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HEALTH CARE REFORMS AND THE VALUE OF FUTURE PUBLIC LIABILITIES

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ABSTRACT

Many developed countries are grappling with the large public liabilities attributable to health care subsidy programs. However, there has been no explicit analysis by economists of how various reforms affect future spending growth and, consequently, how they affect future public program liabilities. We analyze how approval and reimbursement reforms affect public liabilities through their impact on the returns to medical innovation, which many argue is a central factor driving spending growth. We separate how reforms impact innovative returns through changes to expected cash flows, their risk-adjustment, and their timing and defaults implied by the approval process. We argue that the innovation effects of common reforms imply that cutbacks in government programs may raise government liabilities and expansions may lower them. We quantitatively calibrate the implications of these arguments for the US Medicare program and find that further means-testing the program may substantially raise innovative returns and thereby put upward pressure on Medicare liabilities.

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1 Introduction

Many developed nations are increasingly concerned about the growth of future government liabilities in health care and how to assess the effects of health care reforms on these liabilities. In the US, many private and public efforts have attempted to limit the growth in overall health care spending and public liabilities, including prospective payment Medicare reforms in the 1980s, the dramatic rise in managed care firms in the 1980s and 1990s, and the current expansions of consumer-oriented health care. The most recent incarnations include Accountable Care Organizations, bundled payments, and other measures of the Affordable Care Act (ACA). Despite these repeated efforts, the health care economy has grown and is predicted to continue to grow faster than the rest of the economy.[1]

These private and public efforts to slow down spending growth run into difficulty partly because they are motivated by their impact on incentives at a given time rather than the impact on the growth in spending across time. For example, many argue that prospective payment or bundling reforms reduce the incentive to spend at a given time without any explicit understanding of why growth may be altered. Indeed, little explicit economic analysis exists of how various reforms will affect the growth of future health care spending over time. As a result, there is little explicit analysis on how these reforms affect the present value of future public liabilities. This paper addresses these two fundamental questions by offering a framework in which they can be analyzed explicitly and quantitatively.

We analyze how public reforms affect future spending growth through their impact on the returns from medical innovation. Pioneered by the work of Newhouse (1992), research suggests that medical innovation is central to the growth in health care spending. Moreover, public reforms are central to driving global innovative returns, as a large share of the world's care is publicly financed in rich countries. Therefore, public reforms have large impacts on the uncertain future profits associated with medical innovation, which drive future spending growth in both the public and the private sector.

We consider cases in which the impact of government reforms on medical research and development (R&D) returns comes from three different sources: expected cash flows, the risk-adjustment of the flows, and the timing of those cash flows. For the impact on expected cash flows, we stress the non-monotonic effects of government expansions on innovative returns. In particular, we stress that government expansions often lower both demand prices (copays) and supply prices (reimbursements) through government monopsony power. This result may imply that R&D returns rise when government expansions include poorer parts

[1] Indeed, recent evidence suggests that past changes in organizational forms had small effects risk-adjusted levels of care; see, e.g., Ash and Ellis (2012).

of the population by raising quantity more than lowering markups. For example, the recent Medicaid expansions of ACA 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 lower innovative returns in this manner. The non-monotonic impact of government expansions across the income distribution implies that government cutbacks may raise R&D returns, and pose upward pressure on future public liabilities. Likewise, government expansions may lower public liabilities by reducing the incentive for medical innovation.

The second way in which reforms may affect innovative returns is through risk-adjustments of expected cash flows. The risk-adjustment reflects the covariance of cash flows with the stochastic discounting that occurs. The amount of risk-adjustment depends on both private-sector systemic risk such as the business cycle and public-sector risk such as future policy uncertainty. For the impact of private sector risks through the business cycle, we stress that in a world where pro-cyclical earnings are undesirable (e.g., a CAPM world), a means-tested program such as Medicaid lowers risk. This is because means-testing buffers the demand of the poor in recessions and tampers it in expansions, reducing the overall impact of the cycle. Generally, risk-adjustment associated with the cycle will depend on income effects of the subsector in question. Cyclical sectors of health care, such as preventive and elective care, are predicted to lower returns and raise investments compared to less cyclical sectors, such as curative or emergency medicine. For public sector risk, we consider the effects of increased policy variance surrounding new reform proposals. A recent example is the uncertainty surrounding ACA and the slow down in R&D investments it is argued to induce. Increase policy uncertainty surrounding reforms may lead to nontraditional effects on medical innovation. An example would be when Medicaid expansions, which we argue should raise medical R&D, may contract medical R&D due to policy uncertainty.

Lastly, the third way reforms affect medical R&D returns is through the timing of risk-adjusted cash flows. This mainly occurs through medical product approval reforms, such as through the FDA in the US. The length of clinical development affects the financial "duration", or value weighted timing, of innovative returns. Development delays lower returns by both delaying the onset of profits as well as shortening the effective patent life. In addition to affecting the duration of returns, reforms affect nonapproval which is analogous to "defaults" on R&D investments, and thereby act as increased discounting of future profits. Surprisingly, we find that government approval risk often raise innovative returns rather than lower them.

We analyze how these three impacts of reforms on innovative returns drive the growth in health care spending and thereby the value of future public program liabilities. The effect of reforms on the present value of public liabilities stems from the incentives for medical innovation they induce. Many times public spending changes in the opposite direction of innovative returns, which implies that public expansions may lower public liabilities whereas cut-backs may raise them.

We examine quantitatively one such case that concerns the spending effects of further means-testing Medicare. In particular, we calibrate the non-monotonic nature of innovative returns due to such changes using existing utilization and reimbursement data in the US. We find that even a modest contraction in Medicare eligibility of top-income individuals leads to a substantial increase in innovative returns and thus puts upward pressure on future Medicare liabilities. We calibrate the minimum degree by which the increased profits must affect future spending growth in order for Medicare cuts to raise Medicare liabilities.

Our analysis naturally relates to several strands of previous work. As recognized as early as the patent clauses of the US Constitution, R&D needs to be supported by profits and adequate pricing. Chernew and Newhouse (2011) summarize models of health care spending growth in the literature. Baumgardner (1991) presents one such model of the role of managed care in controlling spending. Weisbrod (1991) discussed the importance of third-party pricing for the profits and type of medical R&D undertaken, and Finkelstein (2004) and Clemens (2012) documented evidence on the link between third party coverage and innovation. More closely related to this paper, Koijen, Philipson, and Uhlig (2012) documented a large "medical innovation premium" that historically is paid to medical R&D investors and the growth of the health care sector this premium implied. Malani and Philipson (2012) considered the nonstandard impacts of reforms on clinical trials, by far the largest component of medical R&D costs. Lastly, it serves to note that this work is positive in nature; we do not argue that more or less spending, whether privately or publicly financed, is desirable or not. Rather, we are primarily concerned with predicting how reforms affect program liabilities.

2 The Impact of Reforms on the Expected Cash Flows of Innovative returns

Let a government program be defined by a set of policy variables represented by a vector g, such as the supply price (reimbursement), demand price (copay), eligibility criteria (e.g., means-testing), and payment structures (such as fee-for-service or capitation), all of which ultimately drive quantity and markups in both the private and public sector. Let $F(g)$ denote the share of the population eligible for the public program, potentially 100% if it is a universal single-payer program. For a firm engaged in medical innovation, let $\pi_G(g)$ and $\pi(g)$ denote the average per-capita profits in the public and private sector. The overall profits from both sectors are then given by:

$$\Pi(g) \equiv F(g)\pi_G(g) + (1 - F(g))\pi(g) \qquad (1)$$

This specification is general in the sense that both quantity and markups in both sectors may be affected by the government policies. At this level of generality, changing an element of the policy vector g affects profits as in:

$$\frac{d\Pi}{dg} = F_g[\pi_G - \pi] + F\frac{d\pi_G}{dg} + (1 - F)\frac{d\pi}{dg}$$

The first effect is if the policy affects eligibility, in which case public profits replace private ones for the newly eligible part of the population. The second is the effect on per-capita profits in the two different sectors, weighted by their size. For example, consider when the policy change concerns expanded eligibility by some dimension such as age, income, or disease status. Such an eligibility change may not only affect the newly eligible through the first effect but also the per-capita profits if, for example, the larger public program lowers future reimbursement. We will consider special cases of these within- and between-sector effects by specifying more precisely what policy levers are under consideration and what they imply for profitability.

2.1 Effects of Common Public Program Reforms on Innovative Returns

We consider the impact of expanding public coverage across the income distribution as well as changes in reimbursement and copays altering the supply and demand prices the program induces.

2.1.1 Effects of Eligibility Reforms

We argue that income-based eligibility expansion has important non-monotonic effects on innovative returns. Let $\pi_G(y)$ and $\pi(y)$ denote per-capita profits in the two sectors for a given level of income y. Figure 1 shows the case we will assume throughout that profits rise in both sectors but are higher in the public sector for the relatively poor, who buy more care with lower demand prices, and higher in the private sector for the relatively rich, who may buy care at higher supply prices outside the program. In this case, we have that $\pi_G(y) > \pi(y)$ for $y < x$ and $\pi_G(y) < \pi(y)$ for $y > x$ for some level of income x at which the two coincide.

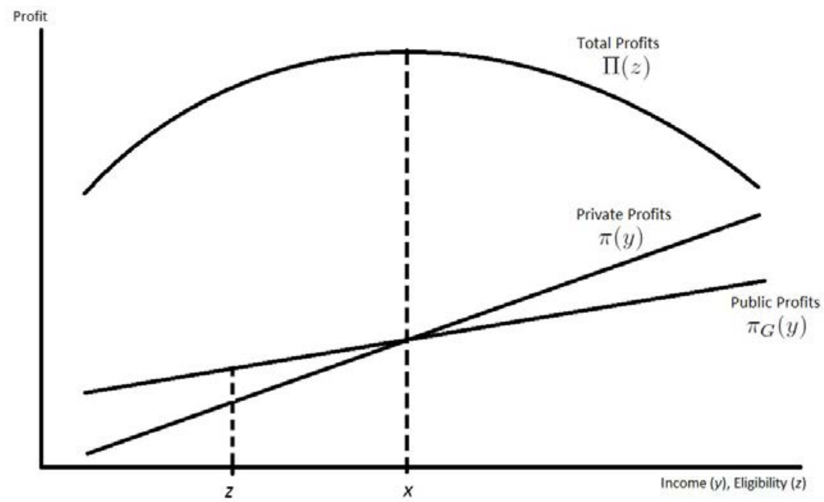

Figure 1: Profit by Sector

For a given income distribution $F(y)$ with density $f(y)$, a means-tested program may be defined by a cutoff level of income z below which eligibility occurs, making a share $F(z)$ eligible and $1 - F(z)$ ineligible. For example, in the US multiples of the federal poverty line are often used as a Medicaid eligibility cutoff. The total profits across the public and private sector for a given level of eligibility are then:

$$\Pi(z) = \int\limits_{y=0}^{z} \pi_G(y)f(y)dy + \int\limits_{y=z}^{\infty} \pi(y)f(y)dy$$

As depicted in Figure 1, the total profits peak where per-capita profits cross at x. Profits increase below x by bringing in the poor at larger profits, and decrease above x by bringing in the rich at lower profits. The marginal impact on profits from raising eligibility is:

$$\frac{d\Pi}{dz} = f(z)[\pi_G(z) - \pi(z)]$$

and is thus positive below x and negative above x. As a result, there is a bell-shaped non-monotonic relationship between profits and eligibility whereby profits first rise and then fall with eligibility.

