cost was about \$802 million (2000 dollars). This cost includes the cost of failures in the FDA approval process as only 12% of products that enter the process actually make it to market (DiMasi and Hansen 2003).

New health care products are often discovered by academic research. However, the high cost of development of medical products requires outside investors, whose main focus is on (risk-adjusted) earnings. Hence, even though the research (“R”) in medical R&D may not be motivated entirely by future returns, the development (“D”) certainly is. Indeed, drugs and biologics are among the most R&D intensive industries in the US as measured by R&D

to sales ratios of about 16% (PhRMA (2013)) compared to a 2.8% share of US GDP being devoted to R&D (Robbins, Belay, Donahoe, and Lee (2012)).

To raise capital for these large development costs, manufacturers often use public capital markets. It is important to note that much of the production of goods and services in health care are not financed through public equity markets, even though medical innovation is driving the growth of the sector. Providers of hospital services, making up about a 35% of health care spending, are about 70% not-for profit and thus rely on debt or donations instead of public equity. Physician services, making up an additional 22% of health care spending (CMS 2012), are often organized in small privately-financed clinics. Given the lack of public equity financing in these major health care sectors, it is understandable that the for-profit firms engaged in medical innovation make up a large majority of the firms listed on public equity exchanges.

Government policies in the US disproportionately affect the returns on medical R&D investments as world sales for medical products is highly concentrated in the US. Egan and Philipson (2013) use data from the World Bank and WHO to estimate that US health care spending was about 48% of world spending in 2012 even though US GDP was only about 24% of world GDP in the same year. For biopharmaceutical spending, the US share of world spending is lower at about 39%, as many emerging markets spend a larger share of their overall health care on biopharmaceuticals (Egan and Philipson (2013)). Given the larger markups on US spending, a larger share of profits than sales are generated in U.S. markets. Because of the concentration of world profits in the US, changes in reimbursement policies that threaten US markups is of primary importance to those investing in medical R&D. This motivates our focus on the risk of U.S. government reimbursement policies on asset prices.



### 3. EMPIRICAL EVIDENCE: THE MEDICAL INNOVATION PREMIUM

#### 3.1. Risk Premia in Health Care Markets

We use data on industry returns, the Fama and French factors, and market capitalization from Kenneth French’s website. The first classification we use splits 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,<sup>7</sup> pharmaceutical products,<sup>8</sup> and health services.<sup>9</sup> We also study the 48 industry classification, which splits the health care industry into the three aforementioned categories. We follow the industry classification as on Ken French’s website for both the entire health care industry and for the three sub-industries.

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. Therefore, we are interested in the intercepts, or “alphas,” of the following time-series regression:

$$(1) \quad r_t - r_{ft} = \alpha + \beta' F_t + \varepsilon_t,$$

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 pricing factors  $F_t$  they account for. As a first

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<sup>7</sup>The corresponding SIC codes are 3693: X-ray, electromedical app., 3840-3849: Surgery and medical instruments, 3850-3851: Ophthalmic goods.

<sup>8</sup>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.

<sup>9</sup>The corresponding SIC codes are 8000-8099: Services - health.

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, that is, value firms, tend to have higher average returns that are not explained by difference in CAPM betas. These additional two factors account for these regularities in asset markets.<sup>10</sup>

We present our main results for annual returns, using the Fama and French model, and for the sample from 1961 to 2012, which is the period for which we observe health care spending. As the risk-free rate,  $r_{f,t}$  in equation (1), we use 1-month T-bill rate from Ibbotson and Associates, Inc., rolled over for 12 months as constructed by Kenneth French and available from his website. As the return per industry,  $r_t$  in equation (1), we use the value-weighted return of all stocks in a given industry.

The results are reported in Panel A 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 alpha of 5.0% (with a t-statistic of 2.4) relative to the Fama and French model.

We also report the alphas of the other industries and find that they do not have large alphas relative to the standard models. We conclude that there is a risk premium for holding health care stocks that cannot be explained by standard asset pricing factors.

If we remove health services and focus on medical equipment and pharmaceutical products, the alphas are even higher at 6.4% and 5.4% per annum, respectively. This is because

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<sup>10</sup>There is a large literature that provides explanations for the size and value effects, see for instance Berk, Green, and Naik (1999), Zhang (2005), Yogo (2006), 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.

the alphas on medical services are close to zero, which lowers the overall alpha of the health care sector.<sup>11</sup> Both alphas are statistically significant at conventional significance levels.

Although both sub-sectors, that is, medical equipment and drugs, earn significant alphas, this is not necessarily driven by exposures to the same risk factor. To test this more directly, we augment the Fama and French model with the health care factor, which we define as the industry return on the entire health care sector in excess of the risk-free rate.

We report the alphas of the sub-sectors relative to the augmented Fama and French model in Panel B of Table 1. We find that the alphas are economically and statistically close to zero once the health care factor is included in the model. This suggests that a similar risk determines the mispricing relative to standard asset pricing models in both sub-sectors.

Our results are consistent with the findings in Fama and French (1997), who 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.

For robustness, we estimate the model also at a monthly frequency and for two additional sample periods, namely from 1927 to 2012 and from 1946 to 2012. The first sample period is the longest sample available. The second sample focuses on the post-war period. Furthermore, we compute the alphas not only relative to the Fama and French model, but also relative to the CAPM. The results for monthly returns and other sample periods are reported in the Online Appendix, but the results are broadly consistent with the findings reported in Table 1. If we use monthly data, or longer sample periods, the statistical significance of the alphas increases further.

Given the trends in health expenditures, as summarized in the Online Appendix, it is interesting to study the trends in market capitalization of health care firms. Figure 1 plots

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<sup>11</sup>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 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 we find that the change in market share and alphas are virtually uncorrelated across industries. 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.

### *3.2. Government Risk and the Health Care Sector*

In this section, we provide new evidence on the importance of government risk on the profitability and asset prices of health care firms.

#### *3.2.1. Risk Factors Identified from 10-K filings*

Our first piece of new evidence comes from a text-based analysis of 10-K reports that each firm files annually with the Securities and Exchange Committee (SEC). 10-K filings have been explored recently in the finance literature to define industries (Hoberg and Phillips (2011)), to measure competition (Feng Li and Minnis (2013)), to predict the volatility of stock returns (Kogan, Levin, Routledge, Sagi, and Smith (2009)), and to predict future stock returns (Loughran and McDonald (2011)). We argue that a particular section of the 10-K filings is helpful to identify risk factors to which a firm is exposed. Our approach may have applications well beyond this paper as understanding risk exposures of firms is central in both macro-economics and finance.

We use the most recent 10-K filings that are available as of December 2013. In each 10-K filing, there is a section 1.A labeled “Risk Factors.” The guidelines for this section are described in Regulation S-K, Item 503(c), requesting companies to list the “most significant factors” which affect the company.<sup>12</sup>

To illustrate the data we use in this section, we include the “Risk Factors” section of the 10-K filings of Pfizer and Apple, which are among the largest health and non-health care firms by the end of our sample, in the Online Appendix.

As is clear from the filings, various forms of government regulation are a major concern to Pfizer, while for Apple traditional risk factors such as economic conditions and competition are more relevant. Moreover, in the spirit of our model, Pfizer explicitly mentions price controls and government intervention as one of the key risk factors that may affect the firm’s operations.

To illustrate that the pattern in the 10-K filings is more general and not particular to just Apple and Pfizer, we hand-collect the sections on risk factors for the largest 50 health care companies and the largest 50 non-health care companies. For each firm, we count the number of times words related to the government or government risk appear in the filings.

The dictionary that we use is summarized in Table 2. The dictionary attempts to capture the prevalence of government-related risks in the 10-K filings. In the main dictionary, we avoid words that are government-related yet particular to the health care sector such as “FDA.”

The results are summarized in Panel A of Table 3. For firms in the health care sector, we find that words in this dictionary appear on average 139 times, compared to on average 77 times for firms outside the health care sector. The standard error of the difference in means

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<sup>12</sup>The precise definition is: *Where appropriate, provide under the caption “Risk Factors” a discussion of the most significant factors that make the offering speculative or risky. This discussion must be concise and organized logically. Do not present risks that could apply to any issuer or any offering. Explain how the risk affects the issuer or the securities being offered. [...] The risk factors may include, among other things, the following: (i) Your lack of an operating history; (ii) Your lack of profitable operations in recent periods; (iii) Your financial position; (iv) Your business or proposed business; or (v) The lack of a market for your common equity securities or securities convertible into or exercisable for common equity securities.*

equals 15.1, implying that the difference is statistically highly significant with a  $t$ -statistic of 4.1.

However, the typical 10-K filings for health care stock is longer. As an alternative measure, we can look at the average *fraction* of words that appear in our dictionary. For firms within the health care sector, this fraction is 1.51% while it is only 1.23% for firms in the non-health care sector, implying that words from our dictionary appear 23% more frequently for firms in the health care sector. If we again test on the difference in means, the standard error equals 0.099%, which implies once more that the difference is significant with a  $t$ -statistic of 2.8.

In our main dictionary, we omit government-related words from our dictionary that are particular to the health care sector. We also explore how our results are affected if we include the health care-specific terms “medicare,” “medicare reform,” “medicaid,” “medicaid reform,” “ppaca,” “cms,” “healthcare reform,” “nhs,” and “fda” in our dictionary. The results for this expanded dictionary are reported in Panel B of Table 3. The differences in the average word count and the average fraction increase substantially, making the differences economically and statistically even more significant.

Taken together, the text-based analysis of 10-K filings provides shows that government risk is an important concern for firms in the health care sector.