A special case of these overlapping profits occurs when expanded eligibility for public coverage may replace either private insurance with profits $\pi_I(y)$ or uninsurance with profits π_U. If we denote by $I(y)$ the increasing private insurance rate as a function of income the profits in the private sector are:

$$\pi = I\pi_I + (1-I)\pi_U$$

Consider when profits among privately insured and uninsured rise with income but vanish without income; $\pi_I(0) = \pi_U(0)$. Then if insured per-capita profits rise above public per-capita profits at some point as income rises, the overall private profits will rise above public profits as well if the insurance rate I rises to full uninsurance for large enough income. As a special case of above, the profits are non-monotonic as a function of eligibility.

2.2 Markup and Quantity Effects from Eligibility Reforms

Specifying how eligibility and the per-capita profits are determined in profits, what the vector of policies g contains, allows one to analyze the channels by which the latter drives the former. Throughout the paper, we consider when overall profits are driven by the medical care quantities or utilization (m), with reimbursement (supply prices) p_S and p'_S in the public and private sector, co-pays (demand prices) p_D and p'_D, and production costs c:

$$\Pi(g) = F[(p_S - c)m_G(p_D)] + (1-F)[(p'_S - c)m(p'_D)] \tag{2}$$

In the most general case, policies g may affect quantities, prices, and costs. The intermediary relationships between payers and providers are therefore subsumed in this particular specification through the direct relationship between government policies and profits that result from the quantity and markups implied by any such intermediary relationships. A medical product may be used more if government reimbursement of doctors and hospitals is higher. For example, in the US Medicare program, the producer may sell to hospitals that participate in part A, doctors in part B, private payers in part C, or drug plans in part D. In this case, the quantities and prices of the formulation above may then be interpreted as those induced by the policies and regulations g governing the four programs. This formulation therefore merges the effects of provider adoption of innovations developed.

To consider eligibility effects in this formulation assume demand is a function of price and income so that profits are $\pi_G(y) = (p_S - c)m(p_D, y)$ and $\pi(y) = (p'_S - c)m(p'_D, y)$. The effect of an expansion of eligibility on overall profits is then:

$$\frac{d\Pi}{dz} = f(z)[(p_S - c)m(p_D, z) - (p'_S - c)m(p'_D, z)]$$

Changes in the levels of eligibility have two offsetting effects on overall profit. First, the program raises utilization by lowering demand prices which has a positive effect on profits.

Second,the public program may lower supply prices which has a negative effect on profits. Thus profits rise or fall depending on whether the positive utilization effect dominates the negative markup effect:

$$\frac{d\Pi}{dz} > 0 \Leftrightarrow \frac{m(p_D, z)}{m(p'_D, z)} \geq \frac{(p'_S - c)}{(p_S - c)}$$

Now if subsidy has the greatest impact on the utilization of the poor, $m_{py} > 0$, then the quantity effect likely dominates for the poor and the markup effect likely dominate for the rich. These effects are reinforced when expansions entail lower unit prices because the government gains monopsony power. In this case, the reimbursement p_S falls in the threshold z. This result is illustrated in Figure 2, which depicts the quantity gains and markup reductions associated with a larger public program.

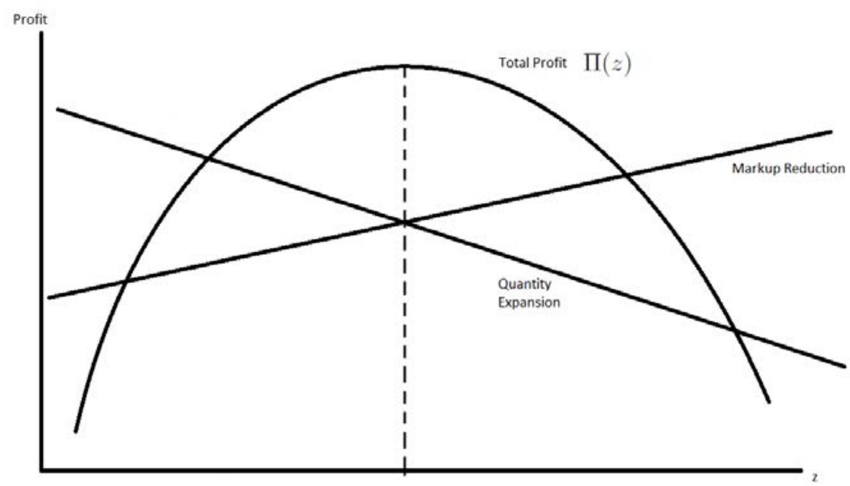

Figure 2: Profits Broken into Quantity Expansion and Markup Reduction

At the extreme left when the poorest people are being added, the quantity effect will likely dominate the markup effect. At the other extreme is when very rich individuals are added, in which case their demand will not be affected much by the lower copay in the public program but their markup will be lowered if they are subsumed under a government buyer. The positive impact may be exemplified by US Medicaid expansions and the negative impact by universal European single payer programs. The end result is a bell-shaped profits curve as a special case of the crossing per-capita profits in the two sectors.

2.2.1 Effects of Demand and Supply Price Reforms

Now consider when the policies are $g \equiv (p_S, p_D)$ representing reimbursement to providers or innovators (supply price) and the copays to patients (demand price). For any subsidy program, the supply and demand prices are separated because the government pays for the wedge between them. Therefore, unlike in the private sector where supply and demand prices coincide, increasing the supply price raises price without lowering quantity, and thus has the monotonic effect of always raising profits. Increasing the demand price discourage utilization without affecting markups and thus has the monotonic effect of reducing profits.

$$\frac{d\Pi}{dp_S} = F\frac{d\pi_G}{dp_S} = Fm_G > 0$$

$$\frac{d\Pi}{dp_D} = F\frac{d\pi_G}{dp_D} = F(p_S - c)\frac{dm_G}{dp_D} < 0$$

When supply and demand prices vary freely, textbook arguments imply that demand subsidy programs raise the equilibrium supply price and lower the equilibrium demand price, thereby raising profits (see, e.g., Varian (2010)). What is less recognized, but relevant to health care, is that many times expansions in demand subsidy programs will simultaneously lower both demand and supply prices. When government programs grow, they often induce lower reimbursements to providers by the monopsony power created. The total effect on profits of the expansion of a demand subsidy program then depends on whether greater use through lower demand prices dominates lower markups through reductions in supply prices.

$$\frac{d\Pi}{dp_D}(dp_D) + \frac{d\Pi}{dp_S}(dp_S)$$

For example, Medicare in the US raises utilization by expanding the pool of customers, but they do so at discounted prices, making the profit effects ambiguous. Government expansions do not always raise incentives for innovation, as evidenced by the European single payer markets.

These arguments do not consider interactions between public pricing and the private market. For example, fee schedules in the public sector may be adopted in the private sector, or if there are cross-subsidies, private prices may rise when public prices fall. The total effect of public pricing when there are also private market effects is given by:

$$\frac{d\Pi}{dp_S} = F\frac{d\pi_G}{dp_S} + (1-F)\frac{d\pi}{dp_S}$$

$$\frac{d\Pi}{dp_D} = F\frac{d\pi_G}{dp_D} + (1-F)\frac{d\pi}{dp_D}$$

If utilization or markups respond in different ways in the two sectors, the effects of changes in public pricing may differ. A rise in public profits from increased public reimbursement may potentially be offset by reductions in private profits, for example if cross-subsidies fall more. Likewise, the fall in public profits from higher copays may potentially be offset by higher private profits if, say, program participants go outside the public program as a result.

3 Risk-Adjustment of Innovative Returns

The previous discussion focused on how reforms affected the cash-flow or expected earnings from innovation. This section discusses the implications of non-diversifiable systematic risk on the risk-adjustment of those expected cash flows. We consider a standard stochastic discount factor (SDF) framework for valuing innovative returns under uncertainty (see, e.g., Cochrane (2002)). In this framework, there is a discount factor that varies across future states of nature to discount the payoffs in each of those states. We consider when future uncertainty comes from both the private sector, in terms of the business cycle, or the public sector, in terms of political risk concerning the government policy that will prevail. For example, such policy uncertainty may be argued to be present currently both in the US, due to the implementation of the ACA, and in Europe, due to the fiscal pressures of many countries.

Consider first the general valuation problem when a given random vector X affects profits according to $\Pi(x)$ as well as the SDF $M(x)$ by which future claims in a given state x are valued. The value of the firm in the first period equals future profits in each state discounted by the SDF:

$$E[M\Pi] = \frac{E[\Pi]}{1+r} + Cov(M, \Pi)$$

Here we have used that a certain payment of one dollar in each state has value $E[M] = 1/(1+r)$ with r denoting the risk-free interest rate. The value of the firm is made up of expected cash flows or earnings (the first term) that are risk-adjusted by how much the flows covary with future discounting (the second term). Downward risk-adjustment of expected earnings occurs when the profits of medical innovation pays off more in "good" times , which are discounted more than "bad" times: $Cov(M, \Pi) < 0$. Generally, a health care reform thus affects the present value of profits from medical innovation through both components:

$$\frac{dE[M\Pi]}{dg} = \frac{dE[\Pi/(1+r)]}{dg} + \frac{dCov(M, \Pi)}{dg}$$

The first is due to the expected cash flow effects of reforms, such as those discussed in the previous section. The second term is due to the effects reforms have on the risk-adjustment of earnings which we address in more in detail here.

3.1 Risk-Adjustment under Private Sector Risk

Consider first when the uncertainty stems from private sector risk. In particular, we want to assess how reforms affect the value of innovative returns when the aggregate private sector risk is the state of the economy or business cycle. We represent this as the mean income e in the income distribution $F(y;e)$ which is thereby increasing in y but assumed decreasing in e as a larger mean income means a lower share of the population has income below a certain level.

Under a given level of eligibility z the size of the eligible population is then $F(z;e)$ and the profits for a given state of the economy are:

$$\Pi(e) = F(z;e)\pi_G(e) + (1 - F(z;e))\pi(e)$$

where $\pi_G(e) \equiv E[\pi_G(y)|y \leq z;e]$ and $\pi(e) \equiv E[\pi(y)|y > z;e]$ are the average per-capita profits in the two sectors given a state of the economy. We assume that countercyclical earnings are desirable so that the SDF $M(e)$ is decreasing in the state of the economy. This implies that when profits $\Pi(e)$ increase (decrease) with the state of the economy, downward (upward) risk-adjustment of earnings occurs.

Figure 3 below depicts how recessions and booms affect such risk-adjustment. It depicts the per-capita profits in the two sectors as a function of income as discussed in previous sections. Without a public program the profits vary according to the average along the private profit line, $\pi(y)$. The slope of the private profit line is higher than the slope of the public one so that overall profits covary to the maximum degree with the cycle, which implies the largest amount of risk-adjustment.

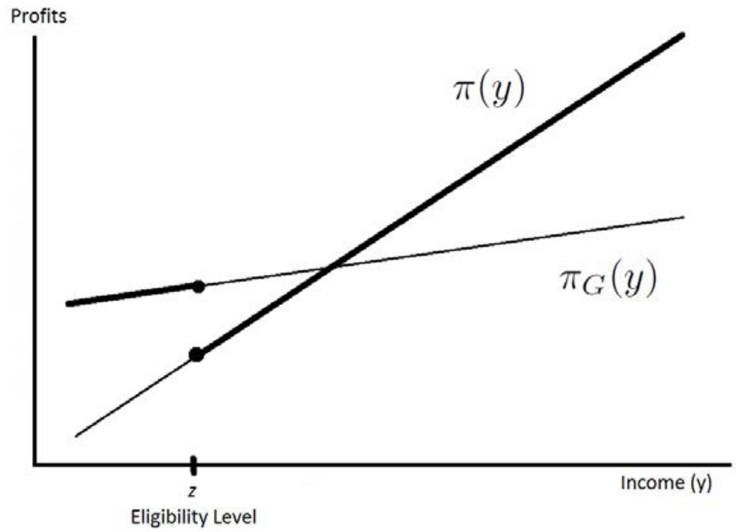

Figure 3: Means-Testing and the Business Cycle

Now consider how a means-tested public program affects the risk-adjustment of earnings. For a means-tested program, the size of the eligible population covaries negatively with the economy, as recessions raise the eligible population; $F(z;e)$ falls in e.[2] For example, the Medicaid program has counter-cyclical participation, as opposed to say the Medicare program where eligibility is by age, and thus does not depend on the cycle. In Figure 3, the overall profits are now made up from both sectors. The darker part of the public profit line are for those eligible for the program ($y < z$) and the darker parts of the private profits are for those not eligible ($y > z$). Thus, the overall profits are a mix of the two darker lines dependent on the income distribution. When a recession hits there are two effects. People who were on the private profit line jump up to the public profit line providing a counter-cyclical boost to profits because some poor become eligible in recessions. This effect is counteracted by the fact that profits fall for those not changing eligibility with the cycle.

More precisely, business cycle risk can be broken down into two components: one due to eligibility risk and one due to risk in per-capita profits as in:

$$\frac{d\Pi}{de} = \frac{dF}{de}[\pi_G - \pi] + F\frac{d\pi_G}{de} + (1-F)\frac{d\pi}{de}$$

The first term shows that booms contract eligibility and the two remaining terms show that booms affect per-capita profits. The cyclicality of per-capita profits is weighted by their relative sizes so naturally if an innovation's demand is financed more by Medicaid, public

[2]For recent empirical work that implicitly relates to this risk, see Cawley et al. (2011) who found a limited effect of the recent "great recession" on overall insurance. Private coverage dropped at the same time Medicaid coverage expanded in this recession.

sector per-capita risk matters more.

There are several factors which determine this overall profit effect of the cycle. First, the location of the innovation's demand in the income distribution matters; means-testing buffers the demand for products with patients near eligibility, e.g. HIV patients financed by Medicaid, more than it does for product with relatively richer patients. Second, the income elasticity in both sectors is central, whether conditional on coverage or due to changes in employment-based coverage when the cycle covaries with employment. Some forms of care are more sensitive to the cycle such as preventive and elective care compared with curative or emergency care. Third, recessions may induce governments to restrict reimbursement and copays, which may dampen the counter-cyclicality due to eligibility expansions. For many European countries with single payer systems this is taking place currently and the cyclicality of markups is more important than no changes in universal eligibility. Lastly, under the maintained assumption that per-capita profits in the public sector are less sensitive to income than those in the private sector, reflected in the lower slope in the figure above, a larger public market share of the product means less of a downward risk-adjustment.

Pricing reforms, in terms of changes in supply or demand prices (p_S, p_D), also affect the impact of the business cycle. Because profits are monotonic in the two prices, changes in either of them shift the public sector line up or down. This may increase or decrease the sensitivity of profits to the cycle dependent on the price change considered. For example, more generous reimbursement lifts the public sector profit line upwards, thereby providing less sensitivity to the cycle and lower risk-adjustment partly because the boost of eligibility in recessions raises profits more.

3.2 Risk-Adjustment under Public Sector Risk

When the policy itself is uncertain it may be represented by a random variable X with distribution $K(x; g)$ where the previous vector of policies g we now interpret as a set of parameters of this distribution. Reforms under policy uncertainty affect the distribution of policy outcomes, with the special case of the previous analysis of certain policies concerning the degenerate case with no variability; $K = 1_{\{g\}}$.

Consider when there is uncertainty about future public per-capita profits $\pi_G(x)$ and reforms affect the distribution of these profits. For example, this may be the case when there is uncertainty about future reimbursement rates, copays, or any other regulations that affect per-capita profits in the public program. Under public sector risk, the value of profits is:

$$E[M\Pi] = \frac{E[\Pi]}{1+r} + Cov(M, \Pi) = \frac{FE[\pi_G] + (1-F)\pi}{1+r} + FCov(\pi_G, M)$$

This equation has the direct implication that risk-adjustment of returns is proportional to the public program's share of demand for the innovation. A larger public share means a larger exposure to systematic government risk. For example, firms whose products have larger market shares in Medicare and Medicaid would be risk-adjusted more as they are more exposed to, say, reimbursement shocks.

Generally, new policy activity will introduce both changes in the expected mean level of the policy, but also potentially raise the variance or covariance of the policy due to the new more uncertain nature of what policy will eventually prevail. Consider when uncertainty is represented by a normal distribution, $N(x; g)$ and the policy variable represented by the vector $g = (\mu, \sigma, v)$ of its mean, standard deviation, and covariance with the SDF M. Now reform initiatives may impact expected per-capita profits $E[\pi_G]$ through the mean, μ, and variance, σ, in a reinforcing or counter-acting manner. The effect of a change in the mean will depend on the first-derivative of $\pi_G(x)$ and the impact of the increase in risk will depend on the second derivative of $\pi_G(x)$.

Consider the impact of uncertain eligibility reforms as captured by the normal distribution $N(z; g)$ over future eligibility levels. Assume as discussed before that profits as a function of eligibility, $\Pi(z)$, are a bell-shaped function which is concave; the first derivate decreases by first being positive and then negative; $\Pi'' < 0$. If we ignore any covariance with stochastic discounting, the expected eligibility first raises and then lowers expected profits; $E[\Pi]$ first rises then falls with μ. However, the future eligibility risk always lowers expected profits; $E[\Pi]$ falls with σ. An example would be the recent Medicaid expansions under ACA; the mean effect likely raised expected profits but the uncertainty of ACA lowered expected profits and R&D investments. Generally, the risk-adjustment due to the uncertainty surrounding new eligibility reforms is likely to be negative.

Consider now the impact of uncertain future reimbursement reforms when the uncertain policy is the supply price $x = p_S$ with a distribution $N(p_S; g)$. Changes in its distribution through $g = (\mu, \sigma, v)$ represents changes in expected future reimbursement rates, the degrees of uncertainty over future reimbursement, and the covariance of reimbursement with stochastic discounting. In this case it follows that:

$$E[M\Pi] = \frac{F(\mu - c)m_G + (1 - F)\pi}{1 + r} + Fm_G v$$

As a result, reforms have the following effects on profits:

$$\frac{dE[M\Pi]}{d\mu} = \frac{Fm_G}{(1 + r)} \qquad \frac{dE[M\Pi]}{d\sigma} = 0 \qquad \frac{dE[M\Pi]}{dv} = Fm_G$$

The mean effect is as discussed in previous sections. Since reimbursements mark up each unit of utilization, an increase in the expected future reimbursement matters more for public programs with higher total utilization. Because of the linearity in the supply price, reimbursement risk *per se* does not affect expected profits in this formulation. However, a change in the covariance with discounting does raise risk-adjustment and does so again proportional to the total utilization in the public sector.

Related to the last effect, Koijen et al. (2012) documented a very large "medical innovation premium" of about 4-6% annually for publicly traded medical R&D firms in the US the last 3 decades.[3] If investors require a premium for holding the additional risk of the medical R&D sector, this reduces medical R&D investments, whose returns must at least cover this premium paid to investors. In the formulation above, such a medical innovation premium comes from the covariance term $Cov(M, \Pi) < 0$. Koijen et al. (2012) analyzed the implications of such a premium for the growth of the health care sector when the premium reflected markup uncertainty in the sense that supply prices were negatively correlated with discounting $v = Cov(p_S, M) < 0$.

4 Approval Reforms and the Duration and Default of Innovative Returns

Innovative returns of medical products are affected not only by cash flow and risk-adjustment of future profits but also by the approval process affecting the timing and non-payment of those profits. In financial valuation, approval reforms affect the "duration" (or value-weighted timing) of returns and the implicit "default" rates of R&D investments.

Let the increasing function $\Pi(q)$ denote the annual profits of the product given the quality of the product q. The product is approved and allowed to be marketed if its uncertain quality, distributed according to the pdf $w(q)$ and cdf $W(q)$, is above the approval hurdle h representing the lowest level of quality required for approval. For a given innovation with a patent life of l years, the time-zero present value is denoted $\Pi_0(g)$ at the start of the patent life. If development is regulated to last for τ years, this present value discounts the annual profits that results from passing the quality hurdle and marketing the products in the patent

[3] The risk-adjustment of returns $R \equiv \Pi/E[M\Pi]$ rather than prices comes from using $E[MR] = 1$. Applying this to the riskless asset, one obtains $E[MR - R_f] = 0$ where R_f is the risk-free interest factor. This in turn implies the risk-premium formulation $E[R] - R_f = -R_f Cov(M, R)$ which says when profits are high when the SDF is low (profits pay off in good times) larger excess returns are required.

window of $l - \tau$ years:

$$\Pi_0(g) \equiv E[\sum_{t=0}^{l-\tau} \beta^{\tau+t}\Pi(q)] = A(\tau)\Pi_{>h}(h)$$

Here, $g = (\tau, h)$ are the policies of interest, $\Pi_{>h}(h) \equiv \int_{q=h}^{\infty} \Pi(q)w(q)dq$ is the expected profits given the approval hurdle, $\beta \equiv 1/(1+r)$ is the discount factor given a discount rate r, and $A(\tau) = \sum_{t=0}^{l-\tau} \beta^{\tau+t}$ is the value of a dollar paid each year of the effective patent life. There are no profits in case of non-approval; $\Pi(q) = 0$ if $q < h$.

The two policy variables affect profits through a negative first derivative; profits clearly decrease both in the development time and the hurdle rate. An increase in the length of development has two reinforcing negative effects (i) it reduces the value by delaying the onset of profits by imposing larger discounting $\beta^{\tau+t}$, (ii) it reduces the value by shortening the effective patent life $l - \tau$. An increase in the hurdle clearly lowers the expected profits by eliminating potentially profitable quality levels.

Now consider the impact of government approval risk on innovative returns which is governed by the second derivative of Π_0. Regulatory uncertainty is captured when the two policy variables are random variables distributed by $V(\tau)$ and $V(h)$, which represent that innovators may be unsure about how long development takes as well as what is required for approval.[4] The regulatory uncertainty induces the expected profits:

$$E[\Pi_0] = \int_{\tau=0}^{\infty} \int_{h=0}^{\infty} A(\tau)\Pi_{>h}(h)dV(h)dV(\tau)$$

This specification of expected profits has some interesting implications about the impact of regulatory risk. The effect of increased risk, in the sense of second-order stochastic dominance, may actually *raise* expected profits when Π_0 is convex.