### 3.2.2. Drawdowns of the Health Care Sector

As a starting point, we study when financial investments in health care sector experienced large negative returns as a way to identify the risks to which the sector is exposed. In Figure 2, we plot the drawdowns for the health care sector alongside the drawdowns of the aggregate stock market. Drawdowns are defined as:

$$(2) \quad D_t = \sum_{u=1}^t r_u - \max_{s \in \{1, \dots, t\}} \sum_{u=1}^s r_u,$$

where  $r_t$  denotes the log return on either the aggregate stock market or the health care sector.<sup>13</sup> Hence, drawdowns measure the cumulative downturn relative to the highest level the indexed reached up to a certain point in time. Drawdowns are a common way to measure the risk of investment strategies (see for instance Grossman and Zhou (1993), Landoni and Sastry (2013), and Kojien, Moskowitz, Pedersen, and Vrugt (2013)).

Figure 2 points to three large downturns for the health care sector during the last two decades: in the early nineties, during the 2000-2002 technology crash, and during the 2007-2008 financial crisis. During the latter two periods, the drawdowns of the market are even larger than those for the health care sector, reflecting the fact that the health care sector has a beta below one.

The drawdown in 1992 and 1993 is of most interest to us, which coincides with the discussions around the Clinton health care reform. During this period, the aggregate stock market increased, while the health care sector shows a large decline.

Interestingly, we do not find a similar drawdown during the recent Obama reform as during the Clinton reform. Hult and Philipson (2012) discuss an interpretation of this result. They stress that government expansions often lower both demand prices (premiums or copays) to raise access, but also at the same time cut supply prices (reimbursements) through government monopsony power. Their analysis implies that R&D returns may rise when government expansions include poorer parts of the population by raising quantity more than lowering markups. For example, Medicaid expansions raise innovative returns in this manner. However, innovative returns fall when expansions include richer parts of the population when markups may fall more than quantity rises. For example, the single-payer European payment systems may lower innovative returns in this manner. The non-monotonic impact of government expansions across the income distribution implies that Clinton reforms may affect innovative returns differently than Obama reforms. Clinton proposed population wide reforms including the entire income distribution which may lead to negative innovation

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<sup>13</sup>For comparability, we scale both returns by the standard deviation of returns over the full sample.

effects. This is in contrast to Obama reforms, which was centered on raising access of the poor through Medicaid expansions and exchange subsidies which thus may raise innovative returns.

### *3.2.3. The cross-section of health care betas and event returns around Clinton's health care reforms*

Ellison and Mullin (2001) and Golec, Hegde, and Vernon (2010) show that health care stocks decline around the Clinton reform in the early nineties. These events provide the best test of our theory as the key component of the reform was to impose price controls on new drugs. Hence, the threat of government intervention has a negative effect on firms in the health care industry.

We extend the evidence in these papers in two ways. First, we show that firms in the health care sector that have more negative cumulative abnormal returns around the major event dates tend to have higher betas with respect to the health care factor. This result is important as different exposures to the health care factor measure different exposures to the risk factor that is not well priced by the CAPM and the Fama and French model and results in the large alphas we document in Section 3. Differences in exposures to the health care factor relate to differences in abnormal returns around news about government intervention, we argue that government risk is an important candidate determinant of the medical innovation premium we document in this paper.<sup>14</sup> Second, we consider a larger cross section of firms. Ellison and Mullin (2001) and Golec, Hegde, and Vernon (2010) select only 18 and 111 companies, respectively. Our sample includes somewhat over 300 firms in the drugs, devices, and services sector.

We analyze stock prices during the Clinton reform in more detail and highlight the importance of political risk. Ellison and Mullin (2001) and Golec, Hegde, and Vernon (2010) identify the key event dates during the Clinton reform proposals, which we reproduce in

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<sup>14</sup>Ideally, we would like to use alphas of individual firms directly, but those turn out to be too noisy. As betas are estimated more precisely than alphas, we use betas with respect to the health care factor instead.



Table 4.

Our key objective is to show that firms that have higher health care betas measured over periods much longer than the Clinton reforms, experience also much more negative returns during these events. This implies that firms that are more sensitive government intervention have higher health care betas with respect to the health care factor, which generates abnormal returns relative to standard asset pricing models.

To this end, we first compute the health care beta by regressing monthly excess returns of a given firm on the market return and the health care factor. This provides us the exposure to the health care factor for each firm. The typical sample to estimate the beta is much longer than the period over which Clinton care was discussed. As follows from Table 5, the average number of years used to estimate the beta is around 20 years.

Next, estimate the cumulative abnormal returns. We use an event window that spans from 5 days before, until 5 days after, each event listed in Table 4. We use 250 daily returns prior to the event window to estimate the betas relative to the CAPM model. If a firm has missing daily returns, it is omitted from the sample.<sup>15</sup> We then compute the cumulative abnormal return by aggregating the residual from this regression (Campbell, Lo, and MacKinlay, 1997). We then sum over all event dates to get the total impact of the Clinton reform proposal on each health care stock.

We then relate the overall risk exposure of health care firms, estimated over a much longer sample on average, to the cumulative abnormal return during the events in 1992 and 1993 through a cross-sectional regression across firms:

$$(3) \quad CAR_i = \delta_0 + \delta_1 \frac{\beta_i^{HC}}{\sigma(\beta_i^{HC})} + u_i,$$

where  $\sigma(\beta_i^{HC})$  is the standard deviation of health care betas across firms. The coefficient  $\delta_1$  measures how the cumulative abnormal return,  $CAR_i$ , changes if the beta with respect to

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<sup>15</sup>This is only the case for 6 firms. Replacing the missing returns with the market return and subsequently including these firms, does not affect any of our results.

the health care factor,  $\beta_i^{HC}$ , changes by one standard deviation.

The main results are presented in Table 5. Firms with higher health care betas are more sensitive to news about future government intervention. A 1-standard deviation increase in the health care beta corresponds to a 7.7% lower cumulative abnormal return. Using heteroscedasticity-consistent standard errors, the effect is significant with a t-statistic of -2.7. As a point of reference, the average cumulative abnormal return across all firms is -23.9%. The R-squared of the regression equals 4%, which illustrates that abnormal returns are noisy, which is to be expected.

Taken together, firms with higher health care betas also showed larger movements during the event windows. We interpret this as evidence that these firms are more sensitive to news about future government intervention

#### 4. 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.

##### 4.1. The Environment

###### 4.1.1. Preferences and Endowments

Time is infinite,  $t = 0, 1, \dots$ . The population consists of households  $i \in [0, 1]$  and entrepreneurs  $i \in (1, 1 + \kappa]$  for some  $\kappa > 0$ , where we shall think of  $\kappa$  being small. We focus on symmetric allocations and equilibria, with a representative household and a representative entrepreneur.

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

$$(4) \quad U = E \left[ \sum_{t=0}^{\infty} \beta^t \frac{\left( c_t^\xi h_t^{1-\xi} \right)^{1-\eta}}{1-\eta} \right],$$

where  $c_t$  is the non-health care consumption at date  $t$ ,  $h_t$  is the health care consumption,  $\xi \in (0, 1)$  determines the trade-off between health care and non-health consumption.<sup>16</sup>,  $0 < 1/\eta < 1$  is the intertemporal elasticity of substitution for the consumption bundle and  $\beta \in (0, 1)$  the time discount factor.

We do not introduce life-extending benefits of health care or medical care, which are central in Hall and Jones (2007) and which could be introduced here as well, in principle. They are, however, an unlikely source for the observed risk premium, see section 7. To focus on our main theme, we have therefore chosen to keep to the simpler specification above, see also Section 2.

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 entrepreneurs, 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 (or what the “eat”)  $e_t$  and, below, their asset holdings. We assume that their preferences are piecewise linear and given by

$$(5) \quad V_t = u(e_t) + \tilde{\beta}E_t[V_{t+1}]$$

$$\text{where } u(e_t) = \begin{cases} \theta(e_t - \underline{e}) & \text{for } e_t \leq \underline{e} \\ e_t - \underline{e} & \text{for } e_t \geq \underline{e} \end{cases}$$

for  $e_t \geq 0$  and parameters  $\tilde{\beta}, \underline{e}, \theta \geq 1$ . This kinked-linear specification can be viewed as a

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<sup>16</sup>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).

simple version of prospect theory, as in Kahneman and Tversky (1979). There are many other preference specification that could serve just as well, as we discuss in an online appendix to this paper. The preferences of the entrepreneurs imply a stochastic discount factor  $M_{t+1}$ , see equation (24), which shall be used to price profits in the health industry.

#### 4.1.2. Technologies and Feasibility

The production of aggregate consumption  $c_t$  is given by

$$(6) \quad c_t + \kappa e_t = \gamma^t L_{ct},$$

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

$$(7) \quad h_t = \underbrace{\underline{h}\gamma^t}_{\text{Exogenous health}} + \underbrace{m_t}_{\text{Health due to medical care}},$$

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  $j \in [0, 1]$ ,

$$(8) \quad m_t = \left( \int_0^\kappa m_{jt}^{1/\phi} dj \right)^\phi,$$

where  $\phi > 1$ . As is standard in models of monopolistic competition,  $\phi$  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,  $\gamma^t$  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

$$(9) \quad q_{j,t+1} = (q_{jt}^\nu + d_{jt}^\nu)^{1/\nu},$$

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  $\gamma^t$  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

$$(10) \quad L_{ct} + L_{mt} + L_{dt} = 1.$$

## 4.2. Government, Markets and Equilibrium

### 4.2.1. 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  $p_t = \mu_t/q_t$ . The economy thus starts from non-intervention, and finds itself in the non-government intervention epoch, until the intervention happens. The probability that  $z_t = 1$  converges to one as time converges to infinity.

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

$$(11) \quad \sigma p_t m_t + \chi d_t = \tau_t + \kappa \tilde{\tau}_t,$$

where  $\tau_t$  are the lump sum taxes collected from households at time  $t$  and  $\tilde{\tau}_t$  are the lump sum taxes collected from entrepreneurs at time  $t$ . We assume that the taxes pays for the subsidies received in each of the two segments of the population,

$$\begin{aligned} \sigma p_t m_t &= \tau_t, \\ \chi d_t &= \kappa \tilde{\tau}_t. \end{aligned}$$

Lump sum taxes and infinitely lived households imply Ricardian equivalence, provided we do not also redistribute between households: we may therefore assume without loss of generality that there is no government debt.

#### 4.2.2. *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 entrepreneurs and owned by the entrepreneurs, 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  $t$  maximizes the firm value  $v_t$  given by:

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

where  $M_{t+1}$  is the stochastic discount factor of the entrepreneurs between period  $t$  and  $t + 1$  derived explicitly in equation (24), where  $(1 - \chi)$  reflects net costs for doing R&D after the government subsidy, and where  $\pi_{t+1}$  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.

#### 4.2.3. *Households*

We assume that 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 (4) by choosing

$c_t$  and  $m_t$ , subject to (8) and the sequence of budget constraints

$$(12) \quad c_t + (1 - \sigma) \int_0^1 p_{jt} m_{jt} dj + \tau_t = \gamma^t,$$

taking prices  $p_{jt}$  for medical care of type  $j$  at date  $t$  as well as the medical care purchase subsidy  $\sigma$  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  $j$ . In the symmetric equilibrium,  $m_{jt} \equiv m_t$ .

Entrepreneurs 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 (5) subject to the sequence of budget constraints:

$$(13) \quad e_t + \tilde{\tau}_t + (1 - \chi) \frac{1}{\kappa} d_t = \frac{1}{\kappa} \pi_t.$$

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

#### 4.2.4. *Equilibrium*

We focus on symmetric equilibria, with representative households, entrepreneurs and firms. Given the exogenous process  $z_t$ , an equilibrium is an adapted stochastic sequence

$$\Psi = (c_t, m_t, h_t, \tau_t, e_t, \tilde{\tau}_t, L_{ct}, L_{mt}, L_{dt}, q_t, d_t, p_t, \pi_t, v_t, D_t(\cdot))_{t=0}^{\infty},$$

with  $q_t$  measurable at  $t - 1$ , such that households maximize their utility, given prices, government interventions, and firm choices, entrepreneurs maximize utility, resulting in consumption  $e_t$ , 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.

## 5. MODEL SOLUTION AND IMPLICATIONS

After some derivation, we shall provide the model implications for the share of health care spending in equation (19) of subsection 5.1, R&D spending in equation (22) of subsection 5.2 and the medical innovation premium in equation (31) of subsection 5.3. We shall compare these to observed magnitudes in the data, after suitably calibrating the model in section 6.

### 5.1. Health Care Demand

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

$$(14) \quad p_t = \mu_t/q_t,$$

where

$$(15) \quad \mu_t = \begin{cases} \phi & \text{if } z_{t+1} = 0, \\ \zeta & \text{if } z_{t+1} = 1. \end{cases}$$

The resulting profits are

$$(16) \quad \pi_t = \frac{\mu_t - 1}{q_t} m_t.$$

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

$$(17) \quad \max_{m_t} \frac{\left(c_t^\xi h_t^{1-\xi}\right)^{1-\eta}}{1-\eta},$$

subject to the household budget constraint (12) as well as (7). This is solved by:

$$(18) \quad m_t = \left( \frac{1 - \xi}{1 - \sigma} \right) \left( \frac{\gamma^t - \tau_t}{p_t} \right) - \xi \underline{h} \gamma^t,$$

where  $p_t$  is given by (14).

Let  $\varphi_t = p_t m_t / \gamma^t$  be the share of gross labor income spent by households on medical care.

Note that  $\tau_t = \sigma p_t m_t = \sigma \varphi_t \gamma^t$ . With this, rewrite (18) as

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

and solve for  $\varphi_t$ . We find that the share evolves as

$$(19) \quad \varphi_t = \frac{p_t m_t}{\gamma^t} = \frac{1 - \xi}{1 - \sigma \xi} - \frac{1 - \sigma}{1 - \sigma \xi} \xi \underline{h} p_t.$$

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, and absent government intervention, 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  $(\sigma)$ .

Upon intervention by the government, private incentives to undertake R&D collapse. Assuming that the government does not directly finance R&D or organizes this industry in some other way, the quality of medical care remains constant from the intervention point onward. The price  $p_t$  for medical care drops from  $\mu_t/q_t$  to  $1/q_t$  due to the elimination of the markup. Equation (19) then implies an increase of the gross income share  $\varphi_t$  spent on medical care in the period of the intervention, due to this price drop and its effect on valuing the health endowment  $\underline{h}$ . From there onwards, the gross income share  $\varphi_t$  remains constant, and will be bounded above by  $(1 - \xi)/(1 - \sigma \xi)$ . If the government finds a way to continue

R&D indefinitely, the quality  $q_t$  may continue to grow to infinity, and the long-run share  $\varphi_t$  once again converges to  $(1 - \xi)/(1 - \sigma\xi)$ .

## 5.2. Optimal Medical R&D

Aggregate profits are

$$(20) \quad \pi_t = x_t(\mu_t - 1).$$

Consider a single firm  $j$ , choosing some R&D level  $d_{jt}$ , resulting in  $q_{j,t+1} = (q_t^\nu + d_{jt}^\nu)^{1/\nu}$ . 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

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

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

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

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

$$(21) \quad 1 - \chi = \frac{(q_{jt}^\nu + d_{jt}^\nu)^{1/\nu-1} d_{jt}^{\nu-1}}{q_{t+1}(\phi - 1)} \left( \frac{q_{j,t+1}}{q_{t+1}} \right)^{\frac{1}{\phi-1}-1} E_t (M_{t+1} \pi_{t+1}).$$

Imposing symmetry yields

$$(22) \quad 1 - \chi = \frac{d_t^{\nu-1}}{q_t^\nu + d_t^\nu} \frac{1}{\phi - 1} E_t (M_{t+1} \pi_{t+1}),$$

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

### 5.3. Risk Preferences and the Stochastic Discount Factor

The budget constraint of the entrepreneurs as well as the government budget constraint implies

$$(23) \quad \kappa e_t = \pi_t - d_t,$$

so that consumption of the entrepreneurial households is current period profits minus the expenses for creating the next generation of firms. With the preferences given in (5), the stochastic discount factor  $M_{t+1}$  is

$$(24) \quad M_{t+1} = \begin{cases} \tilde{\beta} & \text{if } e_t > \underline{e}, c_{t+1,e} > \underline{e}, \\ \tilde{\beta}/\theta & \text{if } e_t < \underline{e}, c_{t+1,e} > \underline{e}, \\ \theta\tilde{\beta} & \text{if } e_t > \underline{e}, c_{t+1,e} < \underline{e}, \\ \tilde{\beta} & \text{if } e_t < \underline{e}, c_{t+1,e} < \underline{e}. \end{cases}$$

We shall assume (or calibrate)  $\underline{e}$  so that the entrepreneurial consumption  $e_t$  during the non-government intervention epoch is above this threshold for all  $t \geq 0$ , and falls below it in the period following a government intervention. In our calculations below,  $e_t$  grows in the non-intervention scenario, so that we simply need  $\underline{e} < e_0$ . Furthermore, in our benchmark government intervention, markups and profits are shrunk to zero, so that entrepreneurial consumption falls to zero: we then just need  $\underline{e} > 0$ .

With that, the stochastic discount factor  $M_{t+1}$  during the non-government intervention epoch can be rewritten as

$$(25) \quad M_{t+1} = R^{-1}X_{t+1},$$

where

$$(26) \quad R = 1/E_t[M_{t+1}] = \frac{1}{\bar{\beta}(1 - \omega + \omega\theta)}$$

is the rate of discounting that is not particular to the health care risk. In a model with standard productivity shocks *et cetera*,  $R$  ought to reflect the risk pricing of such shocks. It is rather straightforward to extend our preference specification and model 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,  $X_{t+1}$ , satisfies

$$(27) \quad 1 = E_t[X_{t+1}]$$

and is the component that is specific to the health care sector, which in our model corresponds to the risk of government intervention. It satisfies

$$X_{t+1} = \begin{cases} \bar{X} & , \text{ if } \Delta z_{t+1} = 1, \\ \underline{X} & , \text{ if } \Delta z_{t+1} = 0 \text{ and } z_t = 0, \\ 1 & , \text{ if } z_t = 1, \end{cases}$$

where  $\bar{X} > \underline{X}$  and solve

$$(28) \quad \bar{X} = \frac{\theta}{1 - \omega + \omega\theta}$$

$$(29) \quad \underline{X} = \frac{1}{1 - \omega + \omega\theta}$$

Per (27), note that

$$(30) \quad 1 = (1 - \omega)\underline{X} + \omega\bar{X}$$

Once the government intervenes ( $z_t = 1$ ),  $X_{t+1} = 1$  and risk premia in the health care sector can be explained by standard risk factors. The fact  $\bar{X} > \underline{X}$  implies 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 not accounted for with the traditional risk factors used in standard asset pricing models.