For risk in the development time, such convexity occurs when a gain in early profits dominates the loss in later profits, which is often the case with discounting. In other words, Π_0 is often a decreasing but convex function of the development time τ. This shape occurs because the annuity of profits under the patent window is decreasing but convex, $A_\tau < 0$ and $A_{\tau\tau} > 0$. Convexity occurs because the loss in the present value is larger when cutting earlier profits than when cutting later ones. Thus convexity of discounting implies that profits rise, rather than fall, in the risk of development times.

For the impact of approval or hurdle risk on profits, consider the marginal impact on

[4]Philipson et al. (2008) provide estimates of the changes in the distribution of development times by estimating the impact on survival functions of FDA delays (induced by the Prescription Drug User Fee Act (PDUFA)).

profits from raising the approval hurdle:

$$\frac{d\Pi_{>h}(h)}{dh} = -\Pi(h)w(h)$$

This equation says that the profits lost by marginally raising the hurdle are the profits at the level of the hurdle. As a result, the expected profits from passing the hurdle $\Pi_{>h}(h)$ are always decreasing in the hurdle. However, as the profits upon marketing $\Pi(q)$ rise in quality and the density $w(h)$ may be increasing or decreasing, the overall profits $\Pi_{>h}(h)$ may be convex or concave. Thus regulatory risk may raise or lower expected profits depending on where the hurdle is located relative to profits.

Another aspect of product development is that it may sometimes entail final profits that never occur, which is the analog of "default" in asset valuation. Put differently, nonapproval is the equivalent of the "R&D loan" to the company defaulting on the future stream of payments. Consequently, the standard effect of default probabilities on asset returns, in terms of raising discounting, applies to the default probabilities induced by nonapproval. The default probability is simply the probability of not clearing the approval hurdle $d = W(h)$. If there are multiple phases, the overall default probability will equal the total probability of not meeting the approval hurdle. For example, in the US, the sampling of the 3 phases of development yield the overall default probability $d_1 + (1 - d_1)d_2 + (1 - d_1)(1 - d_2)d_3$. The expected profits at time zero under defaults are:

$$(1 - d_1)(1 - d_2)(1 - d_3)E[\Pi_0 | q \geq h]$$

This formulation is equivalent to discounting the profits further by the additional discount factor given by the overall probability of not defaulting; according to estimates of DiMasi (2001), the cumulative nondefault probability $(1-d_1)(1-d_2)(1-d_3)$ for new drugs filled from 1990-1992 is 17.2%. The default probabilities are related to both scientific risk (through the uncertain quality q) and regulatory risks (through the uncertain hurdle h). The further back in development, the more sensitive the overall profits are to future default probabilities and the less sensitive they are to changes in variable profits post marketing. This result explains why venture capital investors that provide early rounds of funding are more concerned with approval risk than reimbursement risk, unlike investors in later rounds of funding, such as private- or public-equity investors. However, the two forms of risk, scientific and regulatory, may affect risk-adjustment of returns differently. Scientific risk is likely to be diversifiable and not correlated with the SDF. Regulatory risk may be systematic, but it is an open question whether approval behavior by governments is correlated with the business cycle or other factors determining the SDF.

5 Innovative Returns and the Valuation of Public Liabilities

The impact of reforms on the present value of future liabilities may come from how they affect the level of spending today and from how they affect future growth rates of spending through medical innovation. Thus, level and growth effects may either reinforce or counteract their impact on the present value of public liabilities.

For any public program, total spending is the size of the eligible program population times the per-capita spending of its beneficiaries. In our framework, program size and per-capita spending are given by the fraction eligible and the eligible utilization and reimbursement:

$$S(g) = F p_S m_G \tag{3}$$

Consider when the growth factor in spending for a given year is an increasing function of profits, $\Gamma_t(\Pi(g))$, with the associated growth rate $\Gamma_t \equiv (1 + \gamma_t)$. This relationship between innovative returns and spending growth represents that a larger incentive to innovate implies a larger or smaller growth in spending in the future. The present value of public liabilities, V , is given by the discounted value of current spending and its future growth:

$$V = \sum_{t=0}^{\infty} \beta^t S(g) \Gamma_t(\Pi(g)) \equiv S(g) D(\Pi(g))$$

where $\beta = 1/(1+r)$ is the discount factor and D is the discounted value of spending growth given profitability. The central aspect of a relationship between profits, innovation, and future spending growth is captured in the function Γ. It follows that a reform affects the value of public liabilities according to:

$$\frac{dV}{dg} = \frac{dS}{dg} D + S(\frac{dD}{d\Pi})(\frac{d\Pi}{dg})$$

The liabilities are affected first by current spending (the first term) and second by how future spending growth responds to reforms (the second term). Future spending growth is a result of how the policy change affects innovative profits and how that change in profits affects future spending growth. The impact of policy changes on profits, $\frac{d\Pi}{dg}$, was discussed in previous sections whether through expected cash flows, their risk-adjustment, or their timing. These discussed policy effects may raise or lower future spending growth depending on the sign of $\frac{dD}{d\Pi}$. An example of when lower spending growth may occur is when innovation leads to lower real prices of health care and demand is inelastic so utilization does not offset the price decline. In most of our discussions, however, we will consider positive effects of profits on spending growth motivated by historical evidence relating medical innovation and spending growth.

When profits and public spending are affected differently from reforms, the spending and liability effects may differ. Consider the simplest case when there is constant spending growth and a reform changes the spending from S to S' and profits from Π' of Π. The ratio of the present values of liabilities after and before the reform is then

$$\frac{V'}{V} \equiv \frac{\sum_{t=0}^{\infty} S'[\frac{1+\gamma(\Pi'))}{1+r}]^t}{\sum_{t=0}^{\infty} S[\frac{1+\gamma(\Pi)}{1+r}]^t} = [\frac{S'}{S}][\frac{r-\gamma(\Pi)}{r-\gamma(\Pi')}]$$

Four effects determine the impact of the reform on this ratio. One is the effect on current spending. The second to fourth effects come from how reforms affect the present value of future growth in spending. These effects come from how a marginal change in growth affects the present value (the effect of a change in γ' given the level γ and discounting r), the effect of reforms on profits (g on Π), and the effects of profits on spending growth (Π on γ).

Consider a cut in the level of spending. If the cut has no effect on profits, then the present value falls proportionally with the cut so that the percentage change in the level of spending is the percentage cut in the liabilities, $\frac{V'}{V} = \frac{S'}{S}$. This relationship also occurs when discounting increases to infinity, when future effects become less important so that the present value of the growth difference $(r-\gamma)/(r-\gamma')$ goes to unity. With any effects of innovation on future growth, magnitudes are the same which means the signs are as well. Thus, spending reductions or expansions in the level of spending are associated with reductions or expansions in the value of future liabilities.

However, if the spending cut reduces innovation incentives and spending growth, then the negative level effect is reinforced by the lower growth, $\frac{V'}{V} < \frac{S'}{S} < 1$. If the cut raises profits and growth then the effects are offsetting; the initially smaller program may grow faster, which may be more than fully offsetting $\frac{V'}{V} > 1 > \frac{S\prime}{S}$. Therefore, the profit effects on growth may reinforce or counteract the level effects. If the level and growth effects counteract each other, liabilities may fall with a program expansion or rise with a program cutback. Moreover, because the change in the level of spending is front-loaded and growth effects are back-loaded, less discounting means the growth effects are more likely to offset spending effects.

Figure 4 shows two qualitative cases when reforms affect the present value of liabilities differently than they affect levels of spending. The dark line in the middle is the case of no reform. The gray line on the top is the scenario of a spending cut that raises R&D incentives. With a program cut, spending in the initial period decreases. However, the cut raises profits

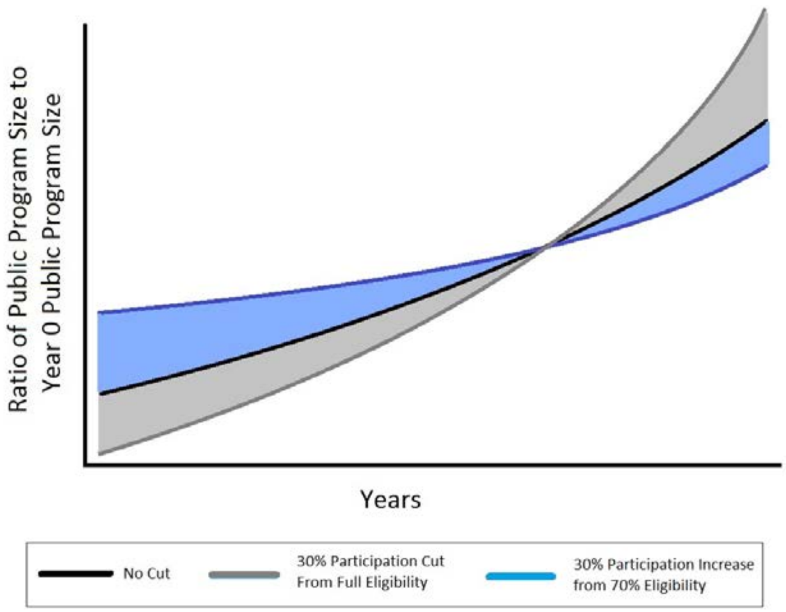

Figure 4: Level versus Growth Effect of Spending

if it is on the decreasing part of the bell-shaped profit curve. The program cut may cause the present value of liabilities to rise when discounting back all the years. The other case concerns when spending rises but growth falls as may be the case when going to a universal single-payer program. This occurs again when a program expansion is on the downward sloping part of the bell-shaped profit function. The present value of future liabilities may fall with the program expansion even though current spending rises.

In general, in order for offsets to occur, the percentage effect on spending S'/S must be offset by the percentage effect on growth $(r-\gamma)/(r-\gamma')$. However, note that the present value of the growth effect is decreasing in the discount rate, converging at unity as the discount rate increases and making the future growth differences less important. This implies that under mild discounting, the growth effects may have large effects. The extreme case is no discounting when the divergence in paths induced by changes in growth always dominates. More precisely, note that the present value of the growth differences is determined by the *relative* growth rate, which may be large for small changes in the *absolute* growth rate. For example, if the current spending of a program is cut 20%, then if growth rates go from 3% to 4%, this entails a relative difference of 33%, which may offset the spending cut under common discount rates.

5.1 Eligibility and Pricing Reforms

The discussion above can be applied to the eligibility and pricing returns previously discussed.

5.1.1 Liabilities and Eligibility Reforms

Consider the effect of changes in eligibility, z, when those changes affect future per-capita spending through innovation:

$$\frac{dV}{dz} = \frac{dS}{dz}D + S(\frac{dD}{d\Pi})(\frac{d\Pi}{dz})$$

Changing eligibility impacts the growth of public liabilities through the current level of public spending and the effect on profits that determine future spending growth:

$$\begin{aligned} \frac{d\Pi}{dz} &= f(z)(\pi_G - \pi) \\ \frac{dS}{dz} &= f(z)m_G p_S + F(z)m_G\frac{dp_s}{dz} \end{aligned}$$

Both profits and the level of spending may increase or decrease depending on the marginal income level where eligibility expansions occur. For profits, if eligibility is expanded marginally for the poor, then the profit effect may be positive but if eligibility is expanded for the rich, then profit may fall. For spending, increased eligibility can raise or reduce spending levels depending on whether the rise in beneficiaries is offset by the fall in the reimbursement from greater monopsony power. Public liabilities will rise (fall) with eligibility if both the spending and innovation effects increase (decrease) $\frac{dS}{dz}, \frac{d\Pi}{dz} > 0$ (< 0). However, public liabilities will fall with increased eligibility or rise with decreased eligibility if the two effects have different signs. When $\frac{dS}{dz}, \frac{d\Pi}{dz} < 0$, the reform may raise liabilities and expansions may reduce them.