Consider a health industry asset that pays a return  $Q$  at date  $t+1$  on a unit of investment at date  $t$ , if there has been no government intervention, and pays nothing, if the government intervened. Since  $1 = E_t[M_{t+1}Q]$ , the return needs to satisfy

$$Q = \frac{R}{(1 - \omega)\underline{X}}$$

An entirely safe asset would have the return  $R$ . To disentangle risk aversion from disaster risk for the return  $Q$ , suppose, that the government intervention for this particular asset was uncorrelated with the intervention giving rise to the stochastic discount factor of the entrepreneur. In that case, this disaster-risk-only return  $\tilde{Q}$  must solve

$$\tilde{Q} = \frac{R}{(1 - \omega)}$$

We therefore find, that we can decompose the medical innovation premium, written as the log excess return on investing in a health industry asset, into two pieces,

$$(31) \quad \ln(Q) - \ln(R) = -\ln(1 - \omega) - \ln(\underline{X})$$

where the first piece is the log excess return that is entirely due to the disaster risk inherent in health industry assets, while the second piece is due to the entrepreneurial risk aversion against such a disaster.

While we have derived this stochastic discount factor from the preference specification

(5), the latter is not essential: only the properties of the stochastic discount factor above matter for the solution of the model. We could have thus alternatively started with assuming these properties of  $M_{t+1}$  and then reverse-engineer entrepreneurial preferences, which give rise to this stochastic discount factor. For the kinked-linear preference specification in (5), it is easy to solve for  $\tilde{\beta}$  and  $\theta$ , given  $\omega$ ,  $\bar{X}$ ,  $\underline{X}$  and  $R$ , satisfying (30), from equations (26) and (28), but the reverse-engineering approach can be applied to a wider variety of utility specifications, which would thus serve just as well. We explore this route in a online appendix to this paper.

The simple form of the stochastic discount factor and the binary nature of the government intervention risk allow for a particularly simple way of solving the model, while respecting key nonlinearities elsewhere in the model during the convergence phase to the steady state.

## 6. CALIBRATION AND QUANTITATIVE IMPLICATIONS

In Section 6.1, we discuss how we calibrate the model's parameters, and provide intuition for how parameters are identified. We then use the model in Section 6.2 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. We conclude this section by studying the long-run implications of the model in Section 6.3.

### 6.1. Moments, Parameters, and Sensitivity

We need to calibrate the following set of parameters:

$$(32) \quad \Theta = \{\gamma, \underline{h}, \nu, q_0, \underline{X}, \bar{X}, \phi, \xi, \zeta, \chi, \sigma\}.$$

The parameters  $\beta$  and  $\eta$  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  $z_t = 0$ ,  $t = 0, \dots, 5$ , which corresponds to no government intervention.

In the model,  $\gamma^t$  is the labor income of the 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  $\gamma$  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 to 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).<sup>17</sup>

In calibrating government intervention risk, we initially consider the case in which gov-

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<sup>17</sup>The ratio of private to public medical R&D spending increased in the last decade, which may also justify a lower value of  $\chi$ .



ernment 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  $\omega$  from  $\omega = 10\%$  to  $\omega = 20\%$ .<sup>18</sup>

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  $X_{t+1}$ , we first note that, using the assumptions made before:

$$(33) \quad \frac{E(\pi_{t+1})}{E(\pi_{t+1}M_{t+1})} = R\underline{X}^{-1}.$$

We think of  $R$  as the return coming from the CAPM or the Fama-French model.  $\underline{X}^{-1}$  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  $R\underline{X}^{-1} = 1.09^{10} = 2.37$ . Also, given our assumptions made previously,  $\overline{X}$  no longer affects spending or R&D decisions.

In our model, only health industry assets are risky, whereas all others are safe. If one were to run a CAPM regression in our model, then these assets would have a premium compared to the market return, which happens to be the safe return. While our model is highly stylized, it does allow us to interpret the CAPM premia of the empirical section as a version of the preference-driven model-based premia here.

Second, equity generally is a claim on the leveraged assets of a company, while we investigate the premia on the unlevered investment in health care companies in the model. However, pharmaceutical firms in particular tend to have very low debt levels, since most of

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<sup>18</sup>One may wonder whether our alpha could simply be a Peso problem. For a 4% alpha per year, the per-year probability of intervention would be  $\omega^A = 1 - 1.05^{-1}$ . To probability of no intervention for a 60-year period then equals  $1.05^{-60} = 5\%$ , which is rather unlikely.

their investment is in intangibles. We therefore directly match the return on assets to the return on equity.

We select the remaining four parameters,  $\underline{h}$ ,  $\nu$ ,  $q_0$ , and  $\xi$  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 3. In Table 6 we summarize the model parameters for  $\omega = 10\%$  as well as  $\omega = 20\%$ .

## 6.2. 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.

### 6.2.1. 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 4. The solid line presents the benchmark case. The dotted line corresponds to the case in which we remove government risk altogether. The figure applies to the no-government intervention epoch.

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 7. Even though the R&D share rises somewhat more rapidly in this case, the effect is quantitatively small. We conclude that changing  $\omega$  and re-calibrating the model has a minor effect on this counterfactual.

### 6.2.2. *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,  $\underline{X} = \bar{X} = 1$ . This case corresponds to the dashed line in Figure 4. 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 4, 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 7. 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.

### 6.3. Long-Run Implications

Absent government intervention, 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 5 illustrates the evolution of the health care spending share and the R&D share as implied by the model, provided no government intervention takes place. 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.

Once the government intervenes, R&D activity will come to a halt, if left to private markets. The R&D share drops to zero, the gross income share  $\varphi_t$  spent on medical care jumps, but then remains constant, as explained below equation (19).

## 7. MECHANISMS FOR HEALTH CARE RISK PREMIA

### 7.1. 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  $\pi_{t+1}$  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  $\sigma$ . The subsidies are financed per lump-sum taxes  $\tau$  on the household. Assume a linear production function and denote the markup with  $\phi$ . Profits of the medical sector are  $\pi$ . 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, mark-ups and profits are:

$$(34) \quad p = \frac{\phi}{q} \text{ and } \pi = (\phi - 1)\frac{h}{q}.$$

The household budget constraint is:

$$(35) \quad y + \pi = c + (1 - \sigma)ph + \tau.$$

The government budget constraint is:

$$(36) \quad \sigma ph = \tau.$$

Together, we obtain the following two key equations:

$$(37) \quad c = y - h/q = y - \pi/(\phi - 1),$$

$$(38) \quad \pi = (\phi - 1)h/q.$$

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

1. Medical progress, including longevity: see subsection 7.2 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  $\sigma$ .

The challenge is the following. Suppose that these shocks result in surprise increases in profits  $\pi$ . 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  $\pi, h, c, y, \phi, q$  as endogenous have more potential to be successful. Consider the following sources of uncertainty:

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  $\pi$  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  $\pi$  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  $\phi$ : if  $\phi$  declines unexpectedly, then so will  $\pi$  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.<sup>19</sup> 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.

### 7.2. 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:

$$(39) \quad \max_{(h_1)} u(c_0) + \beta E_0 [u(c_1)] + \beta^2 E_0 [f(h_1) u(c_2)],$$

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,  $\pi_t = h_t (\phi_t - 1) / q_t$ .<sup>20</sup> 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

<sup>19</sup>This is also with the empirical results in Viscusi and Evans (1990), Finkelstein, Luttmer, and Notowidigdo (2008), and Koijen, Van Nieuwerburgh, and Yogo (2011).

<sup>20</sup>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,  $m_t = h_t$ .

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  $u'(c) < 0$ .

## 8. 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. Although it is generally believed that medical innovation and its demand is a central component of the expansion of this sector, little is known about what risks affect the returns of R&D investments and how those risks, in turn, 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 United States during the period from 1960 to 2010 and provided suggestive evidence of government intervention risk as a determinant of this premium. The excess returns relative to standard risk-adjustments were estimated to be 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 provided a theoretical analysis of the joint determination of financial and real health care markets. We interpreted the medical innovation premium to result from government markup risks that might 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 4%, in the absence of this government risk, holding back innovation.

Our analysis raises many future 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 Federal health care liabilities by U.S. 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 its effect on medical R&D. For example, the 2010 report of the National Commission on Fiscal Responsibility and Reform suggests imposing restrictions on publicly-financed health care spending tied to GDP growth. Our framework and analysis can be used to consider imposing government restrictions on health care spending and to quantify their effects, including the growth effects introduced by implementation uncertainty of the restrictions themselves.

More generally, we believe future analyses needs to better incorporate the feedback role between financial markets, government risk, and the growth of the health care sector. The growth of the health care sector depends on medical R&D, which is affected by government risk, which in turn means that greater uncertainty introduced by government intervention discourages medical R&D. This implies that any future growth of government program liabilities is tied to the risk of policies surrounding those 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 and health.

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Panel A: Industry alphas relative to the CAPM and the Fama and French model							
	Consumer goods	Manufacturing	HiTec	Health	Other	Medical equipment	Drugs
CAPM	1.81	1.66	-0.83	3.31	0.22	3.71	3.70
T-statistic	1.40	1.54	-0.54	1.61	0.17	1.40	1.78
Fama and French	-0.13	1.04	1.67	5.01	-2.66	6.44	5.37
T-statistic	-0.09	0.84	0.86	2.44	-2.75	2.05	2.63
No. of observations	52	52	52	52	52	52	52
Panel B: Industry alphas relative to models extended with the health care factor							
						Medical equipment	Drugs
CAPM + HC factor						0.22	0.31
T-statistic						0.14	0.71
FF+ HC factor						0.81	0.37
T-statistic						0.47	0.70
No. of observations						52	52

Table 1: Industry alphas

The table reports in Panel A the alphas relative to the CAPM and the 3-factor Fama and French model for different industries. The sample is from 1961 - 2012 and returns are annual. The first five industries add up to the market. The last two columns report the alphas of two sub-sectors of the health care sector: medical equipment and drugs. In Panel B, we add the health care sector (Column 4) to either the CAPM or the Fama and French model and report the alphas of both sub-sectors of the health care sector.