5.1.2 Liabilities and Price Reforms

Consider the effect of changes in public reimbursement when those changes affect future per-capita spending through innovation:

$$\frac{dV}{dp_S} = \frac{dS}{dp_S}D + S(\frac{dD}{d\Pi})(\frac{d\Pi}{dp_S})$$

Figure 5 depicts iso-profit curves as a function of the two prices, $\{(p_D, p_S) : \Pi(p_D, p_S) = \pi\}$. The curves involve higher profit levels to the northwest in the figure as supply prices raise profits and demand prices lower them. The implementation of a program that lowers both demand and supply prices from point A to point B concerns a southwest shift in the figure and thus depends on whether the slope of the iso-profit curves will raise or lower profits. Determining if profits increase depends on whether the utilization gains dominate the markup reductions.

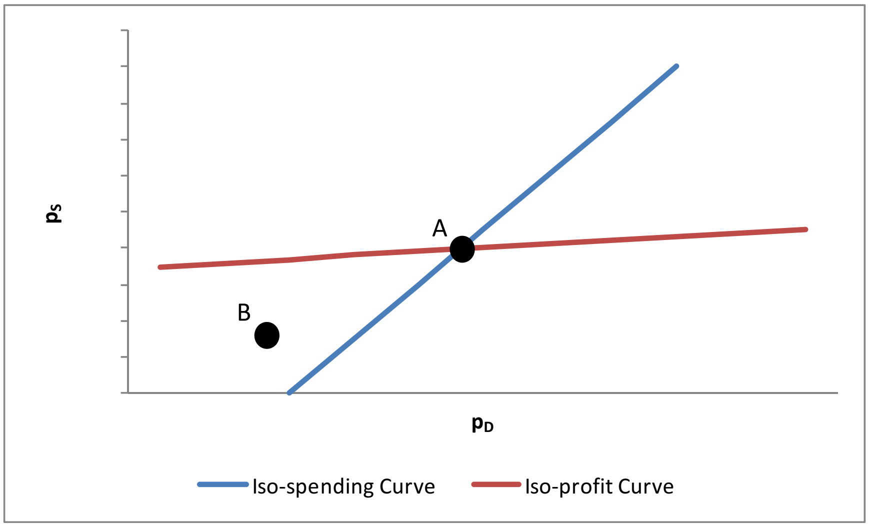

Figure 5: Levels vs Growth Effects for Price Reforms

The figure also depicts the iso-spending curves $\{(p_D, p_S) : S(p_D, p_S) = s\}$ of the public program. Changes in the levels of public program may be reinforced or offset by changes in growth in spending due to higher innovative returns depending on whether they have the same or different signs. Overall profits and public spending are related by the fact that the public profits come from public spending as in:

$$\Pi = F\pi_G + (1 - F)\pi = S[\frac{p_S - c}{p_S}] + (1 - F)\pi$$

Without any interactions between the private and public sector, the overall profit effects of price changes are likely to be the same sign as the public program effects. In other words, lower reimbursements lower both public spending and profits, and lower copays raises both public spending and profits. However, when a public program expansion lowers both demand and supply prices, it is possible that the total effect on growth versus levels may differ as indicated in Figure 4. This occurs when slopes of the iso-profit line and the iso-spending line differ substantially. When they do differ, there is always a reform with reductions in two prices that affects spending in the opposite direction of profits. When this is the case, level effects are counteracted by growth effects.

An important case when iso-profit and iso-spending slopes may differ is when there are interactions between private and public pricing. In this case, the level and growth effects on public pricing reforms may differ. Consider when the private price is $p(p_D, p_S, g)$ as a function of the public pricing. For example, fee schedules in the public sector may be adopted in the private sector or a direct government intervention with price controls in the private sector may take place in conjunction with public price changes. Now the total effect of prices on profits are given by:

$$\frac{d\Pi}{dp_S} = F\frac{d\pi_G}{dp_S} + (1-F)\frac{d\pi}{dp_S} = \frac{dS}{dp_S} + (1-F)[\frac{dp}{dp_S}][\frac{d\pi}{dp}]$$

$$\frac{d\Pi}{dp_D} = F\frac{d\pi_G}{dp_D} + (1-F)\frac{d\pi}{dp_D} = \frac{dS}{dp_D} + (1-F)[\frac{dp}{dp_D}][\frac{d\pi}{dp}]$$

Thus, the difference in the profit and spending effects $\frac{d\Pi}{dp} - \frac{dS}{dp}$ are attributable to spillovers in the private market. Because price effects on spending are ambiguous when demand slopes downward, when there are interactions between the private and public sector growth effects may offset level effects. Offsetting occurs when reimbursement increases in the public sector lowers profits in the private sector or when copay increases in the public sector raise profitability in the private sector. One set of interactions between the two sectors that may occur is through cross-subsidies where lower public prices raise private prices. Another interaction is through competitive effects on providers when a higher public price raises private prices in order to compete for patients. Regardless of the sign and the magnitude of the interactions, they drive a wedge between spending and profit effects and thus between levels and growth effects.

5.2 Reforms of National Programs and World Returns

Innovation incentives are determined by world returns. The larger the share of world returns a reformed program affects the larger the innovation incentive that reform produces. Put differently, reforms in a small or poor country will not affect innovative returns much compared to changing the US Medicare program. Likewise, the US states serving as "laboratories" for national US reforms will not be highly informative about one of the central impacts of those reforms: how they affect spending growth induced by innovation.[5]

Consider when N_1 denotes the potential size of the population under the reformed program and N_0 and Π_0 denote the size and per-capita profits of the world population outside the program. The aggregate world profits Π_w are given by:

$$\Pi_w \equiv N_0\Pi_0 + N_1\Pi = N_0\Pi_0 + N_1[F\pi_G + (1-F)\pi]$$

The population outside the program may be inside the country of the program being re-

[5]Consistent with this argument; Kowalski and Kolstad (2012) find no growth effects of the reforms in the state of Massachusetts, while the similar reforms embedded in the national ACA will clearly have large effects on innovation incentives.

formed. For example, for Medicare reforms the nonprogram population would include both the nonelderly within the US and all populations outside the US. Naturally, the effect of any reform on the absolute and relative world profits falls the less significant the program demand is relative to world demand:

$$\frac{d\Pi_w}{dg}/\Pi_w \equiv \frac{N_1 \frac{d\Pi}{dg}}{N_0\Pi_0 + N_1\Pi}$$

This equation implies that the future R&D effects of reforms must be evaluated in how they interact with any simultaneous other changes in world innovative returns. For example, innovative returns may rise over time even if Medicare is reformed to reduce its per-capita profits because of the growth in emerging markets. Put differently, world markups may be declining in developed markets at a slower pace than world quantity is rising in emerging markets. Just as policies of a small single European country today do not affect world profits and innovation much, the US may affect innovation less over time even though it dominates world profits today. If the flow of new innovations gets marketed irrespective of US reforms because of the market size expansion of emerging economies, this alters optimal US policy.

In addition, domestic versus world returns to innovation have a bearing on attributing national spending growth to reforms or other factors. One such factor is aging, which existing growth accounting has argued does not substantially contribute to total spending growth (see Newhouse (1992) and Zweifel et al. (1999)). Indeed, the US population is younger than other countries but spends more on health care. This analysis has been an accounting exercise tracing out how domestic aging patterns and age profiles contribute to overall domestic spending growth. However, innovation and growth in domestic per-capita spending is driven by world aging as opposed to a given country's domestic aging. More precisely, if the two groups represent two countries with growth factors A_0 and A_1 induced by aging, then the sizes of the populations are $N_0 A_0^t$ and $N_1 A_1^t$ after t years. Now consider a growth factor of domestic spending $\Gamma(\Pi(A_0, A_1))$ as a function of world aging. The value of public liabilities for the first country is then:

$$V_1 = \sum \beta^t S N_1 A_1^t \Gamma[\Pi(A_0, A_1)]^t = S N_1 \left[\frac{1}{1 - \beta A_1 \Gamma(\Pi(A_0, A_1))]}\right]$$

This equation implies that aging has a dual effect on domestic liabilities; domestic aging (A_1) affects the people on the domestic program but world aging (A_0 and A_1) affects its per capita growth rate in spending through innovation. This makes domestic aging assessments misleading; a country may have no aging ($A_1 = 1$) but be greatly affected by world aging through medical innovation ($A_0 > 1$) as would be the case for some European countries. To illustrate this point, consider the US Medicare program, which according to the Centers for Medicare & Medicaid Services has doubled in its beneficiaries since 1980 but risen about 12 times in aggregate spending. According to domestic growth accounting, this suggests that per-capita spending growth rather than aging is far more important to aggregate Medicare spending growth. However, according to the World Health Organization, the world's elderly population doubled during the same period, raising innovative returns in absolute terms dramatically. It therefore seems an open question whether market size expansions through world aging may play a larger role in explaining domestic spending growth than currently estimated. To illustrate, evidence by Acemoglu and Linn (2004) suggests that a doubling in Medicare aging alone would be associated with a 400-600% growth in medical innovation, which could explain part or all of the growth in per-capita spending of the program.

6 Calibration for the Case of Means-Testing Medicare

In this section, we calibrate the impact of means-testing Medicare on innovation incentives and public liabilities. Our main finding is that under observed parameter values means-testing Medicare substantially raises profitability and may raise the value of Medicare liabilities under modest assumptions on how innovative returns affect future spending growth.

6.1 Calibration of Program Effects

Our calibration maps out profits and the value of future liabilities as a function of unobserved income eligibility thresholds z. These thresholds are measured in relation to the federal poverty level and corresponding to the income deciles for individuals 65 and older. Denote by $I(y)$ the counterfactual fraction of individuals with income y who are enrolled in private insurance when ineligible for the public Medicare program. For a given level of eligibility z, this induces the fraction insured $I^E(z)$ for the relatively poorer eligible population and $I^N(z)$ for the relatively richer noneligible population:

$$
\begin{aligned}
I^E(z) &= \int_0^z I(y)f(y)dy \\
I^N(z) &= \int_z^\infty I(y)f(y)dy
\end{aligned}
$$

The aggregate profits for a given level of eligibility $\Pi(z)$ are determined by the per-capita profits in the three sectors of publicly insured, privately insured, and uninsured, denoted by π_G, π_I, and π_U. The per-capita profits are weighted by the fraction of the population in each sector denoted $R_G(z)$, $R_I(z)$, and $R_U(z)$:

$$\Pi(z) = R_G(z)\pi_G + R_I(z)\pi_I + R_U(z)\pi_U \tag{4}$$

Means-testing the program divides the population into eligible and noneligible shares of the elderly, $F(z)$ and $1 - F(z)$.[6] The public participation rate differs from the eligibility rate because individuals who are eligible for public coverage may remain privately insured or uninsured. More precisely, the public participation rate is:

$$R_G(z) = I^E(z)r_I(z) + (F(z) - I^N(z))r_U(z) \tag{5}$$

where r_I and r_U are the public enrollment rates of those privately insured and uninsured in the absence of the public program. The private insurance enrollment rate is the fraction of individuals with private insurance in the absence of the public program who enroll in public insurance when eligible (known as "crowd out"). The uninsured enrollment rate is the fraction of uninsured individuals in the absence of the public program who enroll in public insurance when eligible (known as "take-up").