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Dictionary to identify government risk

Congress	Government regulation(s)	Political risk(s)
Congressional	Government approval	Politics
Debt ceiling	Government debt(s)	Price constraint(s)
Federal	Government deficit(s)	Price control(s)
Federal funds	Government intervention(s)	Price restriction(s)
Fiscal imbalance(s)	Law(s)	Regulation(s)
Government(s)	Legal	Regulatory
Government-approved	Legislation	Regulatory compliance
Government-sponsored	Legislative	Regulatory delay(s)
Governmental	Legislatory	Reimbursement(s)
Governmental program(s)	Patent law(s)	Subsidy
Government program(s)	Political	Subsidies
Governmental regulation(s)	Political reform(s)	

Table 2: Dictionary for 10-K filings

The table reports the dictionary that we use to identify how frequently firms highlight risk factors that are associated with government risk.

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Panel A: Main dictionary without health care-specific terms

	Average word count	Average fraction of words
Health care sector	138.98	1.51%
Non-health care sector	76.58	1.23%
Standard error of difference in means	15.06	0.10%
T-statistic	4.14	2.78

Panel B: Dictionary including health care-specific terms

	Average word count	Average fraction of words
Health care sector	180.60	1.89%
Non-health care sector	78.86	1.27%
Standard error of difference in means	19.68	0.13%
T-statistic	5.17	4.96

Table 3: Average word count to measure government risk from 10-K filings

Panel A of the table reports the average number of words in a firm's 10-K filing appears in the dictionary in Table 2. The average is taken across the 50 largest firms in the health care sector and the 50 largest firms in the non-health care sector. The table also reports the standard error of the difference in means and the corresponding  $t$ -statistic. The first column reports the average word count, while the second column measures the average fractions of words (that is, word count scaled by the length of the document). Panel B reports the results if we expand the dictionary to include health care-specific terms that relate to government programs.



Event date	Description of event
January 19, 1992	Clinton issues health care reform proposals before New Hampshire primary
February 18, 1992	Clinton unexpectedly finishes second in the New Hampshire primary
March 10, 1992	Clinton does well in the Super Tuesday primaries
April 7, 1992	Clinton wins New York primary and becomes the favorite to win the Democratic nomination
June 4, 1992	Republicans in the House of Representatives offer their health care reform proposal
September 24, 1992	Clinton speaks at Merck on health care reform
November 3, 1992	Clinton wins presidential election
January 25, 1993	Clinton names Hillary Clinton to head his Health Care Task Force
February 12, 1993	Clinton says drug prices are too high
September 11, 1993	New York Times describes probable regulations based upon a leaked copy of the plan
September 22, 1993	Clinton officially announces his health care reform plan

Table 4: Key event dates around Clinton’s health care reforms

The table summarizes the key event dates and a description of the event during Clinton’s health care reforms. The table is reproduced from Golec, Hegde, and Vernon (2010).

Intercept	-0.21
<i>t</i> -statistics	-8.28
Slope coefficient	-7.7%
<i>t</i> -statistic	-2.66
R-squared	4.0%
Number of firms	327
Average number of years used to estimate health care betas	20.8

Table 5: Cross-sectional regression of cumulative abnormal returns on health care betas

The table reports the results of a cross-sectional regression of the cumulative abnormal return of a firm during the Clinton health care reform on the beta of a given firm on the health care factor in (3). The beta is standardized by the cross-sectional standard deviation of the beta.

Parameter	Description	Probability of government intervention	
		$\omega = 10\%$	$\omega = 20\%$
$\gamma$		1.35	1.35
$\phi$	Markup	3	3
$\zeta$	Constrained markup	1	1
$\chi$	R&D subsidy	50%	50%
$\sigma$	Medical care subsidy	50%	50%
$R$	Baseline discount rate	1.48	1.48
$\underline{X}$	Price of government risk	0.63	0.63
$q_0$	Initial level of medical knowledge	2.80	1.60
$\nu$	Curvature R&D production function	0.44	0.46
$\underline{h}$	Health endowment	0.45	0.24
$\xi$	Weight non-health consumption in $U$	0.78	0.79

Table 6: Model parameters

The table summarizes the calibrated model parameters for two levels of government intervention risk ( $\omega$ ).

Probability of government intervention: $\omega = 10\%$			
	Benchmark	No government risk	No government risk premium
<b>Health share</b>			
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%
<b>R&amp;D share</b>			
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
<b>Health share</b>			
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%
<b>R&amp;D share</b>			
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 7: Health and R&D share dynamics for both counterfactuals and different levels of government risk.

The table illustrates the impact of government risk and the medical innovation premium on health care and R&D spending. The first column provides the benchmark results, the second column removes government risk altogether, while the third column considers the counterfactual in which there is government risk, but this risk is not priced in equilibrium.



Figure 1: Relative market capitalization

The table reports the share of market capitalization of the U.S. stock market that comes from the health care industry as well as from drug companies and companies that produce medical devices.

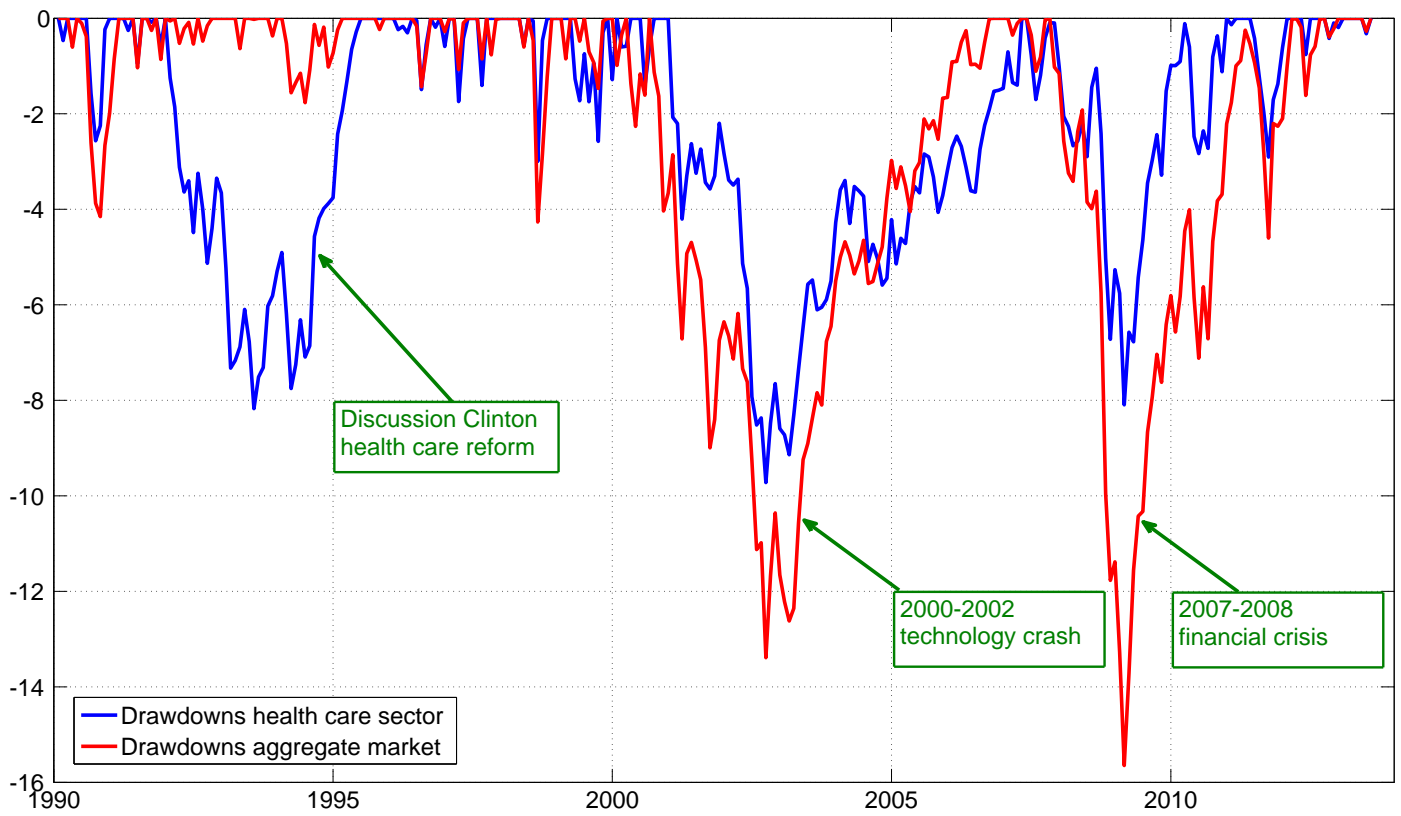


Figure 2: Drawdown dynamics for the health care sector and the aggregate stock market.

The table reports the drawdown dynamics of the health care sector and the overall stock market from 1990 until 2013. Drawdowns are defined in (2).

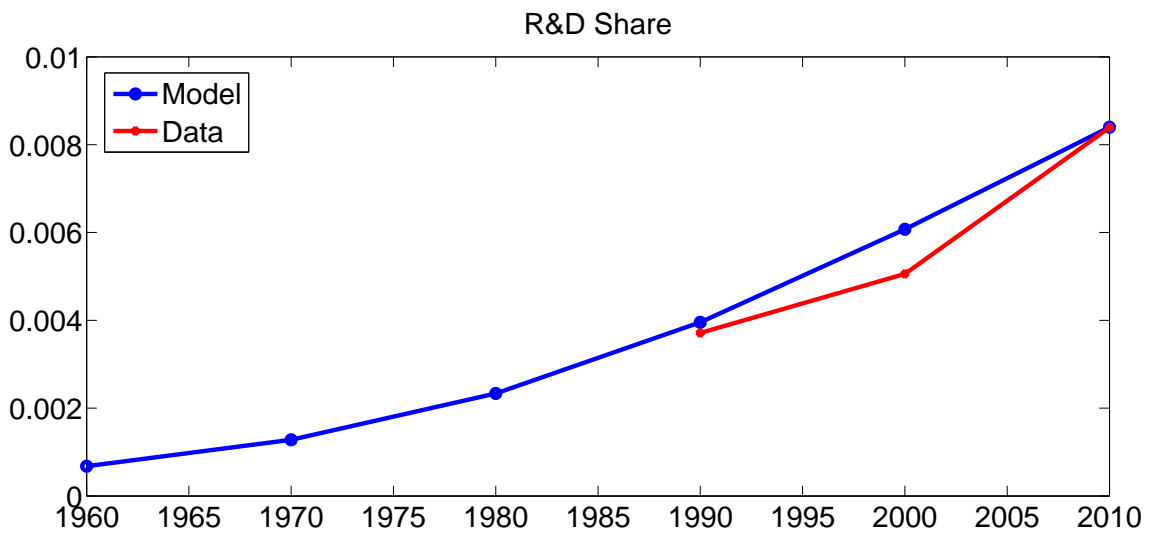
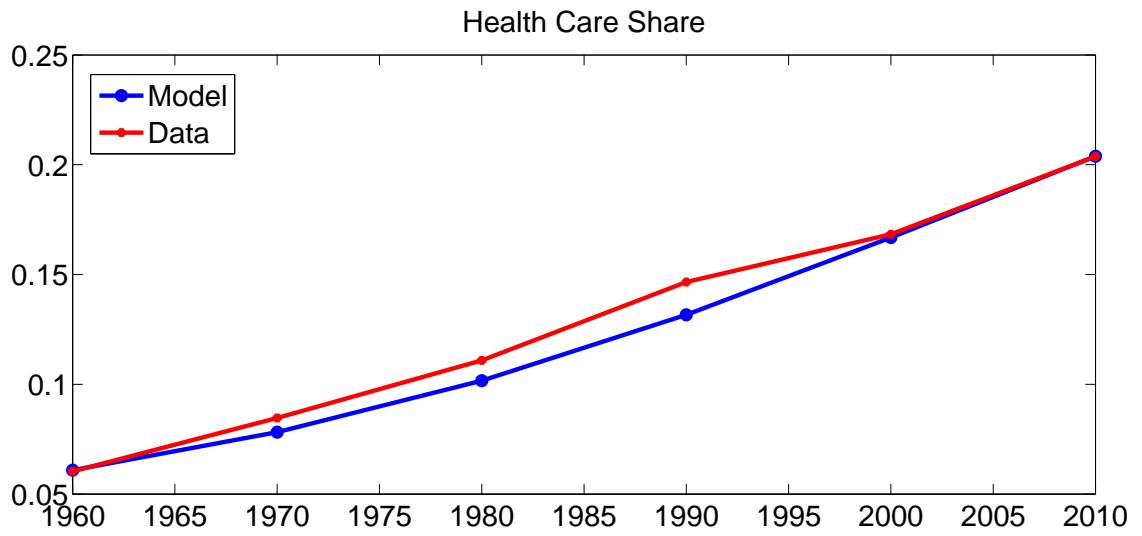


Figure 3: Health and R&D share in the model and in the data

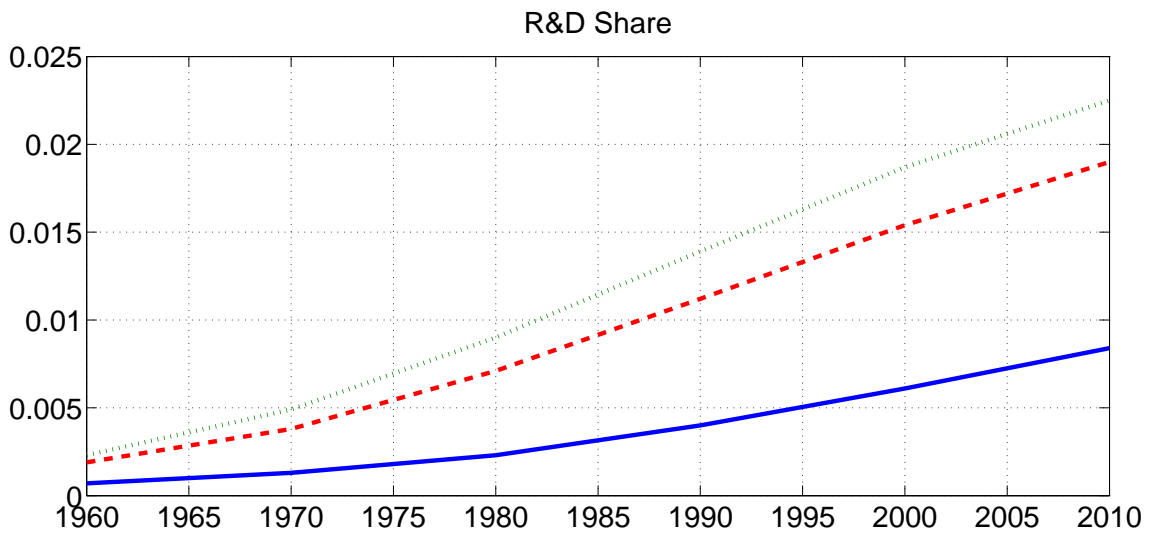
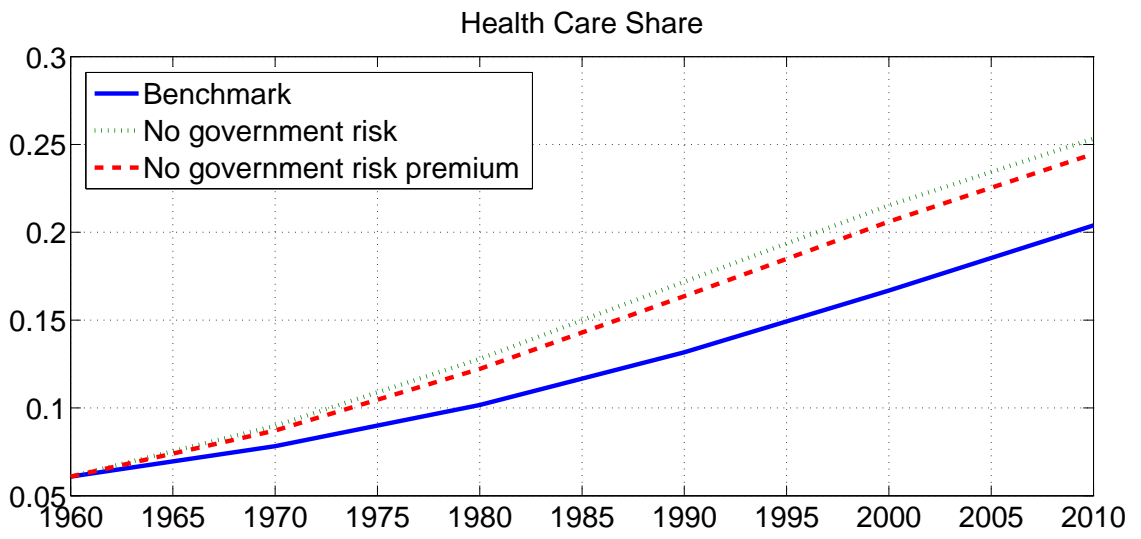