The private insurance rate comes from individuals who are eligible for public insurance but chose private insurance together with individuals who are not eligible for public insurance and chose private insurance:

$$R_I(z) = I^E(z)(1 - r_I(z)) + I^N(z) \tag{6}$$

The uninsurance rate is similarly composed of publicly eligible uninsured individuals and noneligible uninsured individuals:

$$R_U(z) = (F(z) - I^E(z))(1 - r_U(z)) + [1 - F(z) - I^N(z)] \tag{7}$$

It follows that $R_G(z) + R_I(z) + R_U(z) = 1$, as the three categories are mutually exclusive.

The average per-capita profit levels are defined by markups times utilization:

$$\begin{aligned} \pi_G(z) &= [p_{SG}(z) - c]m_G(p_{DG}) \\ \pi_I &= [p_{SI} - c]m_I(p_{DI}) \\ \pi_U &= [p_{SU} - c]m_U(p_{DU}) \end{aligned}$$

where $p_{SG}(z)$, p_{SI}, and p_{SU} are the supply prices and p_{DG}, p_{DI}, and p_{DU} are the demand

[6] We define elderly to be individuals 65 and older and nonelderly as under 65

prices in the government, private, and uninsured sector, respectively. We assume $p_{SG}(z) < p_{SI} = p_{SU}$ capturing that the government has monopsony power and pays a lower supply price and $p_{DU} > p_{DI} = p_{DG}$ capturing that the uninsured have higher copays. The quantities m_G, m_I, and m_U are the medical care utilization consumed by publicly insured, privately insured, and uninsured and are a function of the demand price.

6.1.1 Calibrating Profits and Spending as Function of Program Size

To calibrate the profits as a function of eligibility, we need participation rates, supply prices, and quantities by income deciles. Table 2 on page 39 lists our estimates of these. We consider the profits for a given program size z relative to the profits without a public program ($z = 0$) as in:

$$\frac{\Pi(z)}{\Pi(0)} = \frac{\frac{\Pi(z)}{\pi_I}}{\frac{\Pi(0)}{\pi_I}} = \frac{R_G(z)\left(\frac{p_{SG}(z)-c}{p_{SI}-c}\right) + R_I(z) + R_U(z)\left(\frac{m_U}{m_I}\right)}{R_I(0) + R_U(0)\left(\frac{m_U}{m_I}\right)} \tag{8}$$

By dividing by the insured per-capita profits to calibrate relative profits we need information on the participation rates in the three sectors, the percentage drop in reimbursement in the public sector, $\frac{p_{SG}-c}{p_{SI}-c}$, and the percentage drop in utilization when uninsured, $\frac{m_U}{m_I}$.

6.1.2 Calibrating Participation Rates as a Function of Program Size

In our Medicare calibration for the elderly, we assume there is no age interaction for the income profiles of participation. Therefore, the participation rates, R_G, R_I, and R_U, are the same for the elderly and the nonelderly, other things constant. This assumption allows us to use participation estimates for both the elderly, who have 100% eligibility in Medicare, and the nonelderly, who have 30% eligibility in Medicaid.[7]

To calibrate participation rates (R) as a function of program size as measured by income decile, we calibrate those participation rates within income decile. For the elderly, the March 2011 CPS supplement shows a participation rate of 93%, a private insurance rate of 5%, and an uninsured rate of 2%.[8] In our framework, this corresponds to $R_G(100) = 0.93$, $R_I(100) = 0.05$, and $R_U(100) = 0.02$. For the nonelderly, 30 percent are eligible for Medicaid and the March 2011 CPS supplement shows $R_G(30) = 0.12$, $R_I(30) = 0.66$, and $R_U(30) = 0.22$. For counterfactual eligibility levels z outside of 30% and 100%, we need to calibrate these participation rates, and Appendix 1 describes the methodology of doing this.

Figure 6 shows the participation rates by income decile using this methodology. The

[7]Medicaid eligibility varies by state, but over a third of the individuals in the third income decile have some Medicaid coverage.

[8]We do not count individuals above the third income decile with public coverage.

observed eligibility rates, 30% for the nonelderly and 100% for the elderly, are shown in darker colors in this figure. There is no public participation when there is no program, and public participation rises to 93% with full eligibility as is the case for the current Medicare population.

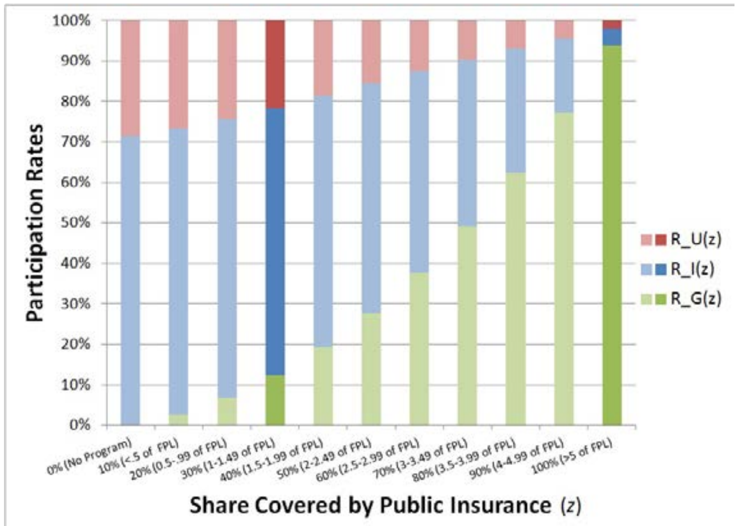

Figure 6: Participation as a function of eligibility

6.1.3 Calibrating Reimbursement as a Function of Program Size

To calibrate the relative markup $\frac{p_{SG}(z)-c}{p_{SI}-c}$, we assume that relative markups are approximated by relative prices, $\frac{p_{SG}(z)-c}{p_{SI}-c} \approx \frac{p_{SG}(z)}{p_{SI}}$ which is more accurate the larger innovative markups are. For example, many drugs markups are almost equal to prices if pills cost pennies to produce. To calibrate the drop in price in the public sector, $\frac{p_{SG}(z)}{p_{SI}}$, we estimate the effect of public program size on reimbursement rates using the expansion of Medicaid enrollment from 1995-2003. Specifically, the regression in Table 1 estimates the impact of the percent change in Medicaid enrollment on the percentage change in total Medicaid rebate as a percentage of the average manufacturer price. We use Medicaid rebate data from the CBO (2005) and Medicaid enrollment data from Bruen and Ghosh (2004).

Table 1: Estimation results : Percent Change in Total Medicaid Rebate

Variable	**Coefficient**	**(Std. Err.)**
Percent Change in Enrollment	0.267	(0.231)
Intercept	-0.001	(0.013)

Notes: Estimate for 1995-2003. Total Medicaid rebate as a percentage of average manufacturer price, source: Congressional Budget Office. Enrollment in percent change, source: Bruen and Ghosh (2004)

According to the CBO (2005), the Medicaid rebate is approximately 30%, so we calibrate the relative supply price markup to 0.7 at Medicaid's 30% eligibility level and calibrate the markup for the other eligibility levels with the elasticity estimated in Table 1.

6.1.4 Calibrating Utilization as a Function of Program Size

Estimates of the relative utilization of the uninsured, $\frac{m_U}{m_I}$, vary by how utilization is measured. Spillman (1992) found that inpatient hospital utilization for the uninsured relative to the insured was 12% for men and 20% for women adjusting for standard explanatory variables. Hahn (1994) found that the uninsured use 43% of the proactive and preventative visits of the privately insured.

We calibrate the relative utilization of the uninsured using an elasticity of coinsurance rate on medical expenditures. This elasticity has been estimated numerous times in the literature and estimates center around an elasticity of -0.17 (Ringel et al., 2002). According to the MEPS Insurance Component, the average coinsurance rate for the privately insured is 18.5% which means that the uninsured pay 440% higher demand prices relative to the uninsured coinsurance rate of 100%. At an elasticity of -0.17, a 440% price change means that the relative uninsured utilization rate is 0.25. This estimate seems reasonable given the other measures of relative utilization in the literature.

6.2 The Impact of Program Size on Medical R&D and Public Liabilities

With our calibrated parameters, we can calibrate the impact on innovation incentives and the effect of means-testing on public liabilities.

6.2.1 Impact on Medical R&D Returns

Figure 7 shows that the calibrated profits follow the bell shape discussed. Table 3 on page 40 contains the associated numbers of the graph. As the lowest income decile becomes eligible, profits rise above levels without any program. As eligibility continues to increase, profits rise and then fall and eventually dip below the level without any public program.

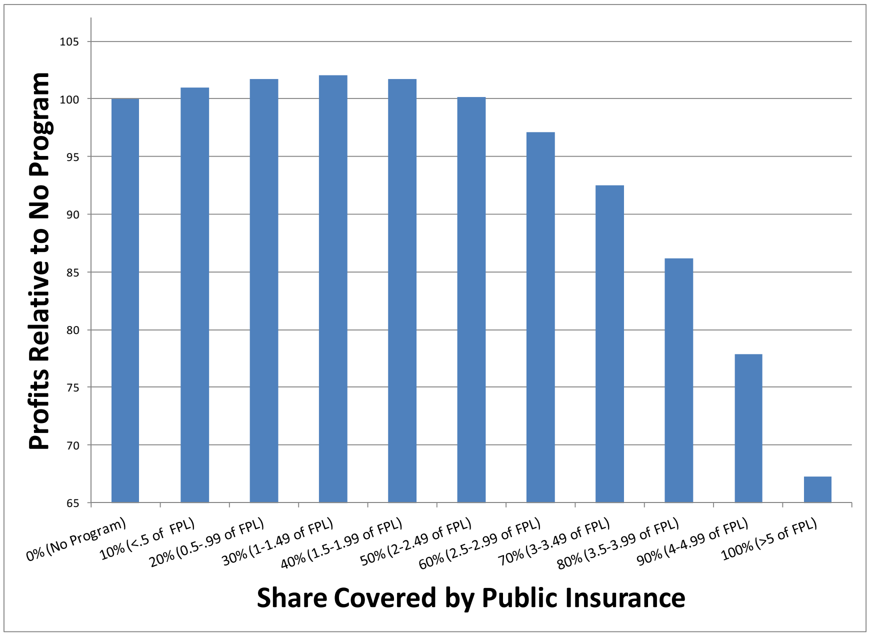

Figure 7: Medicare Profits as a Function of Share Covered

The associated effect on public spending is shown in the figure below. When eligibility increases, it is possible for levels of spending to fall if expansions lower reimbursements more than they raise utilization. In our calibration, however, the decline in supply prices is not steep enough so public spending always increases with a larger public program.