Figure 4: Counterfactual dynamics of health care and R&D spending



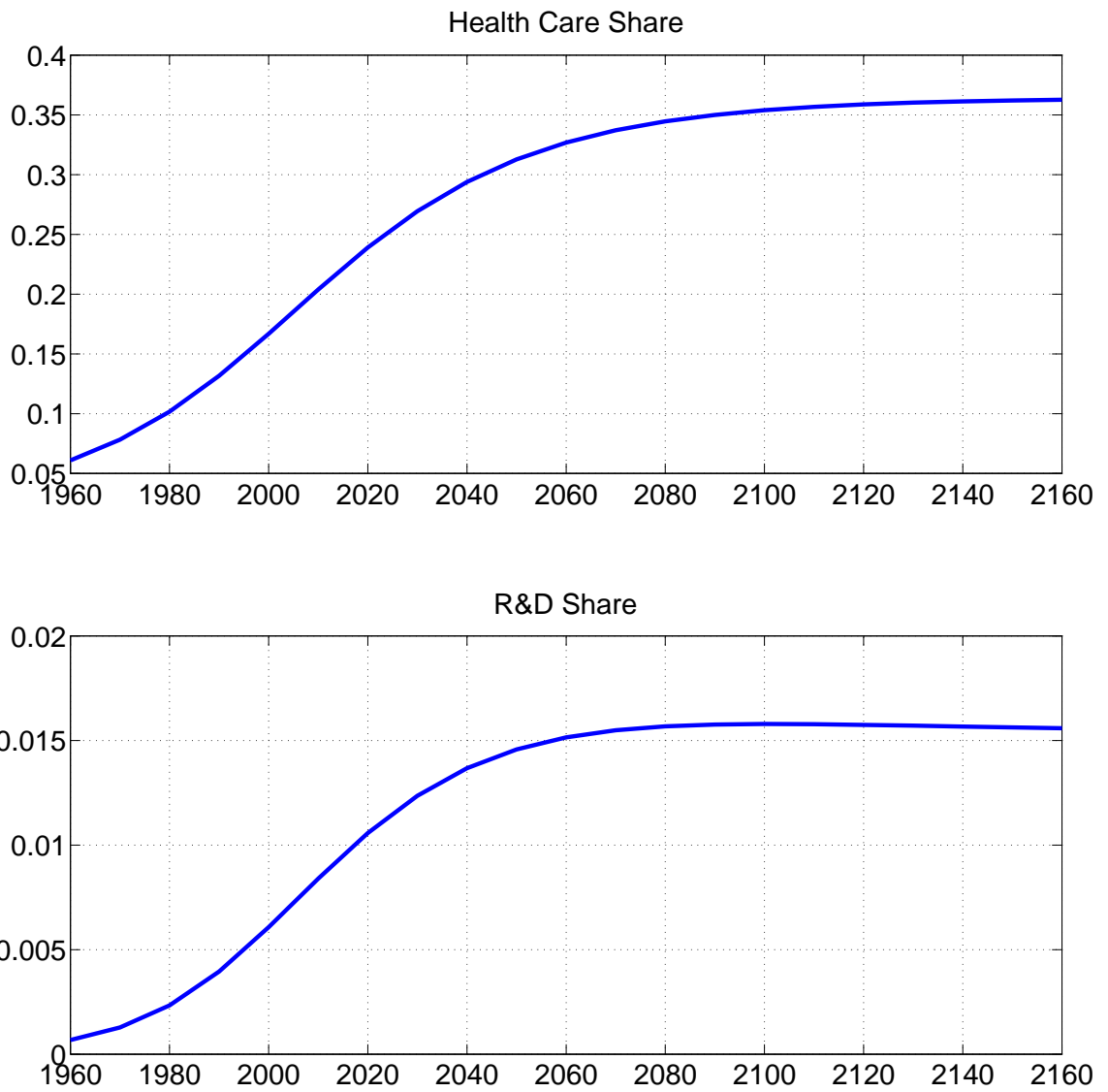


Figure 5: Model-implied long-run dynamics of the health and R&D share

# Online Appendix: Not For Publication

## A. REVERSE-ENGINEERING THE PREFERENCES OF THE ENTREPRENEUR

Given the numerical solution to the model, it may be instructive to “reverse-engineer” the preferences, i.e., to find a value function  $V(\{c_{e,t}\}_t)$  in terms of the stochastic stream of entrepreneurial consumptions so that the assumed stochastic discount factors result from the appropriate first-order conditions. It should be clear that there is considerable freedom in doing so.

Note that we have assumed (or, for the kinked preference specification, derived) that

$$M_{t+1} = R^{-1}M_{t+1}^H$$

where  $R$  is the safe return over the model period of 10 years, and where  $M_{t+1}^H$  is the stochastic component of the discount factor, **satisfying**  $1 = E[M_{t+1}^H]$  and given by

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

Suppose now, that the preferences of the entrepreneur are time separable,

$$V(\{c_{e,t}\}_t) = E \left[ \sum_{t=0}^{\infty} \beta_e^t u(c_{e,t}) \right]$$

The consumption of the entrepreneur  $c_{e,t}$  in the absence of government intervention are proportional to profits minus outlays for R&D, as stated in equation (11) of the paper. The consumption of the entrepreneur with government intervention could either be read as zero, or, in a slight extension of the model, assumed to be some fraction  $0 \leq \xi_t < 1$  of the non-intervention consumption  $c_{e,t}$  at the time of the intervention.

The standard relationships between preferences and stochastic discount factors deliver

$$(40) \quad R^{-1}\underline{M} = \beta_e \frac{u'(c_{e,t+1})}{u'(c_{e,t})}$$

$$(41) \quad R^{-1}\bar{M} = \beta_e \frac{u'(\xi_t c_{e,t+1})}{u'(c_{e,t})}$$

From the numerical calculation done for  $t = 1, \dots, 6$ , one finds that entrepreneurial consumption is growing over time, though not exactly at a constant rate.

The easiest solution to the equations (40) above is to assume that the utility function is piecewise linear, with a concave kink at some positive level of consumption below  $c_{e,1}$  and with imposing that  $\xi_t$  takes post-intervention consumption to a level below  $c_{e,1}$ :  $\xi_t = 0$  will be one possibility that does the trick. With the piecewise linear utility function, one needs to solve for  $\beta$  per

$$(42) \quad R^{-1}\underline{M} = \beta_e$$

and find the slope below the kink (at  $c = 0$ , say) relative to the slope above the kink (at  $c_{e,t}$ , say) per

$$\frac{\overline{M}}{\underline{M}} = \frac{u'(0)}{u'(c_{e,t})}$$

Such preferences are a simple version of loss-aversion preferences that have been proposed for a variety of phenomena, including asset pricing, see Kahneman and Tversky (1979).

If  $\beta_e$  does not satisfy (42), but instead is some other value between that value and, say,  $\beta = 1$ , one can solve the integration problem as follows. For a given value of  $\beta_e$  strictly in this range and with some normalization for  $u'(c_{e,1}) > 0$ , calculate recursively

$$u'(c_{e,t+1}) = \frac{\underline{M}}{\beta_e R} u'(c_{e,t})$$

Note that  $0 < u'(c_{e,t+1}) < u'(c_{e,t})$ . Find a continuous decreasing non-negative function  $u'(c_e)$  connecting these points: this is feasible, since  $c_{e,t}$  is an increasing sequence. Integrate to find the utility function  $u(c_e)$ .

While there are many solutions, it may be instructive to see whether one can bound this exercise, using the CRRA specification. While the CRRA specification will not work exactly, one can calculate  $\bar{\eta}$  as the minimal  $\eta$  so that

$$(43) \quad R^{-1}\underline{M} \geq \beta_e \left( \frac{c_{e,t+1}}{c_{e,t}} \right)^{-\eta}, \text{ for all } t = 1, \dots, 6$$

and  $\underline{\eta}$  as the maximal  $\eta$ , so that

$$(44) \quad R^{-1}\underline{M} \leq \beta_e \left( \frac{c_{e,t+1}}{c_{e,t}} \right)^{-\eta}, \text{ for all } t = 1, \dots, 6$$

Imposing CRRA preferences with these  $\eta$ , one can furthermore ask, what consumption reduction fraction  $\xi_t$  will be necessary in order to reach the marginal utilities required for the intervention case. The results are in table 8. It turns out that the  $\eta$ -bounds are fairly close

to each other, indicating that CRRA is a pretty good fit even for  $\beta_e$ -values different from that in equation (42), for any of the values of  $\beta$ . Furthermore, the values for  $\eta$  are within the entirely reasonable range of  $[0, 2]$ .

The consumption reduction fraction are arbitrary for  $\eta = 0$ , and otherwise range from 0.04 to 0.33. A slightly different utility specification uses a (close-to-) CRRA utility function above these consumption levels, and linear below, splicing it together smoothly at that point: then, one may use any post-intervention consumption level below that consumption reduction level. In that case, one needs a different felicity function for every period.

$\beta_e$ (p.a.):	0.92	0.94	0.97	0.98	1.00
$\bar{\eta}$ :	0.0	0.6	1.1	1.5	1.8
cons.reduct.fract.:	arb.	0.04	0.16	0.26	0.33
$\underline{\eta}$ :	0.0	0.5	1.0	1.3	1.6
cons.reduct.fract.:	arb.	0.03	0.13	0.22	0.29

Table 8: Calculating  $\eta$ -bounds and the corresponding consumption reduction fraction, as a function of  $\beta$ .

It should finally be noted that one needs

$$R^{-1} = \beta_e \frac{u'(\tilde{c}_{e,t+1})}{u'(\tilde{c}_{e,t})}$$

for the post-intervention consumption levels  $\tilde{c}_{e,t}$ . This will automatically be satisfied for  $\tilde{c}_{e,t} \equiv 0$  and the kinked utility specification detailed above. For the CRRA specification, one will need a constant growth rate of  $\tilde{c}_{e,t}$ . Since the required preferences are not exactly CRRA, one needs slightly uneven growth for  $\tilde{c}_{e,t}$  in order to compensate.

## B. TRENDS IN HEALTH CARE AND R&D SPENDING

**Health Care Spending** Figure 6 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 9 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 9 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 7 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.