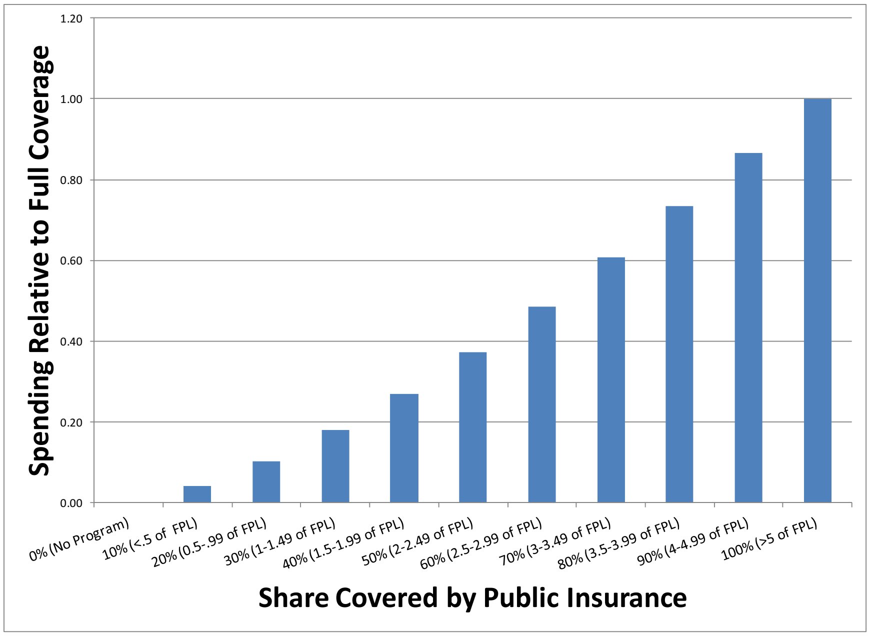

Figure 8: Public Spending as a function of eligibility

Table 3 shows five reductions in eligibility and the associated changes in profits and spending. A reduction in eligibility has three effects on profits, $-\frac{d\Pi(z)}{dz}$. First, the reduction increases the public supply price, which has a positive effect on aggregate profits holding utilization constant. Second, some individuals switch from public coverage to private insurance, which increases profits. Third, some individuals switch from public coverage to being uninsured, which decreases profits.

6.2.2 The Impact of Program Size on Future Liabilities

To calibrate the effect that means-testing Medicare has on Medicare liabilities, we first need the calibrated effect on profitability, $d\Pi/dz$, and then the effect of profitability on future spending growth, $d\gamma/d\Pi$. We are interested in what we refer to as the "profit-to-growth effect" (PGE). More precisely, the PGE is the effect on the absolute percent of growth for a given percentage change in profits. For example, if profits increase by 10% and the PGE is 0.05, then the absolute percentage of spending growth increases by 0.5 percentage points, say from 6% percent to 6.5%.

Cutting the program through means-testing decreases current program spending but raises the growth rate of the program. The key relationship concerns the one between the world profit increase and future spending growth. Figure 9 maps out different liability effects as a function of PGE. For example, for an PGE of 0.1, the program liabilities increase 12% for a 30% cut. As a result, even with a small PGE, the present value of spending increases significantly.

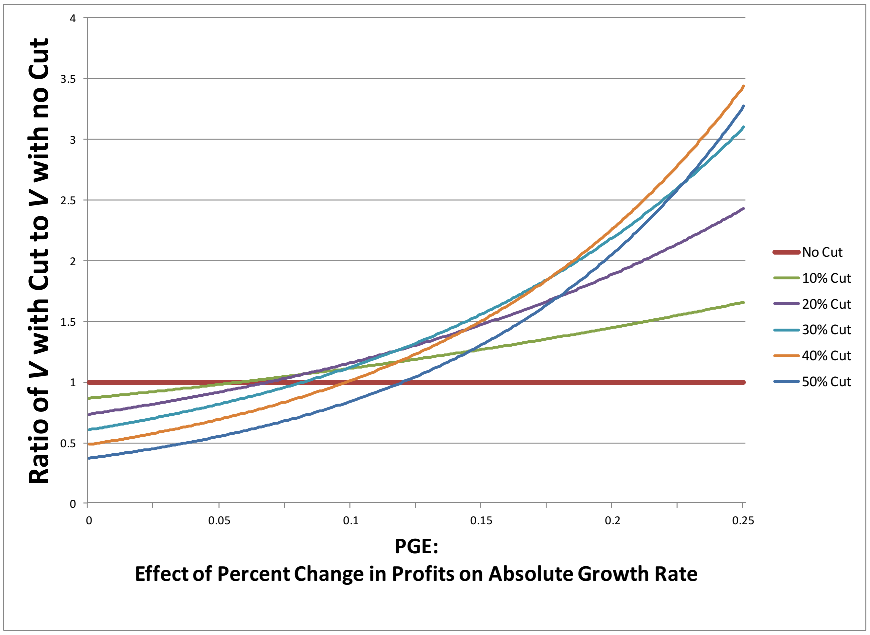

Figure 9: Liability Effects as a function of the PGE

Note: V is present discounted value of spending over 30 years

To illustrate these magnitudes, consider the following hypothetical calculation. Suppose we cut Medicare for the top 20% of the income distribution. If they have 30% higher prices in the private sector, that means overall profits increase 6% with constant utilization. A 6% increase in profits raises the spending growth rate by about 1 percentage point if the PGE is 0.16. A 1 percentage point increase in growth rate affects the present value of future growth by 15% over 25 years when the discount rate is 3% and initial growth is 6%. Thus, the 20% spending reduction is offset by a 15% rise in the present value of increased growth.

These calibrations highlight that although a cut in Medicare eligibility may have small negative effects on spending initially, it has a large effect on the innovative returns that drive future spending growth. A cut in a government program, even with conservative estimates for the PGE, may raise government liabilities substantially. We are not aware of any reliable estimates of the impact of profitability on spending growth. Therefore, we report the smallest PGE for which means-testing actually raises liabilities- in other words, the smallest effect $d\gamma/d\Pi$ for which means-testing does not affect liabilities, $V' = V$.[9]

Figure 10 depicts the lowest PGE level consistent with no change in liabilities as a function

[9]To exemplify the threshold effect, consider when growth is proportional to profits $\gamma = \theta\Pi$. In this case $\theta(= d\gamma/d\Pi)$ satisfies:

$$\frac{V'}{V} = \left(\frac{S'}{S}\right)\left[\frac{r - \theta\Pi}{r - \theta\Pi'}\right] = 1 \Rightarrow \theta = \frac{r(\frac{S'}{s} - 1)}{\Pi\frac{S'}{s} - \Pi'}$$

because when the future growth is discounted more, more of it is required to offset current spending effects.

of common values of the discount rate used for medical spending for a finite horizon of 30 years. For example, if the growth rate without reforms is 6% ($\gamma = 0.06$) and the discount rate is 8% ($r = 0.08$) then the figure tells us that for an PGE of 0.103 the present value of public liabilities, V, is the same for a 30% cut in the program and no cut in the program. For PGE greater than 0.103, V is greater with a 30% cut than with no cut; for PGE less than 0.103, V is greater with no cut than with a 30% cut. The larger the cut in the program, the larger the PGE required to equate V.

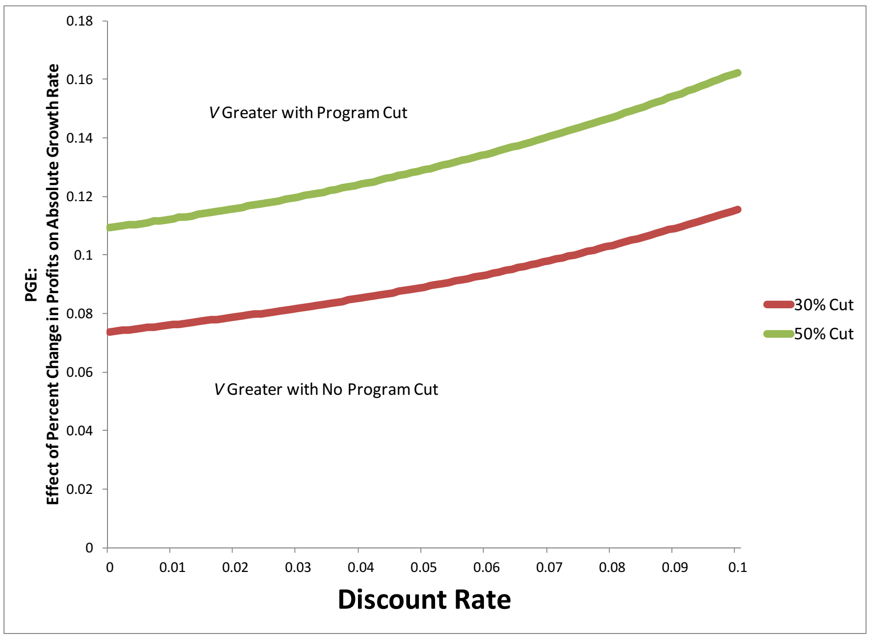

Figure 10: PGE that Equates V for Cut and No Cut

Note: V is present discounted value of spending over 30 years

There exists some evidence on the degree to which innovative returns drive the future spending growth that underlies the PGE calculations. Acemoglu and Linn (2004) estimated an elasticity of about 4 for the effects of revenue on new product innovations; a 10% increase in revenues was associated with a 40% increase in new molecular entities introduced.[10] These effects are magnitudes larger than the PGEs we discuss.

As we discussed, the relative size of the Medicare program in world returns is important for assessing how means-testing Medicare affects innovation. The program only covers about 12% of the US population, and hence about half a percent of the world's population. However, as is well known, the US dominates world health care consumption and the US elderly represent a large share of overall US health care consumption for many products and

[10]These elasticities translate directly into profit elasticities when profits are proportional to revenues. For example, under constant marginal costs and constant elasticity of demand, prices are marked up over costs according to $p = ac$ so that profits are proportional to revenues $\pi = m(p - c) = (1 - \frac{1}{a})mp$

diseases. Furthermore, the share of the world prevalence of a given disease in the Medicare program may differ, as for example between low levels for HIV or pediatric diseases and high levels for Alzheimer's. Figure 11 modifies the calibration for different assumed rates of the share of world profits coming from Medicare. For example, this share would be zero for a nonelderly non-US disease and close to 100 percent for an exclusively US elderly disease. The x-axis measures the fraction of world returns coming from Medicare. The y-axis measures the impact on world profits. The separate lines concern different levels of means-testing.

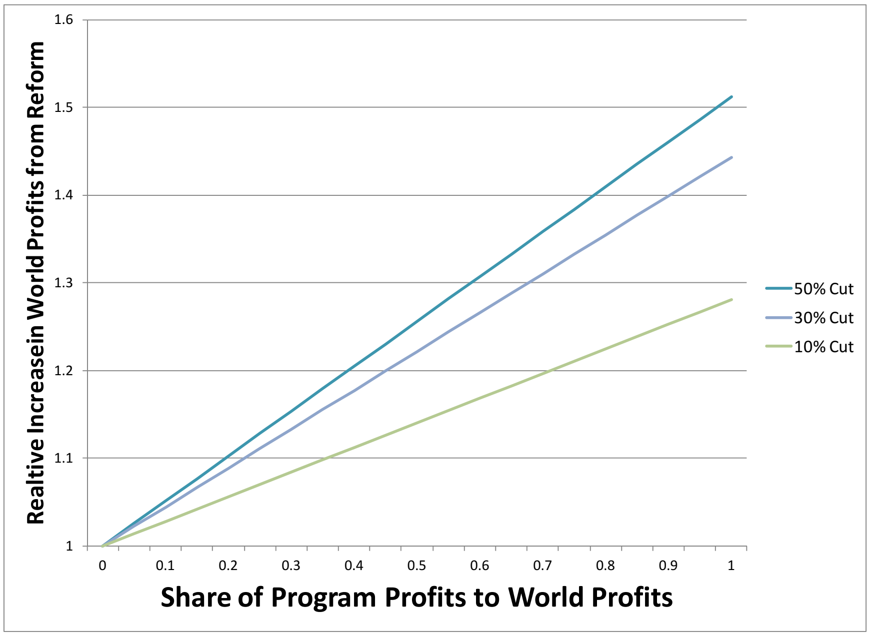

Figure 11: Share of Program Profits to World Profits

Naturally, the more important the program is to world innovative returns, the larger is the overall profit effect and hence the growth effect on innovation. In the extreme case of a US elderly disease, all profits come from Medicare and the right tail effects apply. In the other extreme case when the disease is for the nonelderly or outside the US, the left tail effects apply. For example, a 20% cut in the Medicare program for a technology for which a 25% share of the world profits initially came from Medicare would increase world profits by roughly 10%. These profit effects appear fairly substantial even for modest means-testing.

7 Concluding Remarks and Future Research

Focusing on the return to medical innovation as the major determinant of spending growth, we analyzed the effects of health care reforms on public liabilities. We derived how reforms affected medical R&D returns in terms of cash flows, the risk-adjustment of those returns, their duration as well as the default through the approval process. We argued that government expansions and price regulations have non-monotonic effects on R&D, that means-testing greatly affected risk-adjustment of returns, and that approval risk may raise innovative returns. The analysis implied that cutbacks in government programs may raise the value of government liabilities and that expansions may lower them. We assessed the implications of these arguments for means-testing Medicare and found that modest effects of profits on future spending growth may induce such cuts to raise Medicare liabilities.

It is important to stress that our analysis does not take a normative position on whether higher or lower spending and public liabilities are desirable, but rather only assesses the positive impacts of common reforms on them. It is also noteworthy that most of our analysis, although not our general formulation, assumed that higher overall profits would result in larger spending growth. This may not be the case if cost pressures pushed larger profits to be obtainable only for cost- and spending-reducing innovations. For example, under certain forms of government programs, such as defined contributions plans, larger profits may be obtained only by lowering spending. More generally, positive growth effects may be applicable under existing payment structures but not if those payment structures change.

Our analysis suggests many future avenues of research. First, valuation of government health care liabilities should use discount rates observed in asset markets rather than Treasury rates as is often done by agencies such as the CBO in the US. This is particularly relevant for valuing spending under the Part D program whose spending should be discounted by the discount rates observed for the firms generating the product sales of the program. Given the findings reported in Koijen et al. (2011) of a large "medical innovation premium," it is likely that the present value of Medicare Part D spending is far lower than commonly estimated using Treasury rates. Future empirical work may usefully investigate whether firms that are exposed differentially to government risk, for example from different shares of demand coming from Medicare or Medicaid, have different risk-returns patterns as implied by our discussion.

Second, our discussion of aging effects raises a more general issue about growth accounting of health care spending. Our discussion suggests that a major issue with previous work in this area is that decompositions based on independent factors are invalid. For example, changes in domestic income, aging, and insurance coverage all affect world innovative returns. However, when any of these factors raise R&D incentives, then it is partly the reason why per-capita spending levels grow over time. A more satisfactory decomposition of overall growth in health care spending must analyze innovation being jointly determined by the various independent factors discussed in previous work. A quantitative structural model of how factors contribute to spending growth, rather than just statistical decompositions, seems needed for this.

Third, our analysis concerned a single public program but has alternative implications for when individuals choose between multiple public programs. For example, in the US, older individuals have the choice between traditional Medicare or Medicare Advantage. As is true for most subsidy programs, the relative demand for the two programs seems to have been driven by the relative subsidy rates, as implied by various federal budget reforms in the past. A better understanding of innovation effects under multiple public programs is needed, when participation is endogenous and public prices change participation.

Fourth, our analysis does not distinguish between centralized *health care* pricing (as in Medicare Part A and B) and centralized *health insurance* pricing (as in Part C). Public pricing of health care versus health insurance may have different impacts on innovation incentives and is a useful avenue for future work. This would potentially involve making the supply prices of our analysis a function of various insurance reforms, presumably positively related to insurance generosity.

Fifth, our analysis has important implications for the many reforms worldwide aimed at lowering government spending but preserving medical innovation incentives. Many European nations face this issue with great fiscal imbalances and cost pressure. Our analysis implies that if fiscal pressures lead to further means-testing, it may raise innovation incentives. Thus, innovation incentives are preserved under fiscally induced government cutbacks by reducing government spending on the wealthier in favor of the poor. This will induce short-run effects that may differ from the long run liability effects we discussed.

Finally, the negative impact of government risk on health care investment deserves more general attention. If direct R&D stimuli are partially or fully offset by the government risk that accompanies them, this may mitigate their intended effects. In other words, push or pull measures that are associated with great legislative risk may not stimulate R&D much. For example, the uncertainty surrounding the current health care reforms in the US seems to have reduced investment incentives even though some reforms are clearly pro-innovation.

Generally, the overall argument we hope to have made, that we think deserves more general consideration, is that explicit and quantitative analysis of the impacts of reforms on innovative returns and the implied future spending growth must be developed. These analyses seem fundamental to health economics and very important for both positive and normative analysis of health care reforms.

Appendix

Appendix 1: Calibrating Participation Rates

To calibrate participation rates as a function of eligibility (R), we need to calibrate participation rates within each income decile when the income decile is both eligible and not eligible for the public program. We observe each income decile in one eligibility status (eligible or not eligible) and must calibrate the counterfactual status.

For the nonelderly, the lowest three income deciles are eligible for Medicaid, so we observe eligible participation rates for these income deciles, and the highest seven income deciles are not eligible for Medicaid, so we observe the noneligible participation rates for these income deciles.

To calibrate the noneligible participation rates for the lowest three income deciles, we split individuals with public coverage into private coverage and uninsured. Cutler and Gruber (1996) estimate that 72% of individuals have private insurance in the absence of public coverage, so we calibrate that 72% of individuals with public coverage have private coverage and 28% are uninsured when not eligible.

As an example, for the third income decile, we observe that 29.3% have private insurance, 36.7% have public insurance, and 34.1% are uninsured. To calibrate noneligible participation rates for this income decile, we add 72% of 36.7% (26.4 percentage points) to the private insurance rate and 28% of 36.7% (10.3 percentage points) to the uninsured rate. Therefore, the noneligible private insurance rate for the third decile is 55.7% and the noneligible uninsured rate for the third decile is 44.3%.

To calibrate the eligible participation rates for the highest seven income deciles, we first need to construct enrollment rates. Rearranging the participation rate equations, enrollment rates are:

$$r_I(z) = 1 - \frac{R_I(z) - I^N(z)}{I^E(z)}$$

$$r_U(z) = 1 - \frac{R_U(z) - [1 - F(z) - I^N(z)]}{F(z) - I^E(z)}$$

At 30% and 100% eligibility we can measure enrollment rates using the formulas above. As we mentioned in the text, at 30% eligibility and 100% eligibility we observe participation rates (R) using Medicaid data for the nonelderly and Medicare data for the elderly. We estimate $I^N(z)$ and $I^E(z)$ from of noneligible participation rates, which are either observed or calibrated in the previous paragraph.

For example, for the first three income deciles we calibrated noneligible private participation rates of 49.5%, 53.3%, and 55.7% within each income decile. Therefore $I^E(30) = \frac{.495+.533+.557}{10} = .158$. Summing the observed, eligible private participation rates in a similar manner, $I^N(30) = .554$. As we discussed in the text, $R_I(30) = 0.66$ and $R_U(30) = 0.22$. Plugging these values into the equation above, we get $r_I(30) = 0.33$ and $r_U(30) = 0.50$.

Using these the enrollment rates at 30% and 100% eligibility, we linearly extrapolate enrollment rates across all eligibility levels. With enrollment rates, eligible participation rates are calibrated using enrollment rates and the previously calibrated noneligible participation rates.

For example, at 40% eligibility, we observe for the fourth income decile of the nonelderly, which is not eligible for public coverage, that 59.3% have private insurance and 40.7% are uninsured. At 40%, $r_I = 0.42$ and $r_U = 0.56$. Therefore, 42% of the 59.3% that have private insurance participate in public insurance when eligible and 56% of the 40.7% that are uninsured participate in public insurance when eligible. As a result, when the fourth income decile is eligible, 34.6% have private insurance, 47.6% have public insurance, and 17.8% are uninsured.

With enrollment rates and participation rates within income decile calibrated, participation rates as a function of eligibility are straightforward to calibrate from their equations below:

$$
\begin{aligned}
R_G(z) =& I^E(z) r_I(z) + (F(z) - I^N(z)) r_U(z) \\
R_I(z) =& I^E(z)(1 - r_I(z)) + I^N(z) \\
R_U(z) =& (F(z) - I^E(z))(1 - r_U(z)) + [1 - F(z) - I^N(z)]
\end{aligned}
$$

Appendix 2: Calibration Table

Share Eligible	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Max Income Eligible (Ratio of FPL)	None	< 0.5	1	1.5	2	2.5	3	3.5	4	5	All
$F(z)$	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
$I^E(z)$	0	0.05	0.10	0.16	0.22	0.29	0.36	0.45	0.53	0.62	0.71
$I^N(z)$	0.71	0.66	0.61	0.56	0.50	0.43	0.35	0.27	0.18	0.09	0.00
$r_I(z)$	0	0.16	0.24	0.33	0.42	0.50	0.59	0.68	0.77	0.85	0.94
$r_U(z)$	0	0.38	0.44	0.50	0.56	0.62	0.68	0.75	0.81	0.87	0.93
$R_G(z)$	0.0%	2.7%	6.8%	12.3%	19.3%	27.7%	37.7%	49.2%	62.4%	77.2%	93.7%
$R_I(z)$	71.4%	70.6%	68.9%	66.2%	62.3%	56.9%	49.8%	41.0%	30.6%	18.4%	4.2%
$R_U(z)$	28.6%	26.7%	24.3%	21.5%	18.4%	15.4%	12.5%	9.8%	7.1%	4.4%	2.0%
$\pi_G(z)$	0.00	0.75	0.73	0.70	0.67	0.65	0.62	0.59	0.57	0.54	0.51
Public Spending	0.00	0.04	0.10	0.18	0.27	0.37	0.49	0.61	0.73	0.87	1.00
$\Pi(z)$	0.79	0.79	0.80	0.80	0.80	0.79	0.76	0.73	0.68	0.61	0.53
Relative Profits (100*$\Pi(z)/\Pi(0)$)	100.00	100.98	101.72	102.06	101.74	100.15	97.13	92.47	86.16	77.89	67.31

Table 2: Appendix 2: Profit Calculation

Appendix 3: Profit and Spending as a Function of Eligibility

	Change in Profits	Change in Public Spending
10% cut in eligibility	16%	-13%
20% cut in eligibility	28%	-27%
30% cut in eligibility	37%	-39%
40% cut in eligibility	44%	-51%
50% cut in eligibility	49%	-63%

Table 3: Effect of Medicare Eligibility Cuts on Profits and Public Spending in the Current Period

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