Country	Health exp. (% of GDP)		Pharma. exp. (% health exp.)	
	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 9: Health care spending for OECD countries

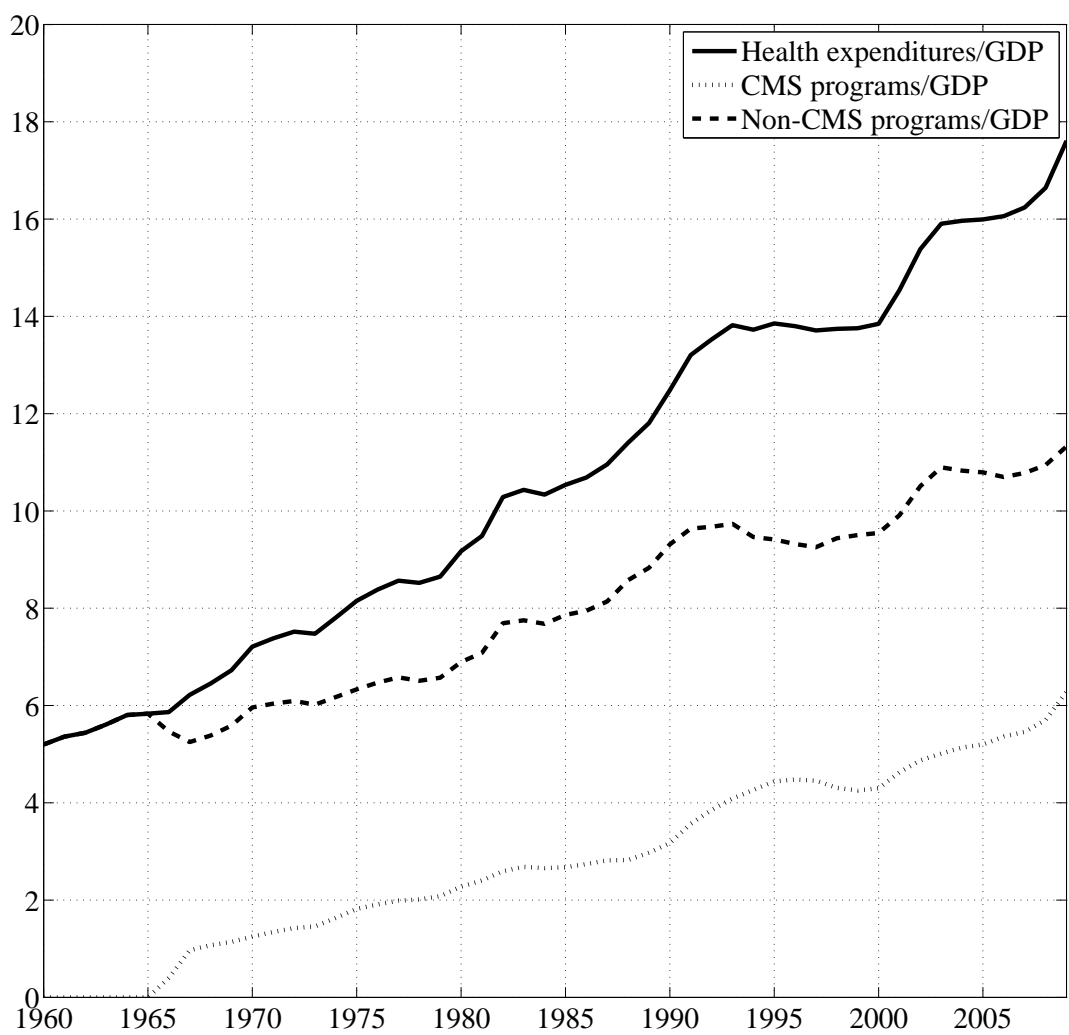


Figure 6: Medical spending relative to GDP

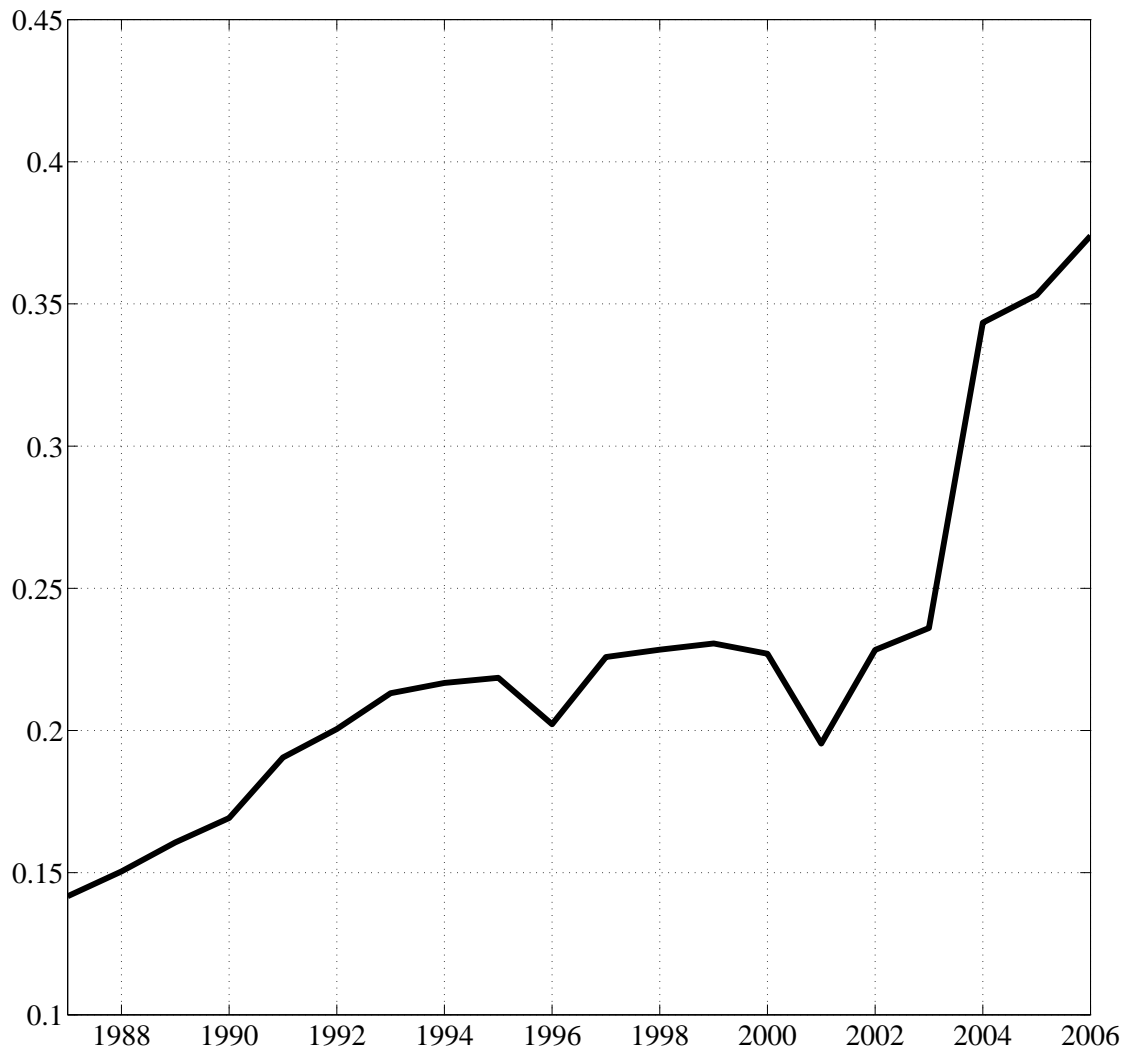


Figure 7: Medical R&D spending relative to GDP

### C. ROBUSTNESS OF THE MEDICAL INNOVATION PREMIUM

In the main text, we document the medical innovation premium for annual returns for our main sample from 1961 - 2012 using both the CAPM and the 3-factor Fama and French model.

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: 1927.1-2013.7, 1946.1-2013.7, and 1961.1-2013.7. 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 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 10. 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 between 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 models. 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.



Panel A: Annual returns							
1927-2012	Consumer goods	Manufacturing	HiTec	Health	Other	Medical equipment	Drugs
CAPM	1.25	1.12	0.68	3.98	-0.96	4.33	4.35
	1.22	1.49	0.57	2.35	-1.01	2.11	2.48
Fama and French	0.78	0.53	2.11	5.56	-2.60	5.80	5.96
	0.74	0.74	1.73	3.37	-3.54	2.83	3.42
1946-2012	Consumer goods	Manufacturing	HiTec	Health	Other	Medical equipment	Drugs
CAPM	1.19	1.66	-0.29	4.29	-0.86	4.07	4.68
	1.07	1.81	-0.21	2.10	-0.77	1.70	2.25
Fama and French	-0.06	0.92	1.91	5.72	-3.10	6.27	6.06
	-0.05	0.96	1.25	2.77	-3.82	2.36	2.87
1961-2012	Consumer goods	Manufacturing	HiTec	Health	Other	Medical equipment	Drugs
CAPM	1.81	1.66	-0.83	3.31	0.22	3.71	3.70
	1.40	1.54	-0.54	1.61	0.17	1.40	1.78
Fama and French	-0.13	1.04	1.67	5.01	-2.66	6.44	5.37
	-0.09	0.84	0.86	2.44	-2.75	2.05	2.63
Panel B: Monthly returns							
1927.1-2013.7	Consumer goods	Manufacturing	HiTec	Health	Other	Medical equipment	Drugs
CAPM	1.46	0.74	0.46	3.07	-1.24	3.27	3.47
	2.12	1.24	0.52	2.43	-1.50	2.03	2.54
Fama and French	1.45	0.26	1.60	3.89	-2.72	3.53	4.34
	2.12	0.48	2.06	3.16	-3.91	2.22	3.27
1946.1-2013.7	Consumer goods	Manufacturing	HiTec	Health	Other	Medical equipment	Drugs
CAPM	1.25	1.34	-0.59	3.18	-0.92	2.85	3.67
	1.61	1.91	-0.58	2.40	-1.12	1.71	2.54
Fama and French	0.58	0.25	1.57	4.85	-3.02	3.81	5.50
	0.75	0.39	1.75	3.78	-4.13	2.25	3.98
1961.1-2013.7	Consumer goods	Manufacturing	HiTec	Health	Other	Medical equipment	Drugs
CAPM	1.76	1.33	-1.01	2.64	-0.10	2.82	3.11
	1.92	1.55	-0.84	1.76	-0.10	1.65	1.89
Fama and French	0.79	0.17	1.24	4.78	-2.46	4.10	5.54
	0.85	0.21	1.14	3.29	-2.82	2.33	3.52

Table 10: Industry alphas